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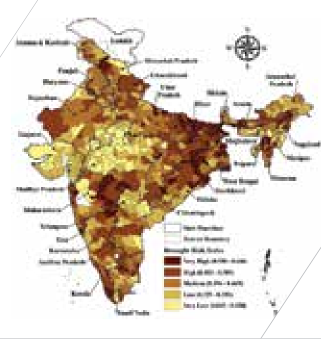
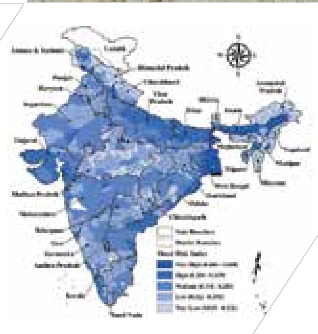
District-Level Climate Risk Assessment for India: Mapping Flood and Drought Risks Using IPCC Framework

REPORT





Indian Institute of Technology Mandi

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CSTEP

District-Level Climate Risk Assessment for India: Mapping Flood and Drought Risks Using IPCC Framework

Submitted by

Indian Institute of Technology Mandi

Indian Institute of Technology Guwahati

Center for Study of Science, Technology and Policy, Bengaluru

Prepared under the DST and SDC funded project:

Climate Change Risk Assessment and Mapping at State and District Level in India

2024

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The maps presented in this report were primarily created by the project team in consultation with the State partners during the capacity-building workshops. State representatives were trained on the methodology during these workshops and empowered to generate risk maps at various scales, leveraging their in-house expertise and on-the-ground insights.

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Flood and Drought Risk Assessment in India

In our previous endeavour, we developed a district-level vulnerability map for India (Dasgupta et al., 2021). In it, we identified the locations of highly vulnerable districts where intervention would be required in anticipation of climate change. Since vulnerability indicators are closely associated with development indicators, addressing vulnerability creates a win-win situation for the government.

The allocation of adaptation funds in vulnerable districts, especially in sectors that act as drivers of vulnerability, creates preparedness for a changing climate condition and results in overall resilience. While vulnerability assessments serve a vital role in financial allocations and have their own merits, the assessment of climate risk is a natural progression to a better understanding of the relative positions of districts with respect to the probable occurrence of hazard, exposure, and vulnerability.

The findings of the district-level flood and drought risk assessment on a pan-India scale and for 29 states and Union Territories (UTs) are presented in Parts IIA and IIB of the report, respectively. The flood and drought risk indices were developed based on the current probability of flood/drought hazards for 1970–2019, exposure to the hazard, and system vulnerability. Based on the relative values of the flood and drought risk indices, the districts have been categorised as 'very high', 'high', 'medium', 'low', and 'very low' risk-prone.

The report aims to compare 698 districts in India in general (in Part IIA) and districts within a particular state/UT (in Part IIB). It may be noted that the districts are comparable only within the states/UT and not across them – in Part IIB.

Key Findings

Flood Risk Assessment

- The flood risk arises at the intersection of flood hazard, exposure, and vulnerability.
- The district-level flood risk indices range from 0.015 to 0.688 across India, indicating that flood risks vary across districts.
- 51 districts fall in the 'Very High' flood risk category (0.440–0.688) and 118 districts fall in the 'High' flood risk category (0.284–0.439).
- About 85% of the districts in the 'Very High' or 'High' flood risk category are in Assam, Bihar, Uttar Pradesh, West Bengal, Gujarat, Odisha, and Jammu and Kashmir.

Drought Risk Assessment

- The drought risk arises at the intersection of drought hazard, exposure, and vulnerability.
- The district-level drought risk indices range from 0.042 to 0.644, indicating the variation in drought risk across districts.
- 91 districts fall in the 'Very High' drought risk category (0.510–0.644) and 188 in the 'High' drought risk category (0.450–0.509).
- More than 85% of the districts in the 'Very High' or 'High' drought risk category are located in Bihar, Assam, Jharkhand, Odisha, Uttar Pradesh, Maharashtra, West Bengal, Karnataka, Tamil Nadu, Chhattisgarh, Kerala, Uttarakhand, and Haryana.

Dual Risk of Flood and Drought

- Of the top 50 districts with the highest flood risk and the top 50 with the highest drought risk, 11 districts are at a 'Very High' risk of flood and drought. Districts facing this dual risk include Patna in Bihar; Alappuzha in Kerala; Charaideo, Dibrugarh, Sibsagar, South Salmara-Mankachar, and Golaghat in Assam; Kendrapara in Odisha; and Murshidabad, Nadia, and Uttar Dinajpur in West Bengal.

Utility of Flood and Drought Risk Assessment

Comprehensive Risk Mapping

- Development of risk maps for floods and droughts facilitates a comparative analysis of districts within a state based on standardised indicators, encompassing flood and drought hazards, the degree of exposure to hazards, and overall vulnerability, fostering a holistic understanding of flood and drought risks.

Determining Flood and Drought Risk Components

- Helps uncover the relative contribution of flood and/or drought hazards, exposure, and vulnerability within each district, facilitating identification of critical indicators that policymakers can utilise to prioritise interventions to mitigate or buffer the impacts of specific climate hazards.

Enhancing Government Preparedness and Policy Guidance

- Both state and central governments confront mounting pressure to deliver drought and flood assistance, driven by the rising frequency and intensity of extreme weather events. Risk assessments enable state governments to prepare proactively, allocate resources and staff, and design programmes. This will foster resilience in districts most affected by floods and droughts.

District-level Flood and Drought Risk Maps to Facilitate Prioritisation and Optimised Resource Allocation

- Hazard-specific risk profiles at the district level help identify districts requiring urgent attention.
- The maps enable policymakers to identify entry points and interventions. Moreover, they focus efforts and resources on critical districts to buffer and/or mitigate the impacts of specific climate hazards.

Mainstreaming Climate Change Adaptation and Mobilising Climate Finance

- The assessments provide valuable insights to policymakers for integrating into the State Action Plan on Climate Change (SAPCC). Periodic assessment updates, based on evolving hazard occurrences, ensure strategies remain relevant and effective and are aligned with the goal of sustainable and adaptive governance.
- They also facilitate the pursuit of climate finance by highlighting the urgency and significance of addressing identified risks. This is crucial for implementing adaptation strategies to address climate hazards in various sectors.
- Risk indices, rankings, and maps support the preparation of adaptation projects, enhancing the credibility of funding proposals for national and international agencies, particularly in identified hotspot districts.

Promoting Community Empowerment

- Local communities and elected representatives can advocate for compensation or insurance measures in response to high drought and flood-related losses.
- Understanding hazard risks strengthen community resilience by fostering proactive measures at the grassroots level.

Targeting user groups

- Government and private sector, practitioners, researchers, academicians, climate professionals, and local communities in concerned districts.

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09th December, 2024

MESSAGE

Climate change stands as one of the most urgent challenges of our time. Its effects are no longer theoretical or distant; they are becoming increasingly evident across India, from vulnerable coastal regions to the fragile ecosystems of the Himalayas. Addressing these challenges demands advanced tools, innovative methodologies, and a unified national effort to understand, assess, and mitigate climate risks.

In response to this pressing need, the Government of India launched the National Mission for Sustaining the Himalayan Ecosystem (NMSHE) as part of the National Action Plan on Climate Change (NAPCC). Since 2018-19, the Department of Science & Technology (DST), in partnership with the Swiss Agency for Development and Cooperation (SDC) and leading academic institutions such as IIT Guwahati, IIT Mandi, and IISc Bengaluru, has pioneered the development of a groundbreaking vulnerability map for the Indian Himalayan Region. This initiative has received strong support from state governments and laid the groundwork for a nationwide expansion.

Recognizing that vulnerability is just one aspect of climate risk, DST and SDC broadened their focus in 2022 to include a comprehensive district-level climate risk assessment. By adopting the IPCC (2014/2022) framework to evaluate flood and drought risks, they began with the Himalayan states, with plans to extend the assessment across the entire country. The result was the creation of district-level flood and drought risk maps, offering a more granular understanding of climate risks throughout India.

I am pleased to acknowledge the successful collaboration between DST and SDC in producing the report, "District-level Climate Risk Assessment for India: Mapping Flood and Drought Risks Using the IPCC Framework." This initiative embodies the essence of cooperative federalism, providing a standardized framework that has enabled states to develop their own district-level risk assessments. These comprehensive tools are crucial for updating State Action Plans on Climate Change and strengthening adaptation strategies at the grassroots level.

The contributions of institutions such as IIT Mandi, IIT Guwahati, IISc Bengaluru, and the Center for Study of Science, Technology and Policy (CSTEP) are particularly commendable. By focusing on two of India's most significant climate hazards—floods and droughts—this assessment provides a vital contribution to understanding the dynamics of climate risk. Furthermore, the emphasis on capacity building has empowered state climate change cells and relevant departments with the tools and expertise necessary to integrate climate risk assessments into effective policymaking.

I extend my heartfelt congratulations to all the institutions and individuals involved in this remarkable effort. This collaborative achievement marks a significant milestone toward building a more resilient and sustainable future for India.

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MESSAGE

Climate change poses one of the most pressing global challenges of our time, with its impacts felt disproportionately across regions, societies, and ecosystems. In India, the reality of climate change is manifesting through an alarming rise in the frequency and severity of extreme weather events, such as floods and droughts. These hazards, coupled with socio-economic vulnerabilities, amplify the risks to livelihoods, ecosystems, and development outcomes. Addressing these multifaceted risks requires a robust understanding of the interplay between climate hazards, exposure, and vulnerability – the cornerstone of the Intergovernmental Panel on Climate Change's (IPCC) risk assessment framework.

Realising the need for a coordinated effort to map climate relevant vulnerability and climate risk, to enhance the understanding in related issues, and to build the capacity of the state departments to carry out their climate vulnerability and risk assessment, the Department of Science and Technology (DST), Government of India has taken up several initiatives. Under the National Mission for Sustaining the Himalayan Ecosystem, State Climate Cells/Centers were established in the Himalayan States for building institutional capacity; later the effort was extended to other states in the country. As a part of this effort, DST has funded a series of projects since 2017 - starting with the development of a common framework for climate vulnerability assessment, followed by developing vulnerability maps for the Indian Himalayan Region that was further extended to an all India level. The present report, "District-level Climate Risk Assessment for India: Mapping Flood and Drought Risks Using IPCC Framework," an outcome of the project jointly funded by the Department of Science and Technology and the Swiss Agency for Development and Cooperation, starting in 2022, is a significant milestone achieved in this line. By adopting a human-centric, district-level approach, it highlights the intricate connections between climatic hazards and socio-economic disparities.

Notably, this study emphasizes the two most widespread climate hazards in India—floods and droughts—and analyzes their occurrence over the past five decades (1970–2019). It employs a scientifically rigorous methodology, leveraging a wealth of data to develop spatially explicit risk indices for all Indian districts. By doing so, it not only identifies areas of heightened risk but also offers an actionable pathway for adaptation planning at both regional and national levels.

The commitment of Institutions involved in this study— Indian Institute of Technology Mandi, Indian Institute of Technology Guwahati, Indian Institute of Science Bengaluru and Center for Study of Science, Technology and Policy, Bengaluru—to capacity building is particularly commendable, as it empowers state climate change cells and allied departments to adopt and implement the risk assessment framework. This aligns with India's disaster risk reduction agenda and enhances the ability of stakeholders to design evidence-based adaptation strategies tailored to local contexts.

As India continues to face the dual challenges of climate change and socio-economic development, this report serves as a timely reminder of the importance of science-led, participatory approaches to climate resilience. It provides a valuable tool for policymakers, researchers, and practitioners, enabling informed decision-making to safeguard communities and ecosystems against climate risks.

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The report, ***"District-level Climate Risk Assessment for India: Mapping Flood and Drought Risks Using IPCC Framework,"*** is a groundbreaking study in climate risk analysis and adaptation planning. It adopts a district-level, human-centric approach to highlight the complex links between climate hazards and socio-economic disparities. By combining previous vulnerability assessments with hazard likelihood and exposure data, the report delivers comprehensive risk maps that support targeted adaptation strategies, disaster preparedness, and resilience building across India.

The report focuses on India's most critical climate hazards—floods and droughts—analyzing their patterns over five decades (1970–2019). Leveraging advanced data-driven methodologies, it develops detailed risk indices for all Indian districts. This enables the identification of areas with heightened vulnerability and provides actionable insights to inform both regional and national adaptation planning.

Acknowledgment

I extend my sincere gratitude to the dedicated teams behind this pioneering effort. Special recognition goes to the contributing institutions—**IIT Mandi, IIT Guwahati, IISc Bengaluru, and CSTEP Bengaluru**—for their exemplary work in advancing climate science. I also express my appreciation to the **Swiss Agency for Development and Cooperation (SDC)** for their invaluable partnership and support in this crucial endeavour.

I extend my heartfelt gratitude to **Prof. Abhay Karandikar**, Secretary, Department of Science & Technology (DST), Government of India, for his invaluable support and overarching guidance. I am deeply thankful to **Dr. Anita Gupta**, Head of the CEST Division, DST, for her dedicated efforts and strategic direction in shaping the program and alignment with national priorities.

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I extend my deepest gratitude to the state-level Climate Cells and their teams for their invaluable contributions to the preparation of this report. The active engagement and collaboration of State Climate Cells across states have played a pivotal role in integrating district-specific climate data, socio-economic variables, and on-ground realities into the risk assessment framework.

This report is a testament to the collective effort and shared vision of all stakeholders involved in tackling climate risks in India. This report represents a significant step toward equipping India with the tools and knowledge necessary to build a climate-resilient future.

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Preface

Over the past decades, there has been an increase in the number of climate-related disasters, the number of people affected, and the economic losses caused by these disasters. The impacts of climate change are being manifested through changes in the frequency, intensity, or duration of extreme weather events. These impacts, together with unsustainable development patterns, pose a serious threat to the achievement of Sustainable Development Goals (SDGs). Management of climate-related risks, including improved understanding and alleviation of the vulnerabilities to extreme events, is imperative to minimize the adverse impacts on human health, society, and the environment. The Global Climate Risk Index 2021, ranks India 7th in terms of the extent to which countries are affected by extreme weather events. To foster and support adaptation with innovative scientific approaches, the Swiss Agency for Development and Cooperation (SDC), is implementing a project, Strengthening Climate Change Adaptation in the Himalayas (SCA-Himalayas). The project is aimed towards enhancing the resilience of communities by integrating climate actions into national and sub-national planning and implementation. An integrated approach and inclusion of risk assessment in overall development planning can significantly strengthen the preparedness and prioritize action towards climate change impacts and disasters. SDC, under the SCA Himalayas project, together with the Department of Science and Technology (DST), and a consortium led by Indian Institute of Technology Guwahati, Indian Institute of Technology Mandi and Center for Study of Science, Technology and Policy, Bengaluru rolled out District-Level Climate Risk Assessment for India. The assessment involved using a common framework, to understand the components of risk (hazard, exposure and vulnerability) associated with two prevalent climate hazards in India—drought and flood—in the context of both historical and current climate conditions. A series of workshops were organized to develop a uniform understanding of the district-level climate risks, and availability of datasets, and to map the vulnerabilities. The present District-Level Climate Risk Assessment for India significantly contributes to enhancing the capacity of State Climate Change Cells and State Disaster Management Authorities in flood and drought risk assessment for adaptation planning. SDC would like to take this opportunity to congratulate the Government of India, all involved States and Union Territories, and stakeholders on the launch of this milestone report. We look forward to continuing and further strengthening our excellent collaboration.

Mr. Philippe Sas
Head of Cooperation in India
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List of Acronyms

AHP	Analytical Hierarchy Process
BMTPC	Building Materials and Technology Promotion Council
CHC	Community Health Centre
DEI	Drought Exposure Index
DHI	Drought Hazard Index
DRI	Drought Risk Index
DRR	Disaster Risk Reduction
DST	Department of Science and Technology
EI	Exposure Index
FCFs	Flood Conditioning Factors
FEI	Flood Exposure Index
FHI	Flood Hazard Index
FRI	Flood Risk Index
GHG	Greenhouse Gas
GIS	Geographic Information System
GIZ	German Corporation for International Cooperation
GLOF	Glacial Lake Outburst Flood
IHCAP	Indian Himalayas Climate Adaptation Programme
IHR	Indian Himalayan Region
IISc, Bengaluru	Indian Institute of Science, Bengaluru
IIT Guwahati	Indian Institute of Technology Guwahati
IIT Mandi	Indian Institute of Technology Mandi
IMD	Indian Meteorological Department
IPCC	Intergovernmental Panel on Climate Change
LULC	Land Use Land Cover
MCDA	Multi-Criteria Decision Analysis
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MoEFCC	Ministry of Environment, Forest and Climate Change
MPI	Multidimensional Poverty Index
NABARD	National Bank for Agriculture and Rural Development
NFHS	National Family Health Survey
NITI	National Institution for Transforming India
NIDM	National Institute of Disaster Management
NRSC	National Remote Sensing Centre
NTFP	Non-Timber Forest Produce
PHC	Primary Health Centre
PMFBY	Pradhan Mantri Fasal Bima Yojana
SAPCC	State Action Plan on Climate Change
SDC	Swiss Agency for Development and Cooperation
SPI	Standardized Precipitation Index
TWI	Topographic Wetness Index
UTs	Union Territories
VI	Vulnerability Index
WBCIS	Weather Based Crop Insurance Scheme
WMO	World Meteorological Organization

PART I:
Introduction and Methodology

1. Introduction

Climate change poses a formidable challenge to society and is a test of the capacity of individual and collective decision-making to implement effective responses (Adger et al., 2018). Climate change, unlike other environmental issues, stands out for its intricate interplay with people, social and institutional structures, evolving environmental system dynamics, and temporal dimensions. Its complexity manifests in cascading risks across physical systems, natural and man-made ecosystems, societies, and the economy. These risks intertwine, interact, and, at times, breach critical thresholds.

The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) Working Group-1 underscores the alarming reality of climate change, affirming that recent climatic shifts are both widespread and unprecedented in millennia (IPCC, 2021). The report emphasises the far-reaching impacts of climate change, stressing its current influence on every region of the planet and asserting that these effects will escalate as surface temperature increases. Further, it indicates that global warming will be higher by 1°C to 1.5°C compared to the historical period, even under a very low greenhouse gas (GHG) emission scenario.

The report also points out that, as global warming intensifies, numerous facets of the climate system will experience amplification, leading to elevated probabilities of occurrence of climate hazards and extreme weather events. This includes heightened frequency and intensity of hot extremes, increased occurrences of heavy precipitation, prolonged droughts, and more powerful tropical cyclones. Importantly, the observed changes in extreme events magnify with each additional increment of global warming. As the IPCC outlines, a warmer climate is expected to exacerbate extremes in both wet and dry weather conditions, with profound implications for flooding and drought occurrences.

The report is a stark reminder of the urgent need for global action to mitigate climate change and adapt to its escalating impacts.

Climate change is affecting ecosystem services that are integral to human health, livelihoods, and well-being. The productivity of key sectors like agriculture, forestry, and fisheries, which rely on these services, is significantly affected. The intensity of climate extremes is surpassing the resilience thresholds of numerous ecological and human systems, resulting in escalating loss and damage.

Existing adaptation measures are proving insufficient in mitigating this loss and damage, underscoring the urgent need to expand the scope and effectiveness of adaptive strategies. Particularly vulnerable are human populations and systems as well as climate-sensitive species and ecosystems. They are exposed to climate hazards, heightening the risk of adverse consequences. For example, the escalating impacts of global warming will progressively undermine soil health and ecosystem services such as pollination, while concurrently increasing pressure from pests and diseases, negatively affecting food productivity in various regions.

Climate change-induced extreme events are expected to amplify significantly both ill health and premature deaths in the near and long term. Further, climate-sensitive diseases transmitted through food, water and vectors are projected to increase under all warming scenarios. In the mid to long term, human displacement and migration are projected to increase due to the intensification of heavy precipitation, droughts, flooding, tropical cyclones, and sea-level rise. Risks associated with water availability and water-related hazards are projected to rise across all regions in the mid to long term, too.

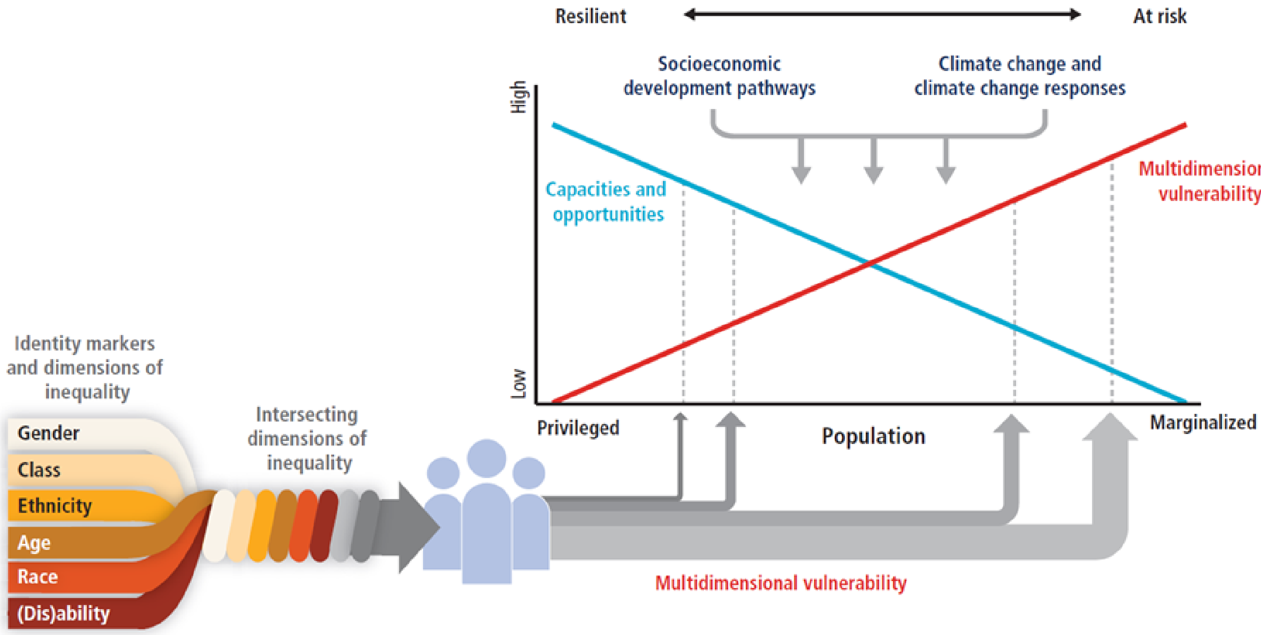


Figure 1.1: Differential multidimensional vulnerability and capacities to adapt, driven by intersecting dimensions of inequality (IPCC, 2014)

The distribution of the impact of climate change is not equal across the world and will depend on different facets of socio-economic and demographic inequalities based on gender, age, class, race, ethnicity, (dis)ability, economic status, etc. (Figure 1.1).

A certain category of climate hazard may pose different levels of risk to two communities that are equally exposed if their adaptive capacities vary, resulting in varied levels of vulnerability. For example, an increase in climate extremes increases the risk of infectious disease epidemics more in developing countries with a higher incidence of poverty than in the developed ones (Oppenheimer et al., 2014) or the demographically vulnerable stratum of a population (Basu & Ostro, 2008; Kovats & Hajat, 2008; Perera, 2008), and poor people with limited access to infrastructure and small resource endowment (Frumkin & McMichael, 2008; Malik et al., 2012).

While emission mitigation is unambiguously crucial to reducing climate hazards, addressing exposure and system vulnerability remains at the heart of adaptation policies, especially so given the disproportionate distribution of climate change's effects. Carefully crafted adaptation policies not only reduce climate risk but also deliver several socio-economic co-benefits.

Further, integrated adaptation frameworks and decision support tools that proactively address multidimensional risks and align with community values, prove more effective than approaches narrowly focused on single risks. While some degree of adaptation is evident in both natural and human systems, there are gaps between existing capacities for adaptation and the level required to mitigate the projected impacts of climate change (IPCC, 2022). For an effective adaptation, policymakers must have a clear understanding of the nature and source of climate risk.

It is also essential that the risk assessment is carried out using a common methodology across spatial units or sectors, so the results are comparable. In countries like India, with many development challenges, such a common approach helps policymakers locate the emerging risk-prone areas and sectors along with the drivers of risk. This, in turn, facilitates the efficient allocation of resources, especially adaptation funds, to address the drivers of climate risk in a targeted manner. The lack of emphasis on prioritising adaptation measures at present, as well as the shift from incremental to transformative adaptation, is limited by finance, institutional support, capacity, and tools.

This report contributes to the development of an all-India flood and drought risk map to identify the country's most risk-prone locations with respect to these two climate hazards. The analysis is based on a common methodology developed in adherence to the IPCC AR5 and AR6 framework. It aims to balance the accuracy of measurement and ease of use by relevant stakeholders, especially the state climate-change cells in the country. Box 1.1 delineates relevant work carried out globally and in India, to understand flood and drought risk and the contribution of the current report to the body of work.

Box 1.1: Relevant Work on Climate Risk

There has been an emergence of studies assessing climate vulnerability and climate risk, across different spatial and sectoral scales since the conceptualisation of a modified climate risk framework by the IPCC in its Fifth Assessment Report (AR5). The framework was retained in the Sixth Assessment Report (AR6) (Figure E.1). While the literature on climate vulnerability assessment has grown over time, a comprehensive climate risk assessment remains challenging, given the methodological complexity and data limitations.

Globally, studies compare climate risk across countries in terms of economic and life losses (Germanwatch, 2021; Swiss Re, 2024). At the national level, risk assessment studies are focused on specific hazards such as drought (Carrao et al., 2016; Villani et al., 2022), extreme heat in Australia (Wang et al., 2023), and flooding in river basins in China (Zhang et al., 2020), Austria (Leis & Kienberger, 2020), and a river in Bangladesh (Roy et al., 2021).

In India, national atlases, such as the Climate Hazards and Vulnerability Atlas of India by the India Meteorological Department (IMD, 2022) and a Disaster Risk Profile by the National Institute of Disaster Management (NIDM n.d.), offer comprehensive hazard mapping for the entire country. There is also the Climate Risk Management Framework for India. The GIZ developed it in collaboration with the Ministry of Environment Forest and Climate Change and the NIDM (NIDM & GIZ, 2019). The framework is focused on mitigating potential loss and damage in specific climate-sensitive regions. The district-level assessment of the risk and vulnerability of Indian agriculture to climate change by the CRIDA-Central Research Institute for Dryland Agriculture is another report in this context (Rama Rao et al., 2019).

1.1. Need for risk assessment using a common framework

The pervasiveness of concurrent and recurring climate hazards is a global phenomenon, intensifying the repercussions on health, ecosystems, infrastructure, livelihoods, and food security across all regions. As climate hazards overlap and amplify, the need for a comprehensive approach to risk management becomes increasingly urgent. The intricate web of interrelated risks necessitates a holistic strategy that considers the intricate interplay between climatic and non-climatic factors to safeguard the well-being of communities and the sustainability of essential systems.

Therefore, risk assessments of a geographical area, sectors, etc., if they are based on a common methodological framework, provide an opportunity to have a systematic and comprehensive perspective of climate risks. Through risk assessments, it is possible to prioritise adaptation policies and implement suitable measures for the efficient management of risks. This entails analysing the probabilities, repercussions, and responses to climate change impacts, all the while considering available options to address the problem within prevailing constraints. Climate risk assessment equips decision-makers with insights into potential courses of action by pinpointing risks and evaluating their impact on individuals, assets, value chains, infrastructure, settlements, and ecosystems.

Thus, vulnerability and risk assessment for a given region of interest is a critical first step in addressing climate change and a step towards effective adaptation. In our previous work on 'Climate Vulnerability Assessment for Adaptation Planning in India Using a Common Framework' (Barua et al., 2021; Dasgupta et al., 2021), we carried out a pan-India vulnerability assessment and identified the driver of vulnerabilities. While the report has its unique utility, it also ushered in the way to advance beyond using vulnerability assessment as a tool for adaptation. It identified the need to transition towards climate risk assessment.

The integration of risk assessment is imperative for a holistic understanding and effective management of climate-related challenges because risk includes vulnerability and the probability of occurrence of a hazard and exposure to it. While experience in this domain gradually accumulates, there is an emerging recognition of the utility of risk indices and maps in informing adaptation action.

Mapping climate change risks using a common framework is integral for understanding the entry point of interventions. This approach aids in identifying the key risk drivers –whether they stem from hazards, exposure, or vulnerability– and provides a comprehensive understanding of the challenges at hand. By delineating the scope for adaptation and highlighting potential maladaptation pitfalls to be avoided, this exercise becomes a guiding tool for states.

Moreover, it serves as a resource for optimising the utilisation of adaptation funds over a specified timeline. For instance, addressing vulnerability may be feasible in the short to medium term, while mitigating exposure requires a more prolonged commitment and substantial financial investment. With this information, states are empowered to prioritise interventions, ensuring a strategic and efficient allocation of resources to tackle the most pressing climate change risks.

Box 1.2: What can climate risk assessment deliver?

- Identify and Prioritise Risks: Helps assess and rank regions, districts, cropping systems, and communities susceptible to climate change-related damages and losses.
- Contribute to Informed Adaptation Planning: Aids communication to decision-makers of the need to address hazards and the drivers of exposure and vulnerability in adaptation planning.
- Anticipate Changing Risks: Improves understanding of how risks, based on historical or recent climate trends, will evolve or intensify over time.
- Predict High-Risk Areas: Helps determine which districts, regions, and communities will face elevated risks or increased impacts in the coming decades due to climate change.
- Quantify Risk Components: Provides an assessment and quantifies the extent of risk that can be attributed to hazards, exposure, and vulnerability individually and their combined impact. It also highlights that exposure and vulnerability are significant contributors to loss and damage from climate change, sometimes outweighing the impact of hazards. It also provides a refined understanding of climate change risks in light of climate hazards, while vulnerability assessments are independent of climate hazards.
- Identify Key Risk Drivers: Helps identify the core factors amplifying risk within communities and ecosystems, examining their origins in hazards, exposure, vulnerability, or their interplay and identify critical indicators that greatly influence overall risk.
- Facilitate Project Identification for Funding: Helps identify tangible adaptation projects suitable for funding from donors, bankers, and other financial sources, integrating considerations of climatic hazards, exposure, and vulnerability.

1.2. Objectives

The project's primary aim was to assess the risk associated with two prevalent climate hazards in India –drought and flood– in historical and current climate conditions. Additionally, it sought to enhance the capacity of state climate change cells and related departments in flood and drought risk assessment for adaptation planning.

The specific objectives of the project included:

1. Develop district-level flood and drought hazard, exposure, and vulnerability maps leading to India's flood and drought risk map.

2. Develop district-level flood and drought hazard, exposure, and vulnerability maps for individual states and UTs of India.

3. Promote capacity building of the state climate-change cells and allied departments in flood and drought risk assessment for adaptation planning.

1.3. Scope of the report

1.3.1. Addressing flood and drought hazards

India's various regions, including states and districts, face distinct exposure to a range of hazards. Their vulnerability profiles are also different. Coastal areas are exposed to storms, cyclones, and hurricanes, while mountainous regions are exposed to floods and landslides. Tropical or low-latitude regions are prone to severe heat stress, although temperate and high-altitude areas may also experience significant challenges.

Droughts and floods, however, are the two hazards prevalent across the majority of the districts or regions in India (Mujumdar et al., 2020). According to the Indian Meteorological Department (IMD), 87% of districts in the country are susceptible to droughts, 30% are at risk of floods, 14% are vulnerable to cyclones, and 13% are exposed to heat waves (IMD, 2022).

Many districts are exposed to both drought and flood events, and during specific years, a district may experience drought followed by floods within the same year. Thus, the current assessment focuses on droughts and floods due to their large-scale socio-economic impacts in India. Nevertheless, the methods and guidelines will also be applicable to evaluating risk to other hazards.

The flood hazard assessment presented here primarily specifies areas prone to recurrent riverine floods and examines the evolution of associated risks over time and space. It is to be noted that this investigation does not include the identification of areas susceptible to abrupt events such as flash floods and GLOF. While the significance of various climate hazards, both direct and indirect, such as landslides and heat stress, is acknowledged, this study focused on two predominant hazards - flood and drought, considering their prevalence in the country.

1.3.2. Adhering to the need towards capacity building

One of this project's central objectives was to enhance states' capacity to conduct flood and drought risk assessments using a standardised (standard) methodology. Consequently, we initiated this endeavour by addressing the two most prevalent hazards nationwide. The rationale was rooted in establishing a standardised framework and building the necessary expertise, facilitating subsequent replication of the process for other hazards, including compound events. In other words, users/practitioners were to be enabled to use the methodology and framework easily to carry out and/or update a risk assessment relevant to them.

Further, adopting scientifically grounded yet relatively simple methods, such as the Standardised Precipitation Index (SPI) for meteorological drought assessment, was intentional. The decision aimed to ensure the assimilation of knowledge by the target group, primarily the states involved in the study. By employing easy-to-use methodologies, our training facilitated improved understanding and implementation of the flood and drought risk assessment process, laying the foundation for future expansion to encompass a broader spectrum of hazards.

1.3.3. Risk assessment for flood and drought under current climate

Based on historical trends for a given hazard, such as drought or flood, a risk could be assessed considering the frequency and intensity of a hazard occurrence, using observations for the past 30 or 50 years. Given historical trends, this ex-ante approach evaluates potential climate hazards a particular location may face in the future.

Box 1.3: Salient Features

- **Focus on drought and flood:** The study focused on drought and flood, the two most prevalent climate hazards in India, while acknowledging other hazards such as heatwaves and cyclones.
  - Drought is defined as meteorological drought, characterised by rainfall anomalies (deviation from the long-term trend).
  - Flood risk is based on the probability of hydro-meteorological floods shaped by rainfall anomalies and topographical, geological, and hydrological factors.
- **Human-centric approach:** Our analysis integrated exposure, vulnerability, and climatic hazards to evaluate flood and drought risk. The risk assessment thus explored the manner and extent to which climate hazards may impact people and livelihoods, considering hazard-specific exposure and inherent vulnerability.
- **Ex-ante approach:** Our approach aligns with the Prime Minister's 10-point agenda (NDMA, n.d.) for Disaster Risk Reduction (DRR), since the current approach is rooted in an ex-ante DRR framework – prioritising proactive measures over relief-based strategies.
- **Spatial scale:** The assessment had been carried out at district level – an essential administrative unit for decision-making throughout India.
- **Temporal scale:** The assessment was for both the historical or current climate, considering a 50-year time period of 1970 to 2019.
- **Comparability:** The risk indices are relative in nature, and serve to rank districts within the country or within a state or UT. A higher value of risk index signifies a district's elevated risk compared to others. The true utility lies in the comparative assessment.
- **Capacity building:** Training and capacity building at state level has led to creating awareness on the utility and use of risk assessment framework. A broad approach and common framework for risk assessment had been shared with states, thereby creating a knowledge network of state departments, academic institutions, and universities.

1.4. The journey and approach

Capacity building of state climate-change cells and allied departments in flood and drought risk assessment was a primary objective of the current phase of the project. In Phase I (2018 –2020), the focus was on vulnerability assessment – introducing states and UTs to the IPCC AR5 framework.

Transitioning to the current phase, the overarching aim was to emphasise the need for risk assessment (encompassing flood and drought hazards, exposure, and vulnerability), and train states or UTs to develop district-level risk maps using a standardised common methodological framework.

To date, three capacity-building and consultation workshops have been conducted. They sensitised states on the need for flood and drought risk assessment, its application, methods, and framework, including the selection of common indicators for the Indian Himalayan Region (IHR). These workshops provided hands-on training to all IHR state representatives (and some non-IHR states) to develop flood and drought risk maps. While the IHR states participated heavily, engagement from non-IHR states remained around 60%. This, we think, poses a persistent challenge.

Training for capacity building was through interactive workshops and hands-on experiences. These workshops not only imparted training to state participants but also served to validate the assessment. This served to procure state endorsement of the findings. We foresee that this exercise will enhance its utility in various contexts, including developing State Action Plans on Climate Change (SAPCCs) and proposals to seek funding. Leveraging the capacity built during Phase-1 (on vulnerability assessment), particularly among IHR states, the current phase aims to bridge capacity gaps. Representatives from IHR states also helped build capacity for non-IHR counterparts.

This inclusive approach distinguishes our project from pure academic endeavours. It has empowered state representatives to make informed decisions, allocate resources efficiently, prioritise interventions, and formulate effective flood and drought risk mitigation and disaster management policies. In addition, they have gained expertise and knowledge they could leverage to train people within their states or from other states. The exercise empowered state representatives to replicate and update this assessment in the future in a manner relevant to them. Figure 1.2 provides a snapshot of the journey and the timeline.

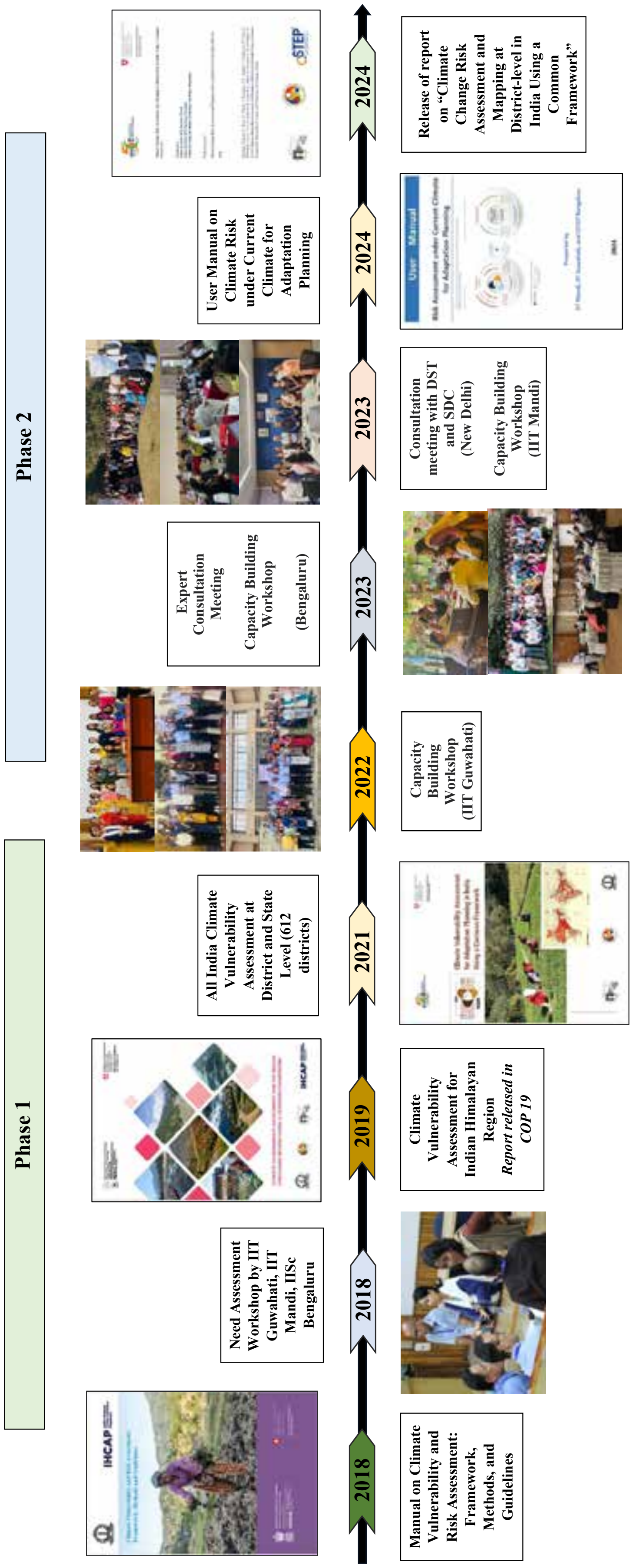


Figure 1.2: The journey and approach

2. Methodology

2.1. Conceptualising climate risk based on IPCC AR5 framework

The IPCC (2014) highlights the concept of risk and its constituent elements, providing a comprehensive framework encapsulated in Figures 2.1(a) and 2.1(b). Assessing potential risks to an ecosystem, infrastructure, cropping systems, or communities hinges on the dynamic interplay of various factors. These include the nature and intensity of the hazard, the scope of exposure experienced by communities and ecosystems, and the susceptibility and adaptability of these entities—their sensitivity and adaptive capacity—to specific climate hazards.

These three components of risk (hazard, exposure and vulnerability) could be conceptualised very differently from the perspective of policy intervention. Reductions in hazards require long-term GHG mitigation. Therefore, any policy to reduce climate risk by reducing hazards must be long-term and based on comparing short-term economic benefits and future risks.

Land use alteration could reduce exposure in the medium to long run. In the short to medium term, reducing vulnerability as an entry point of risk mitigation can be achieved (see Fig 2.1 b) (Thomas, 2017).

Table 2.1: Risk, Hazard, Exposure, and Vulnerability

Risk (R)	Risk is the potential for consequences where something of value is at stake and where the outcome is uncertain, recognising the diversity of values. It is often represented as the probability of the occurrence of hazardous events or trends multiplied by the impacts of these events or trends actually occur. Risk results from the interaction of vulnerability, exposure, and hazard.
Hazard (H)	The potential occurrence of a natural or human-induced physical event or trend or physical impact may cause loss of life, injury, or other health impacts as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, hazard usually refers to climate-related physical events such as droughts, floods, and hurricanes.
Exposure (E)	The presence of people, livelihoods, species or ecosystems, environmental functions, services, resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.
Vulnerability (V)	Vulnerability is the propensity or predisposition to be adversely affected. It encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and a lack of capacity to cope and adapt.

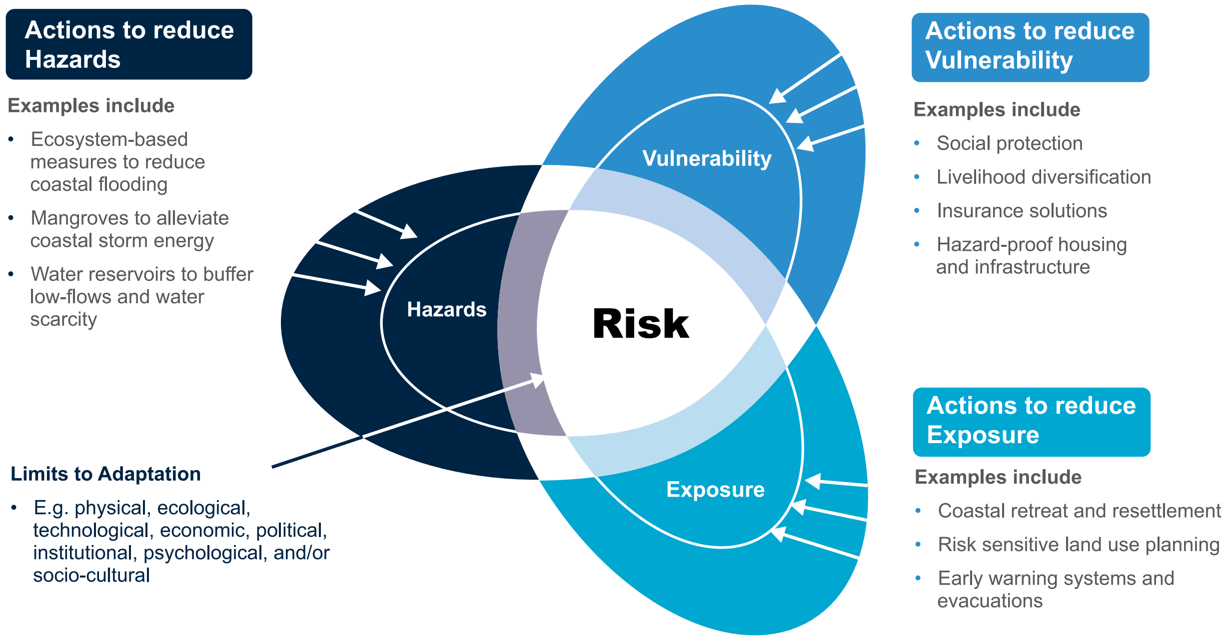


Figure 2.1(a): **IPCC Risk Framework (IPCC, 2014)**

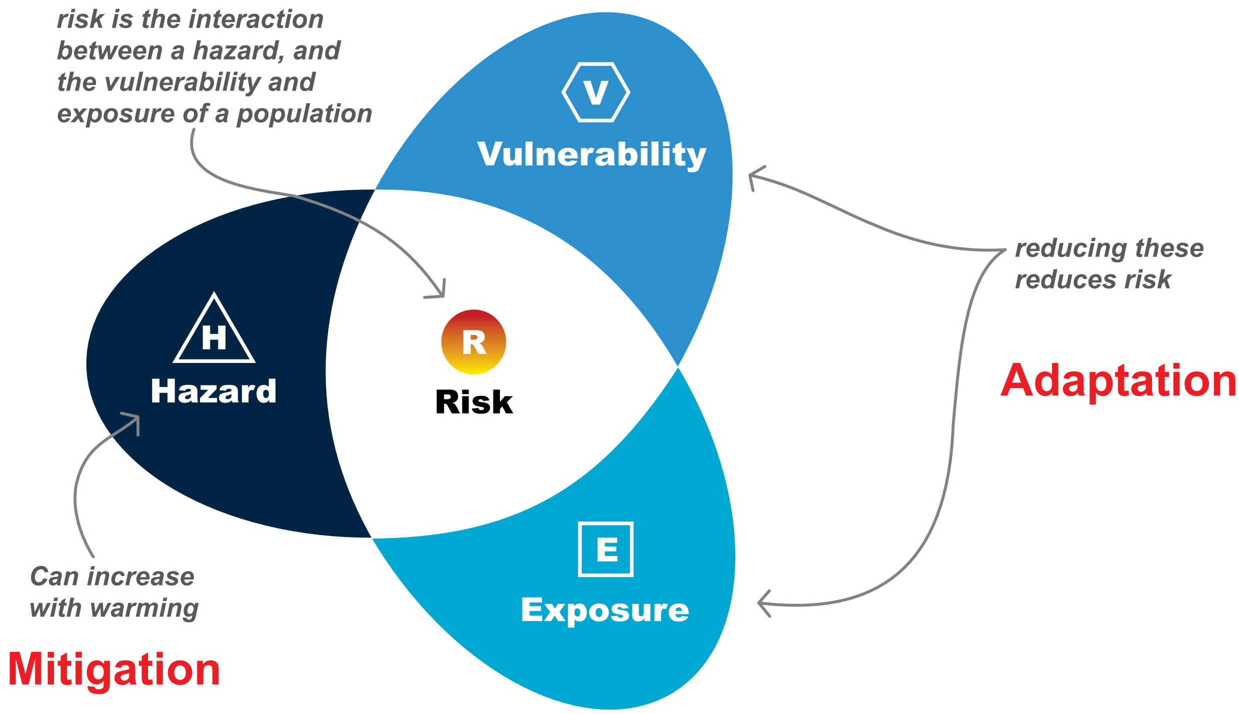


Figure 2.1(b): **Risks arising from climate change impacts resulting from dynamic interactions (adapted from IPCC Risk Framework (IPCC, 2014)**

2.2 Assessment of Hazard, exposure and Vulnerability as components of flood and Drought Risk

This report provides a brief description of the common methodological framework. The manual developed as part of the same project presents a detailed discussion.

Figure 2.2. is a schematic representation of the methodology.

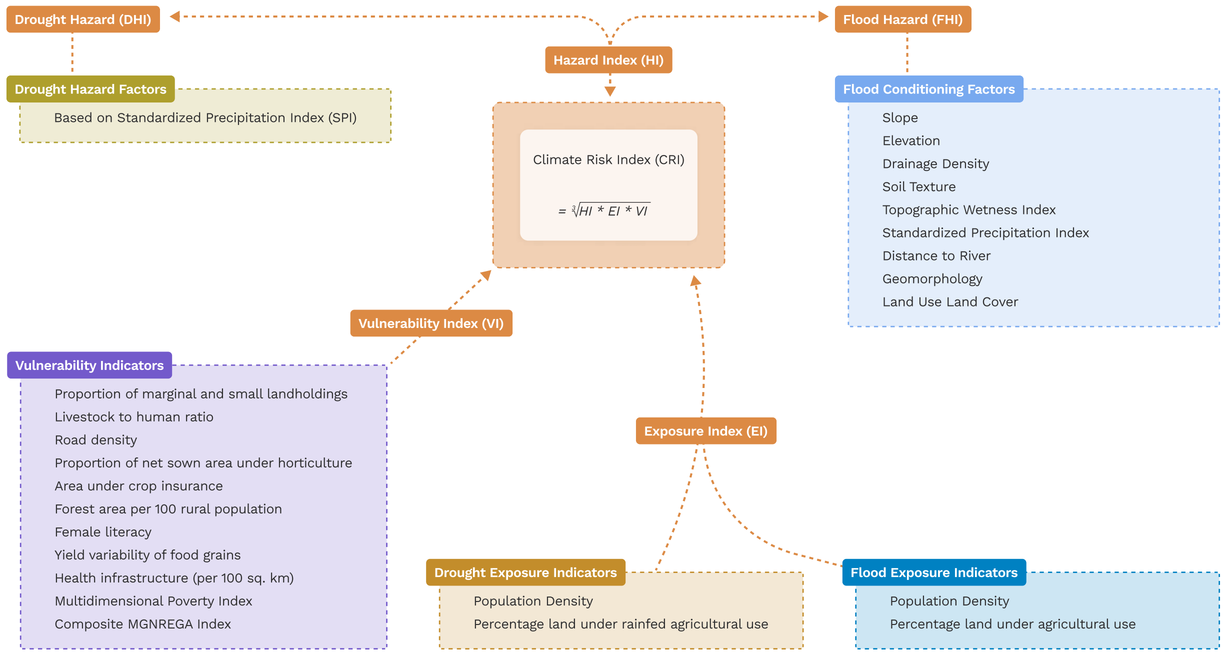


Figure 2.2: Schematic depiction of the methodology

2.2.1. Hazard Assessment

Hazard is conceptualised as the probability of occurrence of two physical climate events - drought and flood.

- **Drought:** This study assessed meteorological droughts using the Standardized Precipitation Index (SPI). McKee et al. (1993) introduced the SPI as the most common and widely used method to evaluate drought occurrences. It provides a comprehensive account of the probabilities associated with both wet and dry events. Numerous studies have validated its simplicity, flexible adaptivity at different temporal and spatial scales along with its efficacy in identifying, monitoring, and predicting drought occurrences and their severity (WMO 2012; WMO & GWP, 2016; Kirono et al., 2020; Verma et al.,2022; Verma et al., 2023; Sharma-IMD, n.d.).

  This assessment utilised gridded precipitation data from the IMD with a spatial resolution of 0.25 x 0.25 degrees, spanning 1970–2019 (50 years). District-wise, monthly precipitation was extracted from this dataset, which served as input data for calculating the SPI-6.

  The SPI 6 assesses precipitation anomalies over 6 months, which is crucial for understanding how variations in rainfall affect stream flows and reservoir levels. It provides insights into short-term impacts on meteorological and agricultural conditions (over 6 months) and longer-term influences on hydrological systems, including streamflow and groundwater, essential for sustainable water management.

  The SPI-6 values were used to categorise the severity of drought conditions into three levels: moderate, severe, and extreme. The Drought Hazard Index (DHI) was calculated by assigning weights to different drought categories. Each weighted category was then subdivided into specific ratings based on the probability of occurrence for each category. (Shahid and Behrawan, 2008; Wang & Sun, 2023). A high DHI for a district indicates rainfall anomalies and deviations in rainfall (in terms of rainfall reduction) from its long-term mean. This approach helps identify districts that have become drier over the past five decades (1970–2019).

- **Flood:** The susceptibility of a particular area to flood hazards was systematically assessed through the integration of GIS and Multi-Criteria Decision Analysis (MCDA) techniques (González-Arqueros et al., 2018; Mahmoud & Gan, 2018a, 2018b; Das, 2020; Dash & Sar, 2020; Chen, 2022; Gupta & Dixit, 2022).

  A comprehensive examination of nine key flood conditioning factors (FCFs) was conducted, viz. slope, elevation, drainage density, soil texture, Topographic Wetness Index (TWI), SPI (probability of occurrence of severe and extreme wet events), distance from the river, geomorphology, and Land Use Land Cover (LULC). It was followed by constructing a geospatial database of these thematic layers within the GIS.

  These factors and layers collectively represent the study areas' topographic, hydrologic, and geologic characteristics. Using weights derived from the Analytical Hierarchy Process (AHP), a composite flood map for each state/UT was generated using the weighted overlay technique in GIS.

  Subsequently, each district's Flood Hazard Index (FHI) was computed by taking the proportion of the area in 'high' and 'very high' flood susceptibility categories to the district's total geographical area. This comprehensive approach considers various factors that influence floods. It employs a rigorous analytical process, providing a robust foundation for evaluating and depicting flood susceptibility.

2.2.2. Hazard-specific exposure assessment

Exposure is conceptualised as the 'presence of people and livelihoods' in 'places and settings that could be adversely affected' by flood and drought (IPCC, 2014). Given that the agricultural sector is particularly susceptible to these hazards, indicators such as population density and the percentage of land under agriculture (for flood) and rainfed agricultural land (for drought) are considered indicators of exposure.

Table 2.2: Construction and Rationale for Choice of Flood and Drought Exposure Indicators and Data Sources

Indicators	Construction	Rationale for selection	Sources
The area under rainfed agriculture (Drought exposure)	Net sown area - net irrigated area)/net sown area (2020–21)	Rainfed agriculture is susceptible to the vagaries of weather. Lack of irrigation indicates a lack of adaptive capacity to mitigate the impacts of climate risks, leading to increased crop loss and income of households dependent on rainfed agriculture. (Rani et al., 2011).	Ministry of Communication (n.d.)
Proportion of land under agriculture (Flood exposure)	[(Net area sown + current fallow + fallow lands other than current fallow + culturable wasteland + land under miscellaneous tree crops) / Geographical area)] (in sq. km) (2022)	Agriculture is India's primary source of livelihood. The sector is largely rainfed and sensitive to climate variability and weather extremes. Floods' impact on agricultural lands increases food insecurity, making them more vulnerable to climate change.	Ministry of Communication (n.d.) and NABARD (n.d.)
Population density[4] (Both flood and drought exposure)	Total population / geographical area	This indicates the population exposed to drought and flood in the given geographical area. The more a population is exposed to an event, the more vulnerable the system will be; thus, there will be a high risk.	Dhar (2022) and District websites

2.2.3. Hazard-specific vulnerability assessment

Vulnerability is a system property influenced by several biophysical, socio-economic, and institutional factors. Our study incorporated specific indicators to encapsulate these factors.

These include the proportion of net sown area under horticulture, crop insurance coverage, variability in food grain yields, the proportion of marginal and small landholdings, multidimensional poverty index, forest area per 100 rural population, female literacy, the ratio of livestock to human population, road density, health infrastructure, and a composite MGNREGA index.

4. For the revised values of population, the percentage growth rate of population is calculated, based on population data from the 2011 Census and the IIPS 2020 for all districts. For the newly formed and missing districts, the population numbers have been taken from respective district websites (if applicable) and from other government sources. We then multiplied this population by the percent growth rate of the population in the parent district. Likewise, for the bifurcated and parent districts, the population of newly formed districts was deducted from the population of the parent district. This value was revised by adding the percent growth rate of population in the respective parent districts.

Table 2.3: Construction and Rationale for Choice of Vulnerability Indicators and Data Source

Indicators	Construction	Rationale for selection	Sources
Multidimensional Poverty Index (MPI)	Calculated using the indicators of standard of living, health and education by assigning equal weights that are further based on 12 sub-indicators (2023)	MPI captures the standard of living, health, and education. Climate change and poverty are dynamically associated and affected through several pathways. (Leichenko & Silva, 2014)	NITI Aayog (2023)
Proportion of marginal and small landholdings	Marginal + small landholdings) / Total landholdings (hectares (2016–17)	Marginal and small landholder farmers experience immediate hardship in the face of any climatic hazard. They cannot make adequate decisions about when to sow, what to grow, and how to time inputs, along with low adaptive capacity (Sathyan et al., 2018). They also find it difficult to cope with high food price fluctuations in the same (Aryal et al., 2020).	https://inputsurvey.dacnet.nic.in/databasehome.aspx
Yield variability of food grains	Coefficient of Variation (Standard Deviation/ Arithmetic Mean) of the major food grains over a specific period (2006–2018)	High variability in crop yields indicates fluctuations in agroclimatic conditions. The agriculture sector is susceptible to climate fluxes and remarkably variable rainfall (delayed rainfall, dry spells, drought, extreme rainfall, and floods), and this indicator captures this sensitivity. (Davis et al., 2019).	(Crop Production Statistics Information System, 2006–2018); Kerala State Planning Board, 2006–2018; Odisha University of Agriculture and Technology (2013–14); Kerala et al. (2017); (Abraham, 2019)
Composite MGNREGA index	A composite index is formed by taking the average of normalised values of 4 indicators (Average person days per household employed, wage rate per day, women's participation, funds utilisation) (2014–2023)	Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) is an alternative source of income and helps build adaptive capacity, particularly in dealing with unforeseen hazards (Adam, 2014). It acts as a safety net by providing any adult household member registered under the scheme with 100 days of non-climate sensitive wage labour a year and 150 days in case of hazards such as droughts, floods, cyclones, and hailstones. This provides households with a menial but essential source of additional income to help them tide over the impacts of hazards. This index also reflects the participation of women in the labour force.	

Indicators	Construction	Rationale for selection	Sources
Female literacy rate	Percentage of literate women (15–49 years) (2019–20)	The literacy rate has a direct relation to the reduction of vulnerability. As the number of literate women increases, better livelihood methods will be adopted (Barua et al., 2019).	Ministry of Health and Family Welfare (2021a)
Forest area per 100 rural population	The total area of forest in sq. km is divided by 100 rural populations. (2021–2020)	Forests are an important source of alternative livelihood and food through the extraction of non-timber forest products (NTFPs). They also provide essential ecosystem services that are vital for the sustainable productivity of rural economies and build adaptive capacity (Barua et al., 2019).	Ministry of Environment, Forest and Climate Change (2021)
Health infrastructure (per 100 sq. km)	The sum of the number of functional health centres (Sub- centres, PHCs, CHCs) per 100 sq. km (2021)	Access to functional healthcare infrastructure is essential for the overall health and well-being of a community (Indian Himalayas Climate Adaptation Programme (Barua et al., 2019).	Ministry of Health and Family Welfare (2021b)
Livestock to human ratio	Total number of livestock, equivalence applied/ human population (2019–2020)	Livestock is an alternate source of income/ asset. Income earned from livestock can compensate for agricultural loss due to climate events. It is also an essential asset that can be sold during distress. Thus, livestock helps compensate for loss and reduce vulnerability. (Barua et al., 2019).	Ministry of Fisheries, Animal Husbandry, and Dairying (2019)
Proportion of area under crop insurance (2022)	(Crop area insured under Pradhan Mantri Fasal Bima Yojana and Weather-based Crop Insurance Scheme/ net sown area) *100 (2021)	Crop insurance helps farming households mitigate floods and drought losses, enhancing their adaptive capacity (Swain, 2014). The risk and insurance market to promote adaptation to climate change in the agriculture sector is still not fully developed in South-Asian countries (Aryal et al., 2020).	Ministry of Agriculture & Farmers' Welfare (n.d.)
Proportion net sown area under horticulture	Net sown area under horticulture/ net sown area (total) (2017–18/2021)	Horticulture trees are hardy and more resilient to climate variations than agricultural field crops. They provide alternate income sources for agriculture. Once established, they are far less sensitive to the impacts of climate risks, remarkably rainfall variability and droughts. (Barua et al., 2019).	Ministry of Agriculture & Farmers' Welfare (2018)
Road density	The sum of the length of surface road (in km)/ total geographical area (in sq. km) (2023/2020)	Transport becomes crucial during extreme weather events (Ebinger & Vandycke, 2015). This indicator represents accessibility and connectivity, which are essential in regions exposed to climate and disaster risks to allow for relocation and provide support services. It also implies a region's overall development because better connectivity comes with better access to markets, essential services, the potential for industrialisation, etc.	OpenStreetMap

2.2.4. Calculation of risk index

All exposure and vulnerability indicator values are normalised based on the max-min principle. The arithmetic means of the normalised values are used as Exposure Index (EI) and Vulnerability Index (VI), respectively (Alam et al., 2022). The risk index is calculated based on the geometric mean of the Hazard Index (HI) (i.e., DHI for drought and FHI for flood), Hazard-specific Exposure Index (EI) and Vulnerability Index (VI) is given as:

$$Risk\ Index\ =\ \sqrt[3]{(HI * EI * VI)}$$

Using the geometric mean is the best way of calculating the average value of components in ratios. Various important global indicators, such as the Human Development Index (UNDP, 2021), are calculated using a similar normalisation method and taking the geometric mean).

2.3. Categorisation of districts based on flood and drought hazard

Districts are categorised with natural breaks based on their flood and drought risk indices. This classification identifies breaks in the data with significant differences between adjacent values, indicating natural groupings or clusters within the dataset. Natural breaks identify meaningful risk categories compared to other classification methods like equal interval or quantile.

In this study, we have categorised risk as ‘Very high’, ‘High’, ‘Medium’, ‘Low’ and ‘Very Low’ to reflect the relative ranking of districts.

PART II:

District-level Flood and Drought Risk Maps for India and the States and Union Territories

3. District-level flood and drought risk: All-India mapping

In our previous endeavour, we developed a district-level vulnerability map for India (Dasgupta et al., 2021). That map identified highly vulnerable districts where intervention would be required in anticipation of climate change. Since vulnerability indicators are closely associated with development indicators, addressing vulnerability creates a win-win situation for the government.

Allocation of adaptation funds in vulnerable districts, especially in sectors that act as drivers of vulnerability, creates a preparedness for a changing climate condition and results in overall resilience. Vulnerability assessments are vital in financial allocations and have their own merits. However, assessing climate risk is a natural progression towards developing a better understanding of the relative positions of districts with respect to the probability of occurrence of hazard, exposure and vulnerability.

India's districts vary significantly in climate patterns, topography, socio-economic conditions, and vulnerability to climate-related hazards, particularly floods and droughts. Conducting flood and drought risk assessments at the district level allows for a detailed, administrative understanding of specific risks. These assessments consider local environmental conditions, infrastructure, livelihoods, and communities. Further, in India, districts play a crucial role as decision-making units for implementing policies and programmes, especially in disaster management, development planning, and resource allocation. Hence, flood and drought risk assessment at the district level will allow decision-makers to tailor adaptation and mitigation strategies according to specific risks a particular district faces.

In addition, all-India district-level risk mapping involves the spatial identification and visualisation of districts prone to flood and drought hazards, as well as populations, livelihoods, and assets that are exposed and vulnerable to these hazards. Risk maps provide valuable insights into where and how flood and drought risks are distributed across districts in India by analysing historical data, socio-economic factors, and infrastructure vulnerabilities.

Once high-risk districts and factors driving flood and drought risks are identified through risk mapping, policymakers, planners, and stakeholders can prioritise resources and interventions more effectively. This ensures that limited resources are directed towards the most vulnerable districts and populations, where they are most needed. By proactively addressing flood and drought risks in high-risk districts, the impacts of climate change can be minimised.

Overall, district-level flood and drought risk mapping for India serves as a vital tool for informed decision-making. It enables policymakers and practitioners to prioritise actions, allocate resources efficiently, and implement targeted interventions that enhance resilience and reduce the adverse impacts of climate change on communities.

3.1. Indicators of hazard, exposure, and vulnerability

As discussed in Section 2, the flood risk is determined as an interaction of flood hazard, exposure, and vulnerability. Flood hazard is calculated through the integration of GIS and MCDA techniques where slope, elevation, drainage density, soil texture, Topographic Wetness Index (TWI), SPI (probability of occurrence of severe and extreme wet events), distance from the river, geomorphology, and LULC were considered. The SPI-6 is used to understand the deviation of precipitation from the long-term average.

An area is considered under the risk of drought hazard if precipitation systematically falls below the long-term average. The indicators of flood exposure are population density and the proportion of area under agriculture. Drought exposure is calculated based on population density and area under rainfed agriculture.

Vulnerability is a system property. Its indicators are MPI, the proportion of marginal and small landholdings, yield variability of food grains, the composite MGNREGA index, the female literacy rate, forest area per 100 rural population, health infrastructure available per 100 square kilometres, the livestock-to-human ratio, the proportion of area under crop insurance, the proportion of net sown area under horticulture, and road density.

The Flood Hazard Index (FHI)/ Drought Hazard Index (DHI), Flood Exposure Index (FEI)/ Drought Exposure Index (DEI) and Vulnerability Index (VI) obtained are then combined in the following formula to arrive at a Flood Risk Index (FRI) and Drought Risk Index (DRI). Districts are categorised according to their risk indices.

$$Risk\ Index = \sqrt[3]{(HI * EI * VI)}$$

3.2. Components of flood and drought risk indices – hazard, exposure and vulnerability

3.2.1. Flood Hazard

The district-level[5] Figures 3.1, 3.2, and 3.5 present flood hazard, exposure, and vulnerability maps for India. Figure 3.6 presents an overall flood hazard map. The flood hazard index across districts varies from a negligible positive value (close to zero) to 0.84. This large range for flood hazard is consistent with the representation of flood maps prepared by the NDMA (n.d.), BMTPC (2019), IMD (2022), and NRSC (2023).

These maps (not detailed at the district level, though) point out the presence of flood-prone locations in the Brahmaputra and Ganga river basins in the Indo-Gangetic Brahmaputra plains in North and North-East India. This is followed by the northwestern regions of west-flowing rivers such as the Narmada and Tapi, Central India, and the Deccan region, which has major east-flowing rivers like the Mahanadi, Krishna, and Cauvery. Our map also shows the presence of multiple very high to high flood hazard-prone districts in Assam, West Bengal, Jammu and Kashmir, Uttarakhand, Himachal Pradesh, Manipur, coastal parts of Odisha, Andhra Pradesh, and Kerala, and parts of Gujarat located in the above-mentioned geographical regions.

However, it may be re-emphasised that all index values depict the relative position of a district in comparison to others. A lower value of a flood hazard index does not necessarily mean that the location will have no probability of flood occurrence. What sets the current study apart is that it goes beyond hazard analysis and mapping. It aims to understand exposure and vulnerability characteristics and the interplay of the three components of risk, resulting in differential impacts.

5. It is better not to consider the risk obtained from 7 major cities (going by 2014 data). These are Ahmedabad, Chennai, Hyderabad, Kolkata, Pune, Bangalore, and Mumbai. This also applies to a few Union Territories: Andaman and Nicobar Islands, Chandigarh, Dadra and Nagar Haveli, Daman and Diu, Delhi (NCT), Ladakh, Lakshadweep, and Puducherry. These cities and UTs have very different characteristics in terms of income, infrastructure, population density, etc. and may not be considered together with other districts.

3.2.2. Flood Exposure

The flood exposure index varies from a negligible positive value to 0.97. Many districts in the Indo-Gangetic plain, especially Uttar Pradesh, Bihar, and West Bengal, exhibit a high exposure to floods due to their dense population and agricultural lands. Exposure is shallow in districts in Arunachal Pradesh on account of its very thin population density, along with a few districts in states of the Indian Himalayan Region (such as Lahaul and Spiti in Himachal Pradesh, None in Manipur, and North Sikkim).

3.2.3. Drought Hazard

The drought hazard index across districts in India varies from 0.07 to 0.68. Unlike the concentrated flood hazard, drought is spread out more evenly in districts across the country. Sixty-five districts under the very high drought-hazard category (0.68–0.47) are located in 22 states, including Uttar Pradesh, Bihar, Punjab, Tamil Nadu, Uttarakhand, Haryana, Karnataka, Rajasthan, Assam, Kerala, Nagaland and Chhattisgarh, hosting more than one such district.

We observed a dearth of national-level drought hazard mapping. Hence we compared our results with data from publications such as Chuphal et al. (2024). They found a similar spread in the distribution of the frequency of severe and exceptional droughts that had occurred in India from 1901 to 2021.

3.2.4. Drought exposure

The drought exposure index ranges between a nominal positive value and 0.98. The reason behind a very low exposure in certain regions is, again, formed by a very thin population density. On the other hand, the very high drought-exposed districts (DEI ranging between 0.65 and 0.98) are found to be primarily located in the geographical belt of Bihar, West Bengal, and Jharkhand, followed by Assam and Kerala because of a very high population density there. However, many districts in Maharashtra are also highly exposed to drought due to their high dependence on rainfed agriculture.

3.2.5. Vulnerability

The vulnerability index varies from 0.294 to 0.793, consistent with our earlier pan-India assessment (Dasgupta et al., 2021). Again, this emphasises that all districts in India are vulnerable, and the drivers may vary. Despite very low index values for hazard and exposure in some districts, it should be emphasised that no district in India has near-zero vulnerability. Continued efforts to handle this source of risk remain important, not only for climate resilience but also for overall development. Districts with high vulnerability (0.67 – 0.793) are mostly found in Uttar Pradesh, Bihar, Jharkhand, Madhya Pradesh and Assam. Again, this shows a spatial distribution similar to our previous vulnerability assessment. Still, it needs to be kept in mind that this does not mean that the rest of the states do not have districts without high vulnerability.

3.3. District-level flood risk in India

Flood risk arises at the intersection of flood hazard, exposure, and vulnerability. Figure 3.6. represents a district-level flood risk map of India. The flood risk index range is 0.015 – 0.688. It is divided into five categories: Very High (0.440 – 0.688; 51 districts), High (0.284 – 0.439; 118 districts), Medium (0.194 – 0.283; 216 districts), Low (0.122 – 0.193; 205 districts), and Very Low (0.015 – 0.121; 108 districts). Of the 51 districts in the 'Very High' risk category, 24 are in Assam, 14 in West Bengal, and the remainder in Manipur, Bihar, Jammu and Kashmir, Odisha, Uttarakhand, and Kerala.

3.4. District-level drought risk in India

The drought risk map is presented in Figure 3.7 where, similar to flood risk, drought risk is conceptualised at the intersection of drought hazard, drought exposure and vulnerability. The calculated drought risk index ranges from 0.042 to 0.644. The range is divided into five categories: Very High (0.510 – 0.644; 91 districts), High (0.450 – 0.509; 187 districts), Medium (0.396 – 0449; 176 districts), Low (0.329 – 0.395; 165 districts), and Deficient (0.042 – 0.328; 79 districts). More than 90% of districts in the Very High category (83 out of 91) are located in Bihar, Assam, Jharkhand, Odisha, Uttar Pradesh, and Maharashtra.

3.5. Dual risk of flood and drought

Several districts are experiencing both flood and drought risk. Of the top 50 districts with a high flood risk and the top 50 with a high drought risk, 11 districts are at dual risk of flood and drought. Districts facing this type of risk are Patna in Bihar; Alappuzha in Kerala; Charaideo, Dibrugarh, Sibsagar, South Salmara-Mankachar, and Golaghat in Assam; Kendrapara in Odisha; and Murshidabad, Nadia, and Uttar Dinajpur in West Bengal. While Alappuzha is flood-prone (Binoy et al., 2023), it experienced multiple drought events, especially in 2018, and was declared a 'drought-hit' by the Kerala State Disaster Management Authority (The Hindu, 2018). The districts mentioned above in Assam are susceptible to floods due to their proximity to the Brahmaputra river and positive rainfall anomalies during the monsoon in some places (Bora et al., 2023; District Disaster Management Plan Charaideo, 2024; Saharia et al., 2024). However, these districts have experienced droughts in the last few decades due to erratic rainfall, especially in August and September (Parida & Oinam, 2015; Singh et al., 2024). In West Bengal, Murshidabad, Nadia, and Uttar Dinajpur we experienced flooding and a decreasing trend in annual and monsoon precipitation in specific locations (Kumar et al., 2023). Patna experiences localised intense rainfall events leading to floods, while long dry spells were recorded in July 2023, with 43% less than the average rainfall (The Pioneer, 2024). Likewise, in Kendrapara, flood and drought events have increased due to highly variable rainfall, high water deficit, and frequent rainfall failure (Banerjee, 2016).

3.6. Drivers of flood and drought risk

The study's findings clearly bring out two things: a) Flood and drought hazards are one of the driving forces behind the overall risk. b) Such risk can be amplified, even when the hazard probability is low, in the presence of high exposure and vulnerability.

This, in turn, highlights the importance of short to medium-term development policies with adaptation benefits that can effectuate a significant risk reduction through a vulnerability reduction and some of the elements of exposure.

This becomes evident in Figures 3.8 and 3.9. They identify the contribution of hazard, exposure and vulnerability in the overall flood and drought risk respectively, for the top 50 risk-prone districts. The two Figures show that the contribution of drivers varied across districts - both in case of flood and drought.

For example, if we consider Patna (Bihar) and Majuli (Assam) in Figure 3.8, their flood risk indices are comparable – 0.45 for Patna and 0.47 for Majuli. However, the profiles of these two districts are completely different in terms of hazard, exposure, and vulnerability. While the flood hazard index is very high in Majuli (0.84), it is much lower in Patna (0.18). At the same time, very high exposure (Flood Exposure Index = 0.84) owing to dense population and high vulnerability (VI = 0.62) elevated the flood-risk of Patna to a level as high as Majuli. It is worth noting that while Majuli is highly flood-prone, it has relatively lower exposure (0.27) and vulnerability (0.46) than Patna.

Similarly, Gopalgunj in Bihar and Kottayam in Kerala (Figure 3.9) have comparable drought risks, with a drought risk in Gopalgunj of 0.55 and in Kottayam 0.56. But the hazard index is much higher in Kottayam compared to Gopalgunj. The former is operating at this level of risk, even with a drought hazard index at 0.55 compared to 0.33 in Gopalgunj.

The exposure indices in these two districts are also comparable (0.71 in Gopalgunj and 0.75 in Kottayam), making it a perfect illustration of high probability of climate hazards being neutralised by low vulnerability. The vulnerability index of Kottayam is at 0.43 while the same for Gopalgunj is 0.71.

The flood and drought risk assessment underscores the importance of understanding the drivers of these climate events to design targeted interventions. A district with a low flood hazard but high exposure and vulnerability may suffer significant losses, despite a fewer number of floods or floods of lower magnitude due to a limited coping capacity.

Conversely, districts with a high flood hazard but low exposure and vulnerability demonstrate the value of adaptation and resilience building – leading to a higher coping capacity that helps buffer hazards. For hazard mitigation is possible only in the long term and requires global efforts.

Understanding risk at the nexus of hazard, exposure, and vulnerability is crucial, because it reveals that high-hazard proneness alone does not equate to high risk; it is the interaction with exposure and vulnerability that triggers risk and determines its extent.

Flood and drought risk assessment highlights the need to go beyond environmental factors leading to these two events, since social, economic, and political factors shape vulnerabilities and resilience. While mitigating hazards is crucial in the long run, enhancing adaptive capacity in the short and medium term is vital to shield communities from climate-related hazards. Integrating human-centric and interdisciplinary interventions into flood and drought risk assessment facilitates the development of holistic, inclusive strategies fostering sustainable development and bolstering community resilience against climate change.

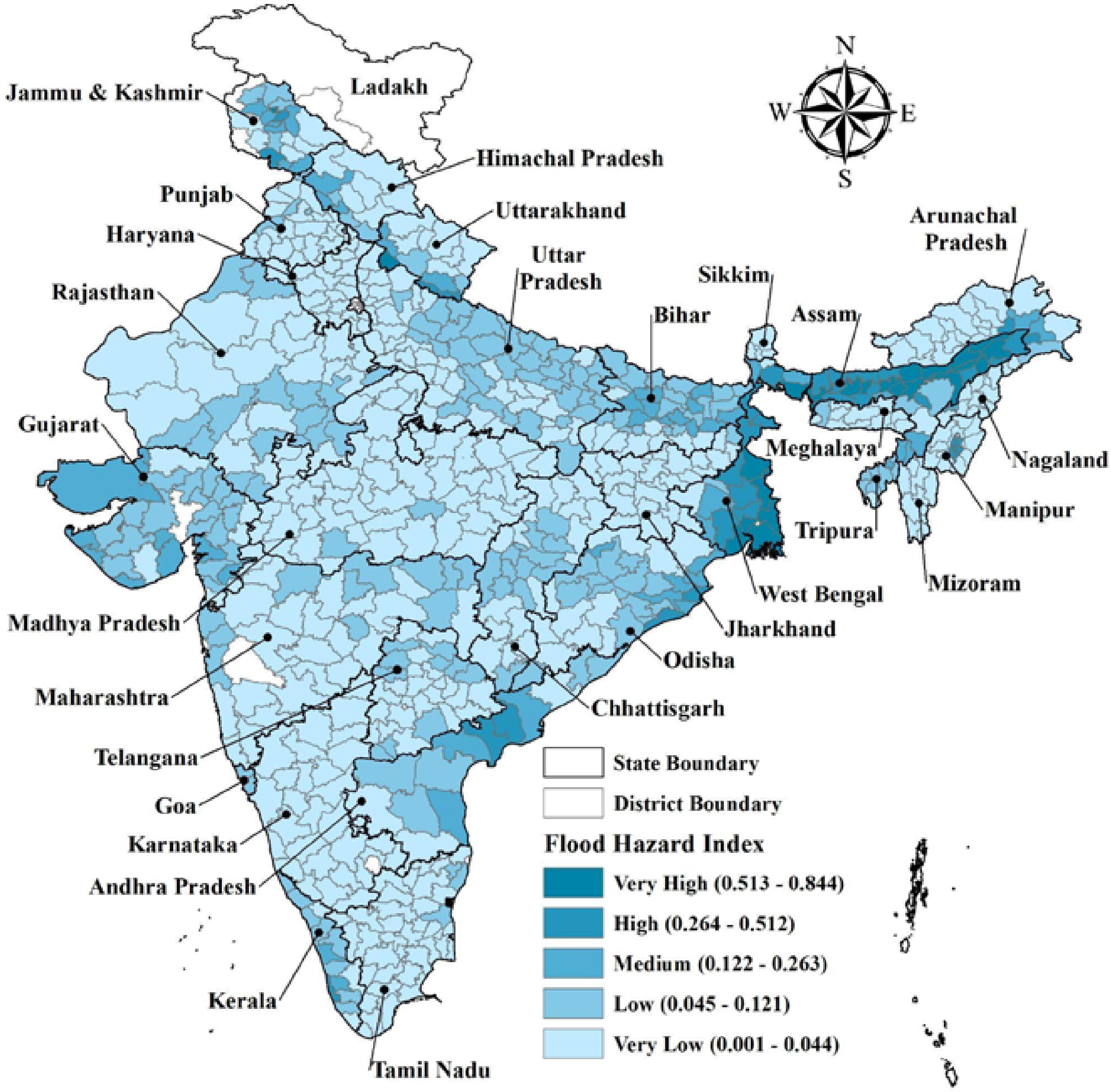


Figure 3.1: **District-level Flood Hazard Map of India (for the period 1970–2019)**

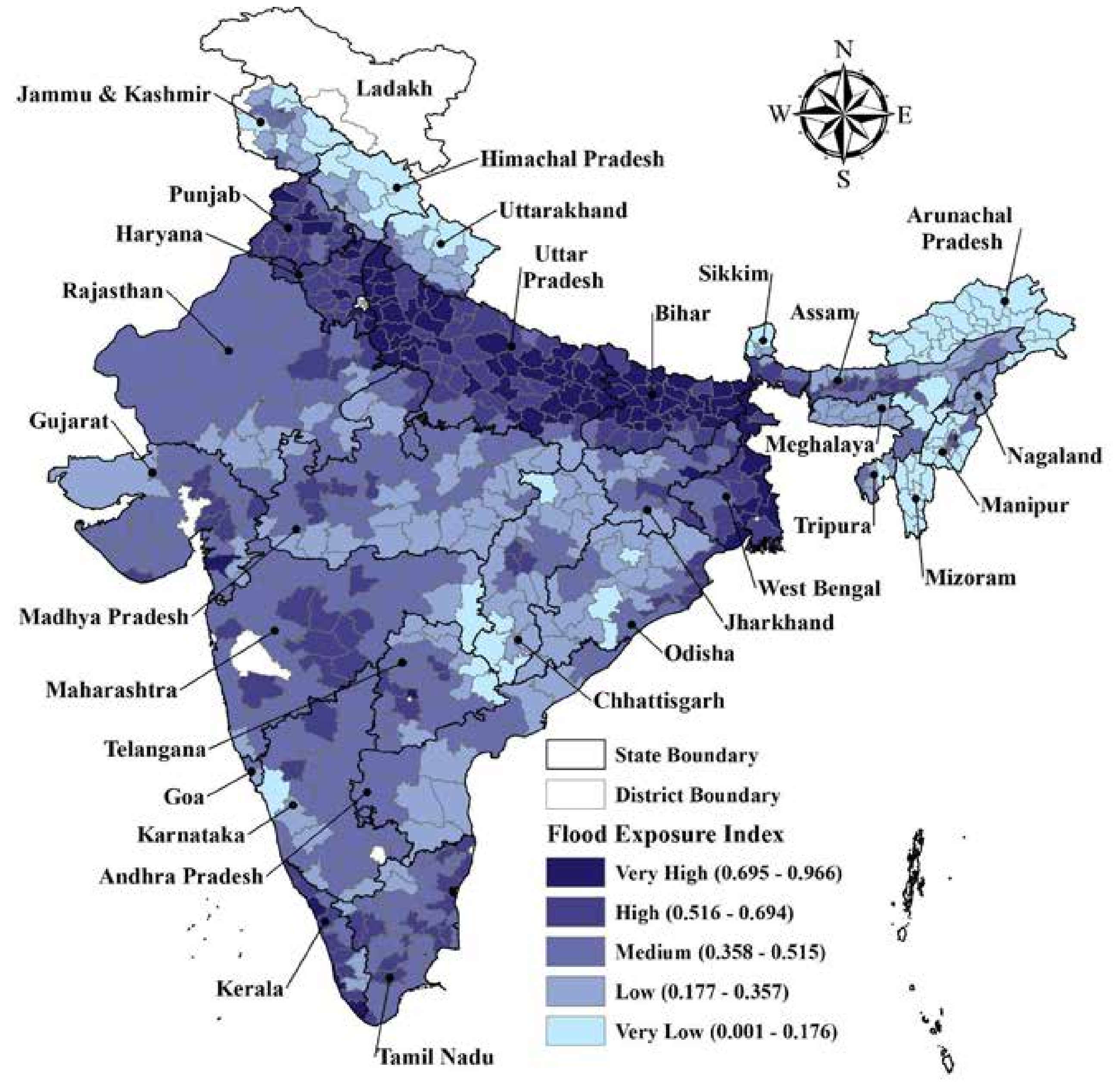


Figure 3.2: **District-level Flood Exposure Map of India**

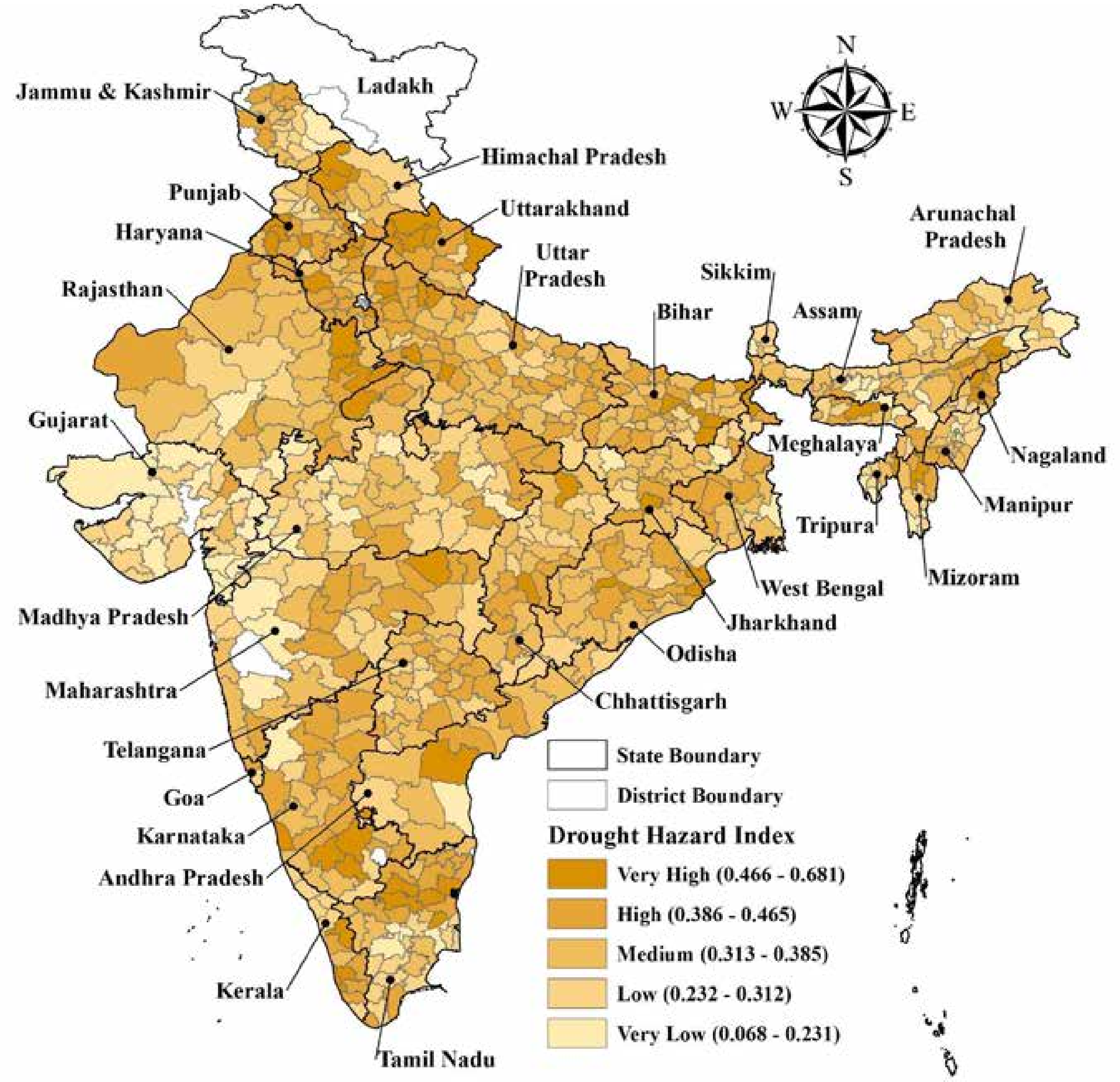


Figure 3.3: District-level Drought Hazard Map of India (for the period 1970–2019)

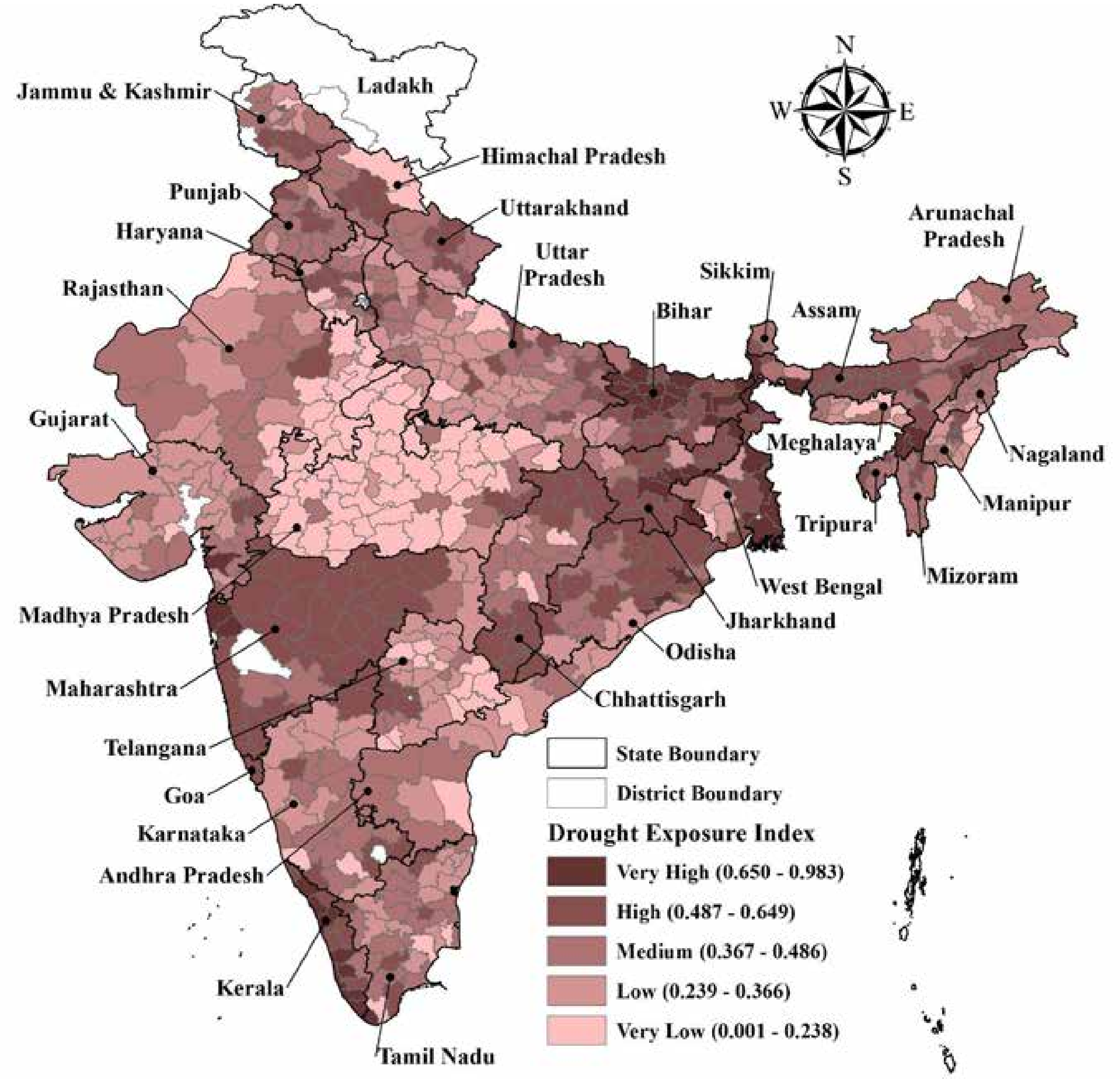


Figure 3.4: **District-level Drought Exposure Map of India**

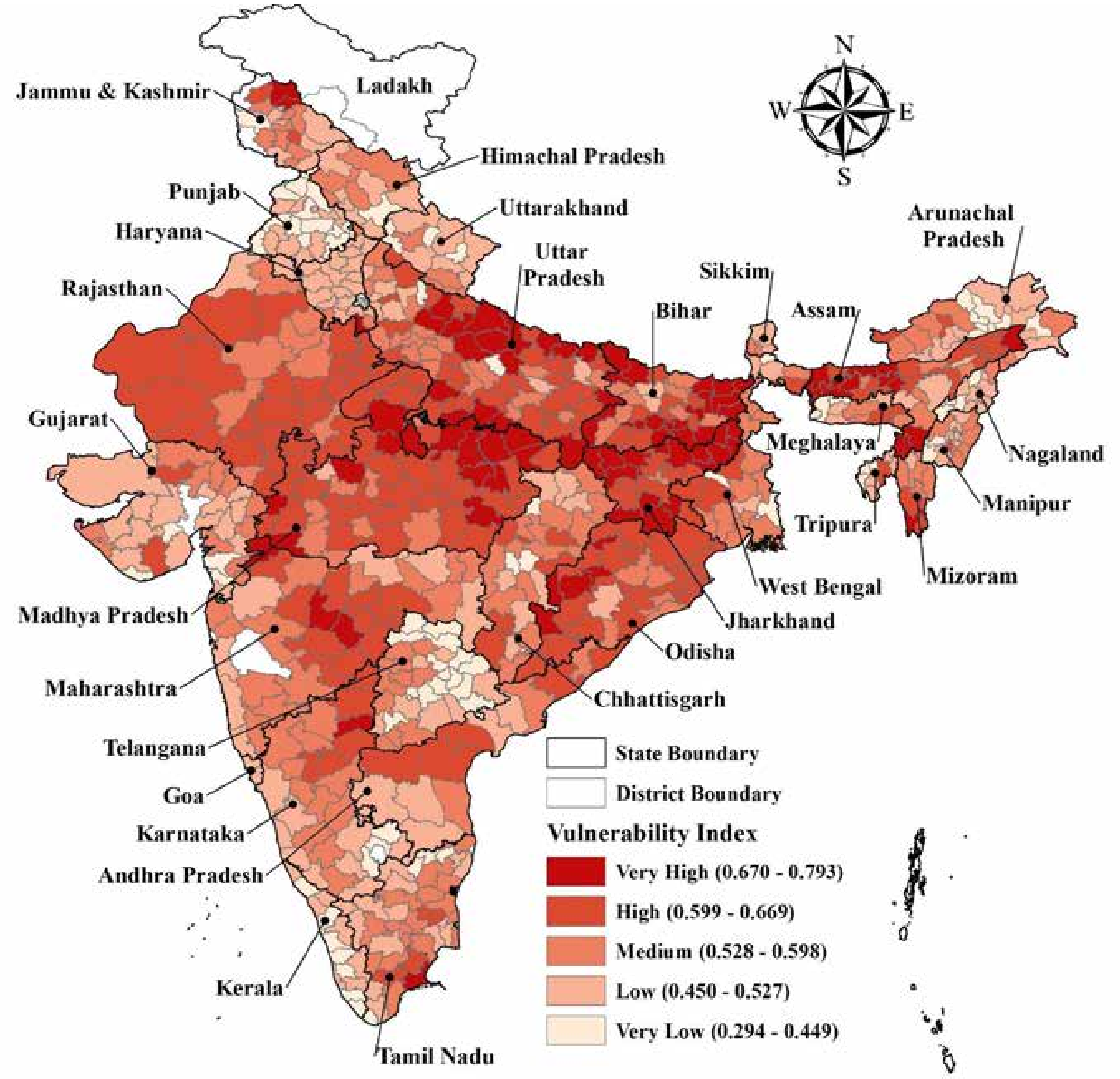


Figure 3.5: **District-level Vulnerability Map of India**

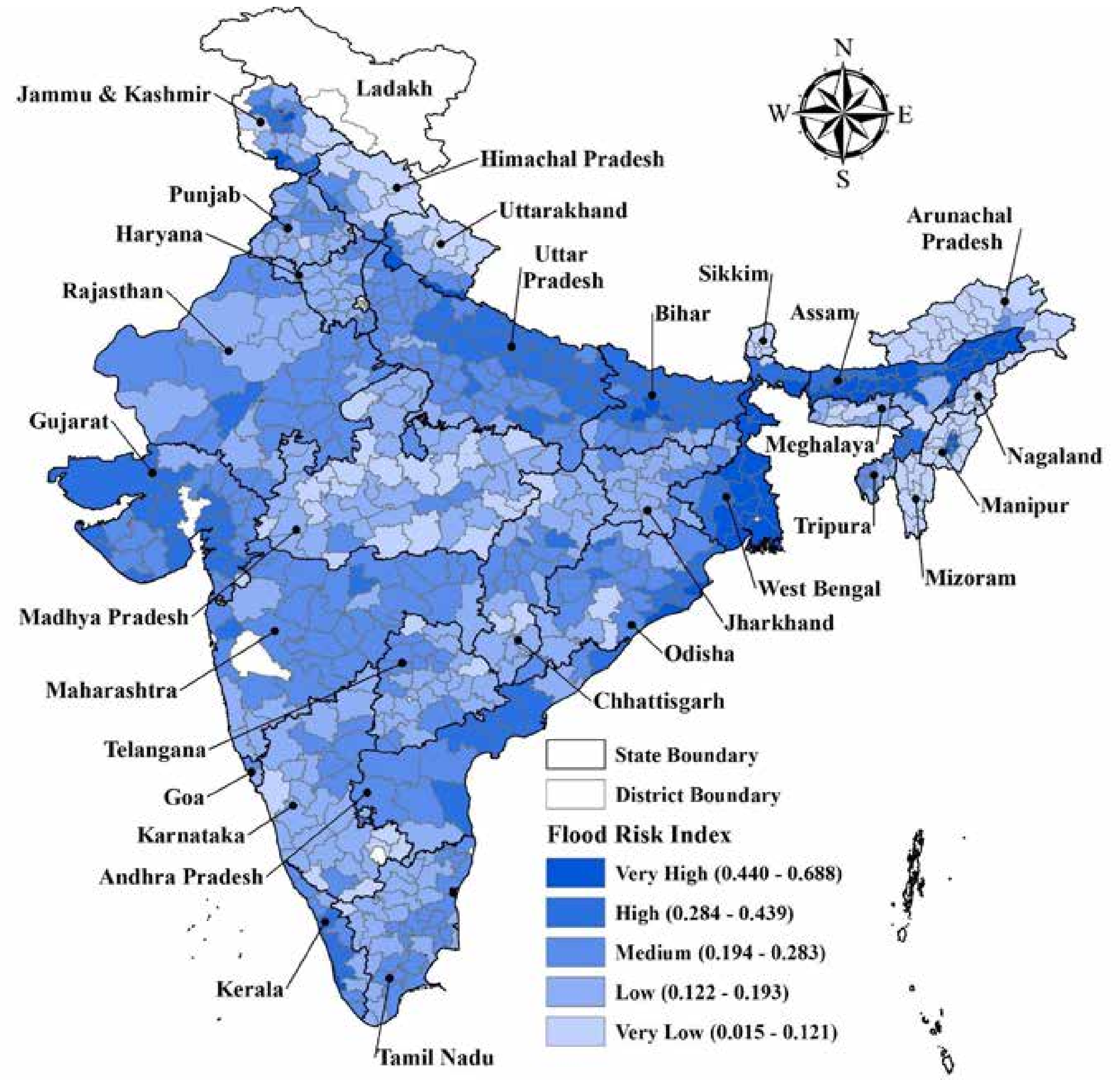


Figure 3.6: District-level Flood Risk Map of India (for the period 1970–2019)

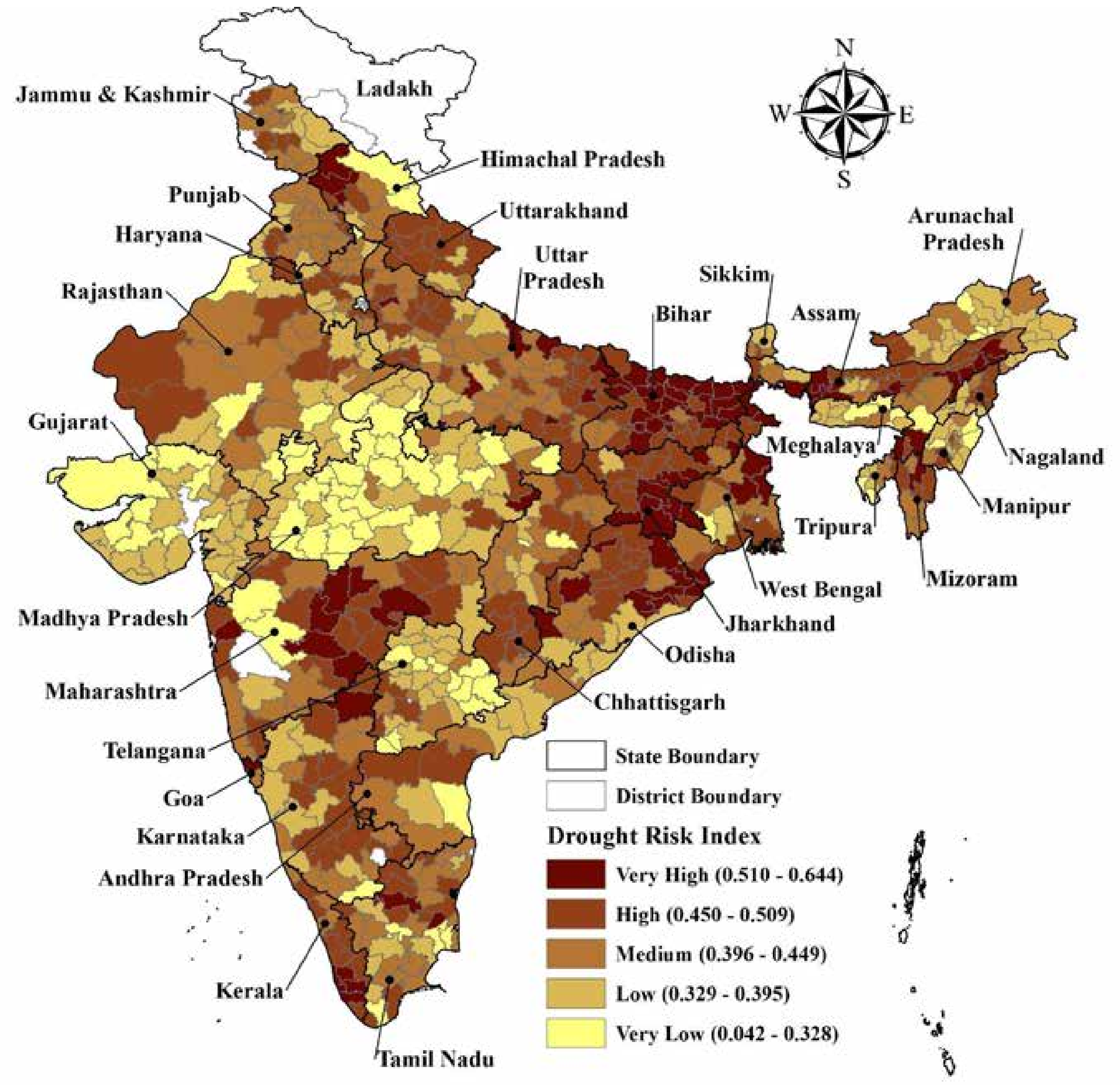


Figure 3.7: District-level Drought Risk Map of India (for the period 1970–2019)

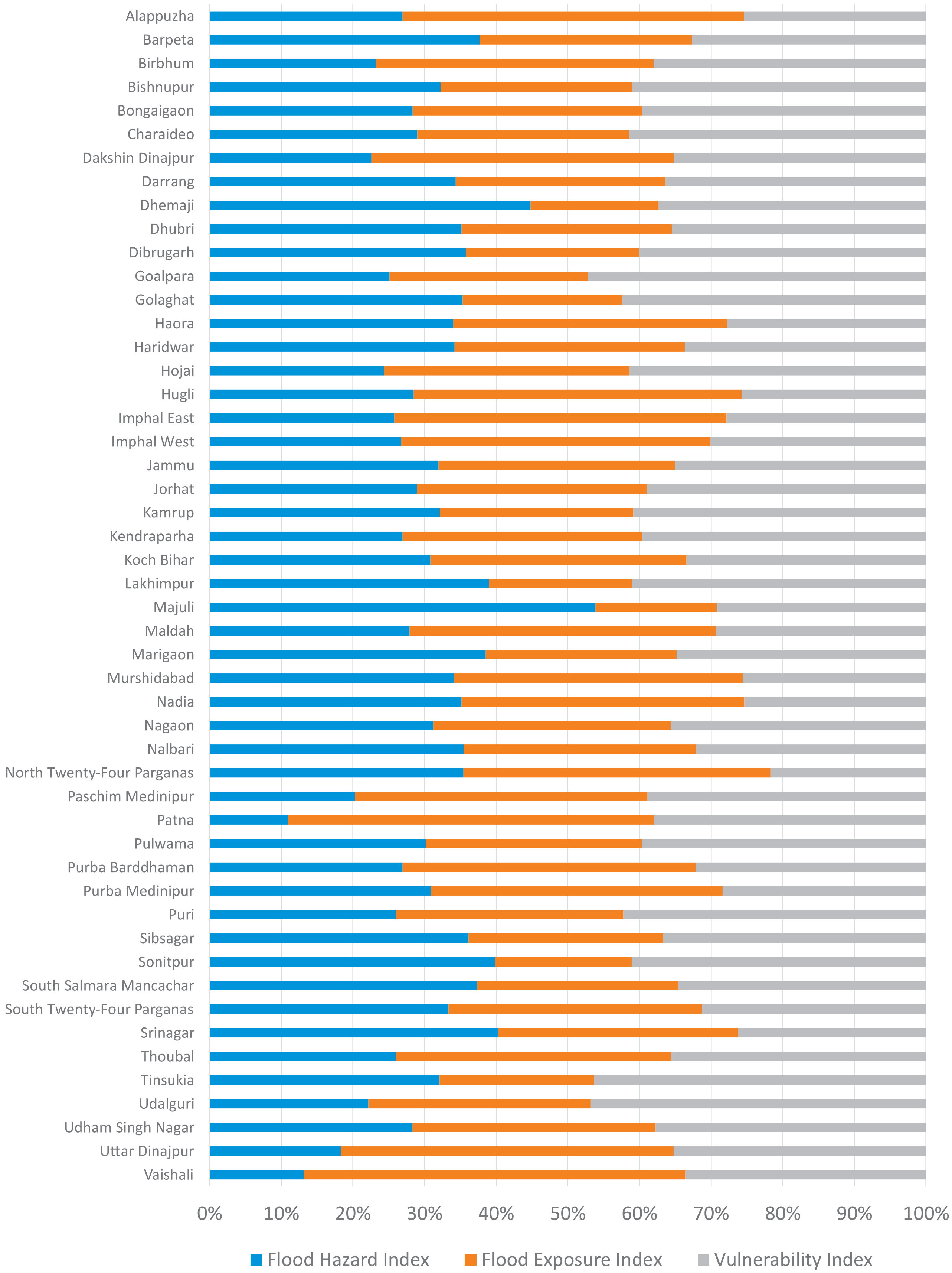


Figure 3.8: Contribution of flood hazard, exposure and vulnerability to overall flood risk for 50 districts in India with the highest flood risk index

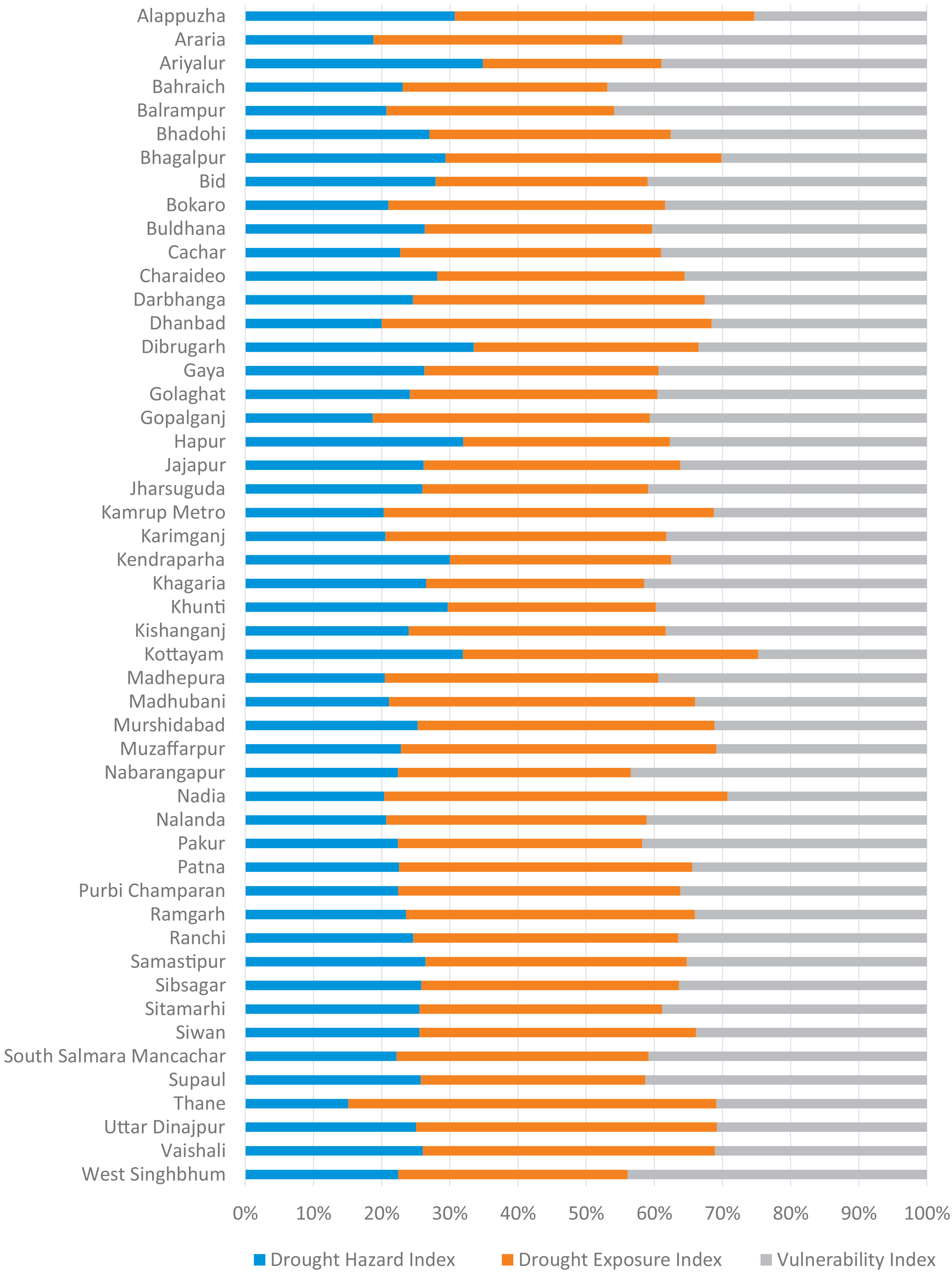


Figure 3.9: Contribution of drought hazard, exposure, and vulnerability to overall drought risk for 50 districts in India with the highest drought risk index

4. District-level flood and drought risk: Mapping for Indian states and UTs

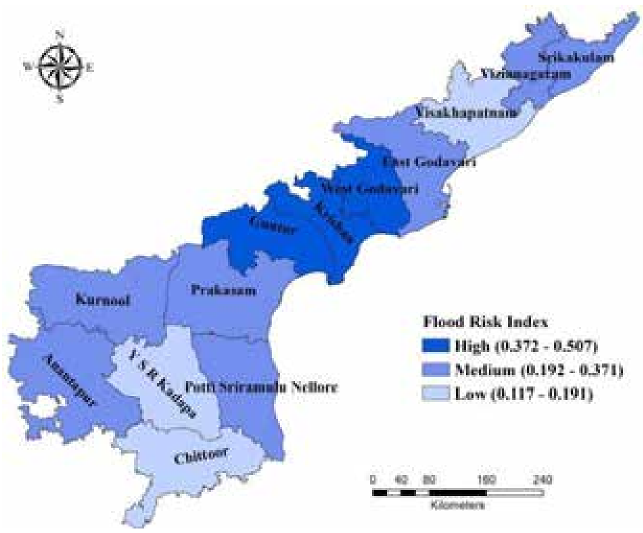
India's vast and diverse landscape necessitates state-level flood and drought risk assessments to gain localised insights into climate-related hazards, vulnerabilities, and exposures. These assessments enable tailored adaptation and mitigation strategies to address specific challenges different regions and communities face within each state. By conducting district-level flood and drought risk assessments, states can pinpoint areas and populations most at risk, facilitating targeted interventions and resource allocation where they are most needed. This ensures that adaptation and resilience-building measures are prioritised and effectively implemented to address the unique vulnerabilities of each locality.

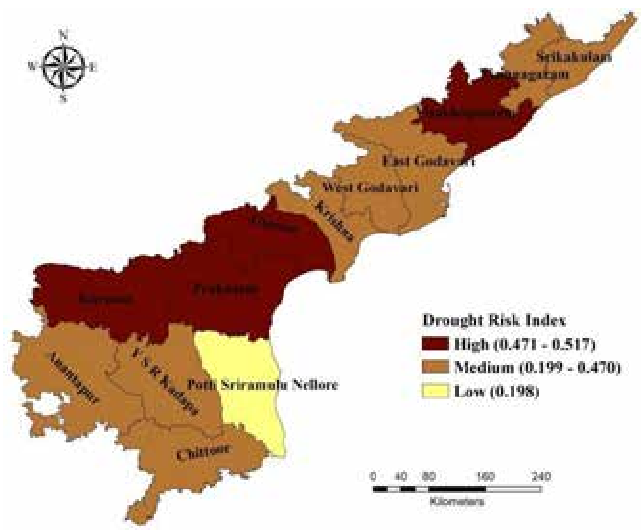
Further, the findings from state-level risk assessments can inform the development of state-specific policies, plans, and strategies to manage flood and drought risks. This alignment with local contexts, priorities, and needs enhances the relevance and effectiveness of interventions, ensuring they resonate with each state's specific challenges.

Building state capacity was paramount to our project. State-level flood and drought risk assessments empowered state representatives to engage actively in the process, identifying key indicators relevant to their state and contributing to the development of common indicators. This collaborative approach resulted in the strong involvement of states in creating state-specific flood and drought risk maps at the district level, a significant outcome of our engagement.

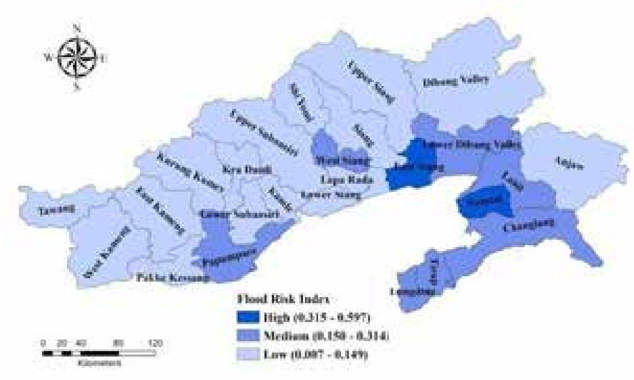
4.1. District-level flood and drought risk: Mapping for Indian states and UTs

Flood Risk Map - Andhra Pradesh	Drought Risk Map - Andhra Pradesh

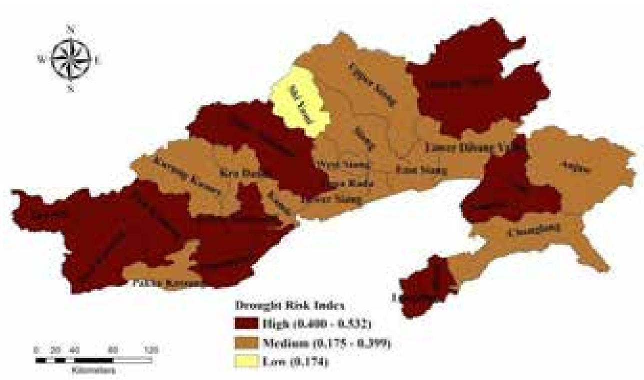




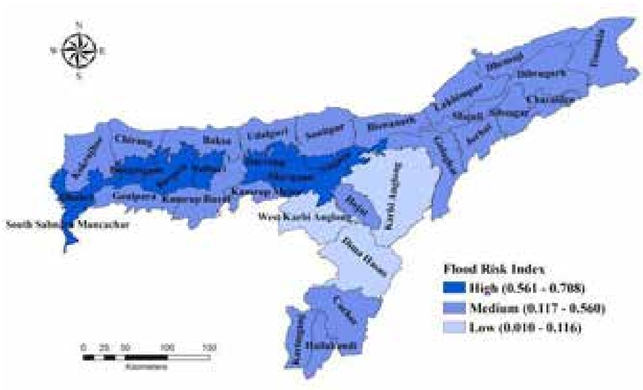
Flood Risk Map - Arunachal Pradesh



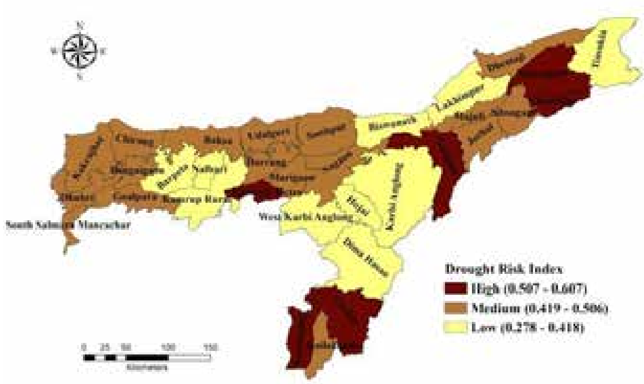
Drought Risk Map - Arunachal Pradesh



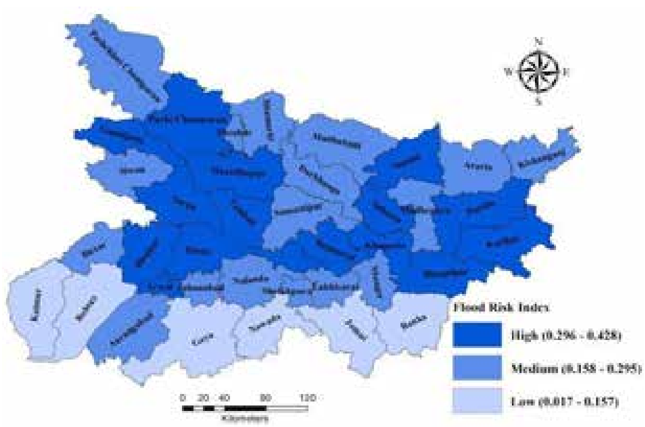
Flood Risk Map - Assam



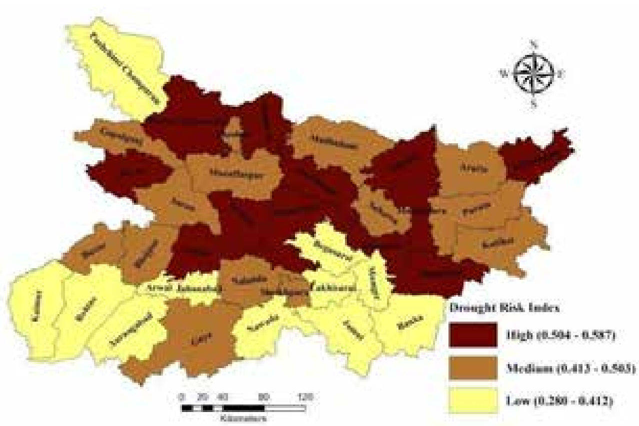
Drought Risk Map - Assam



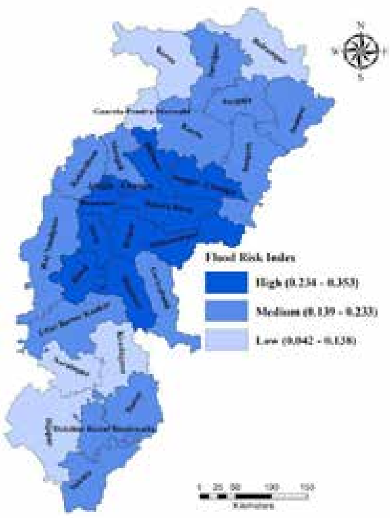
Flood Risk Map - Bihar

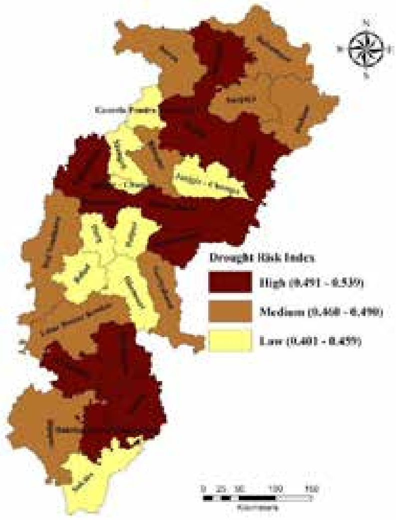


Drought Risk Map - Bihar



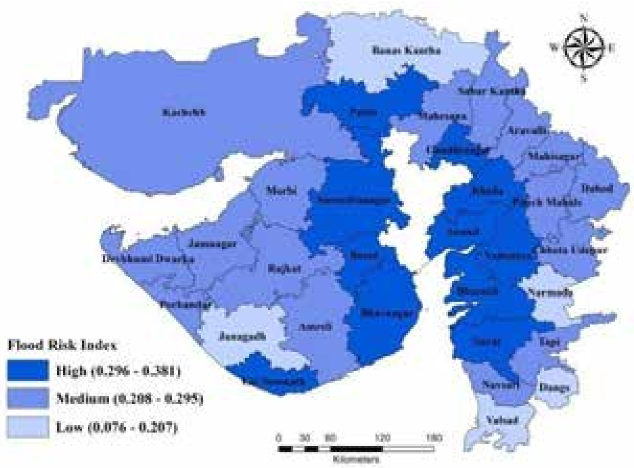
Flood Risk Map - Chhattisgarh	Drought Risk Map - Chhattisgarh

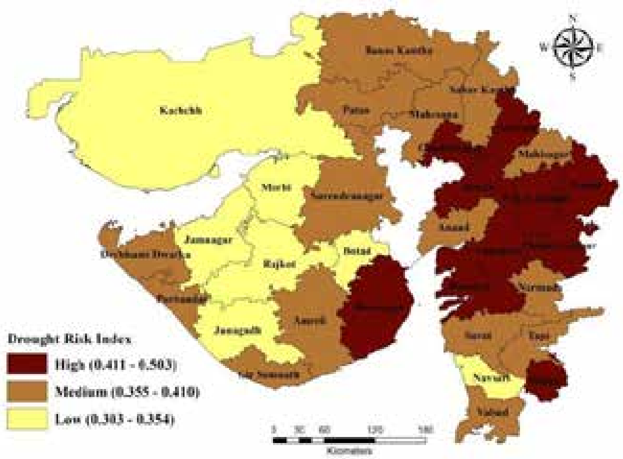




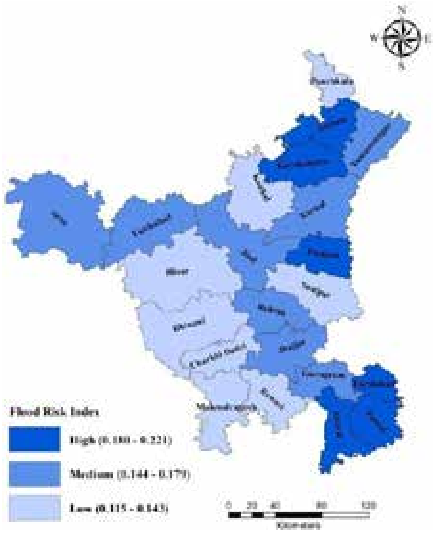
Flood Risk Map - Goa	Drought Risk Map - Goa

Flood Risk Map - Gujarat	Drought Risk Map - Gujarat

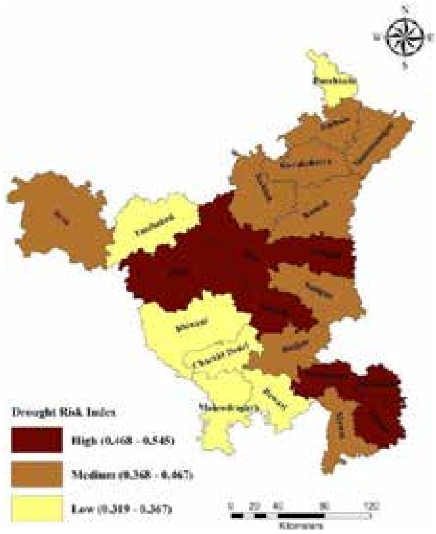




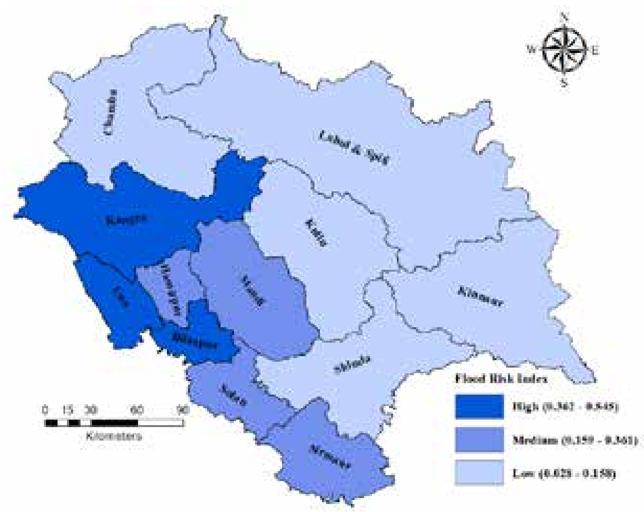
Flood Risk Map - Haryana



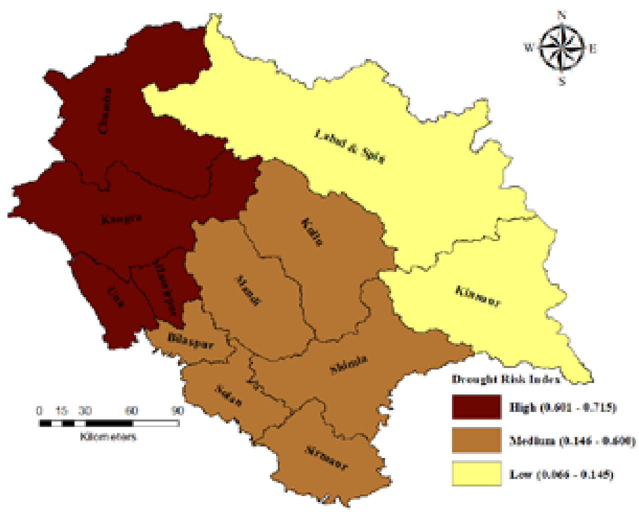
Drought Risk Map - Haryana



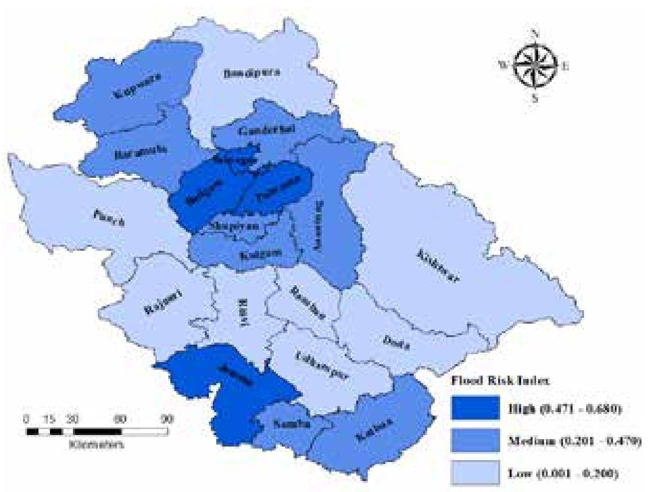
Flood Risk Map - Himachal Pradesh



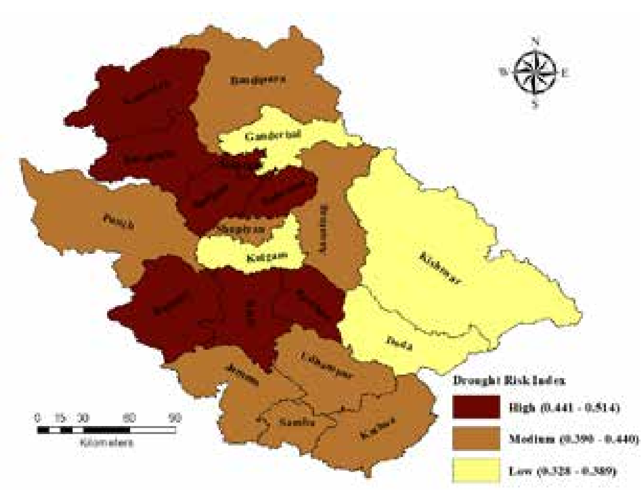
Drought Risk Map - Himachal Pradesh



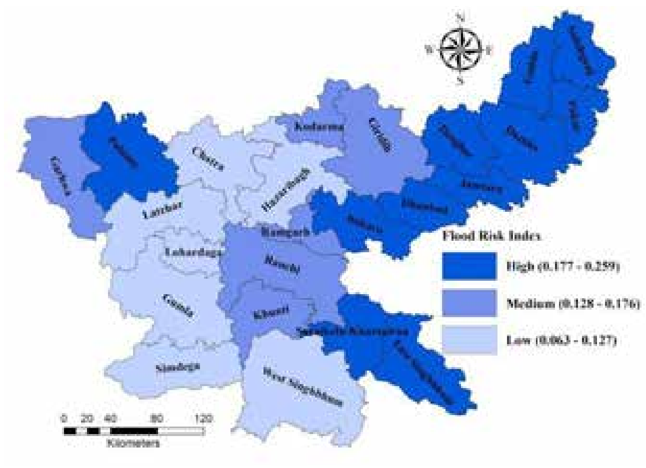
Flood Risk Index - Jammu and Kashmir



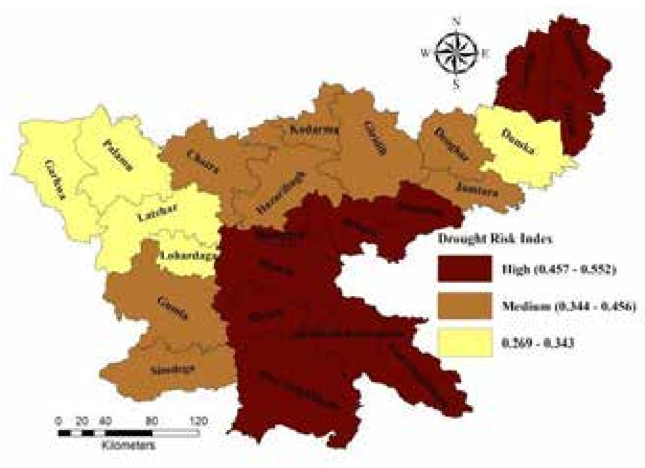
Drought Risk Index - Jammu and Kashmir



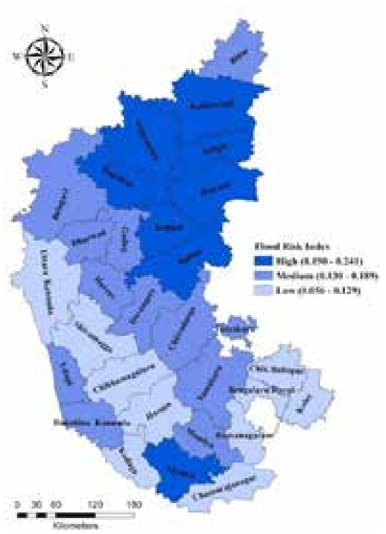
Flood Risk Index - Jharkhand



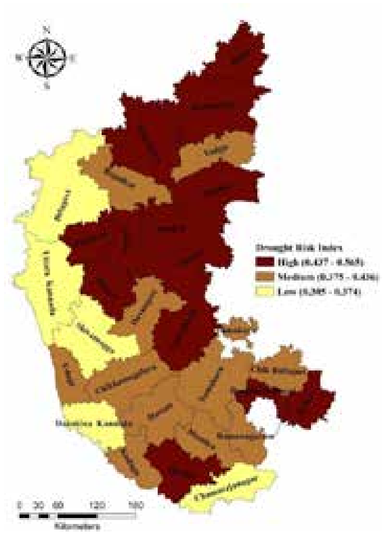
Drought Risk Index - Jharkhand



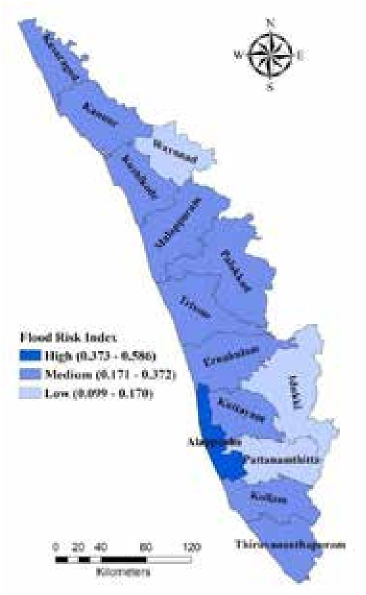
Flood Risk Index - Karnataka



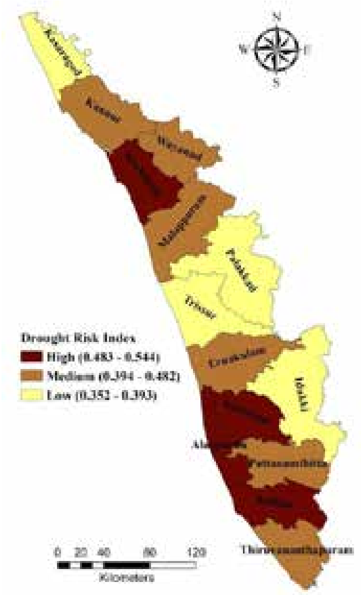
Drought Risk Index - Karnataka



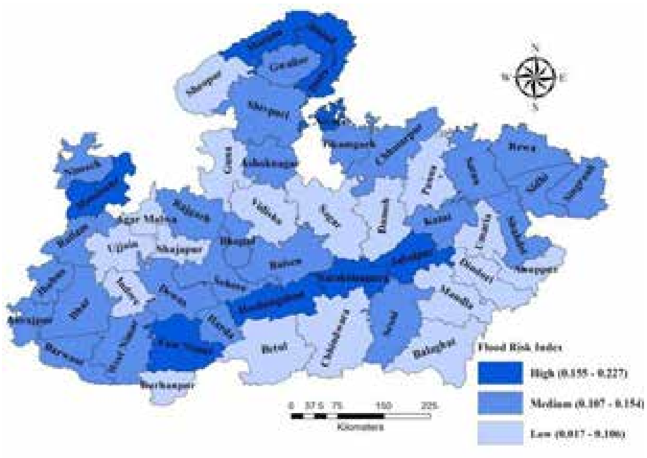
Flood Risk Index - Kerala

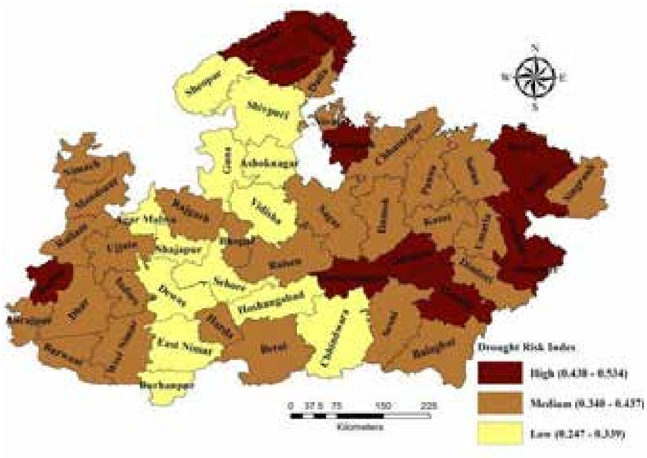


Drought Risk Index - Kerala

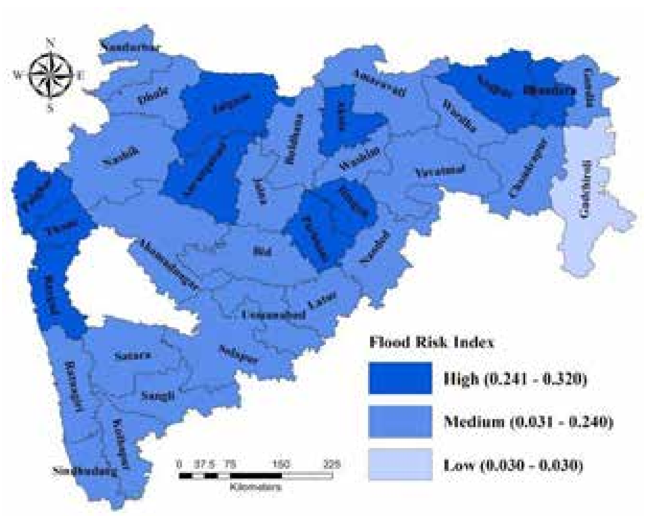


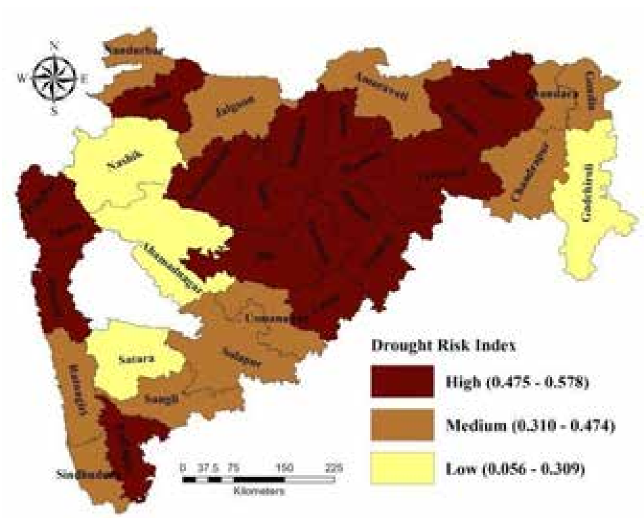
Flood Risk Index - Madhya Pradesh	Drought Risk Index - Madhya Pradesh



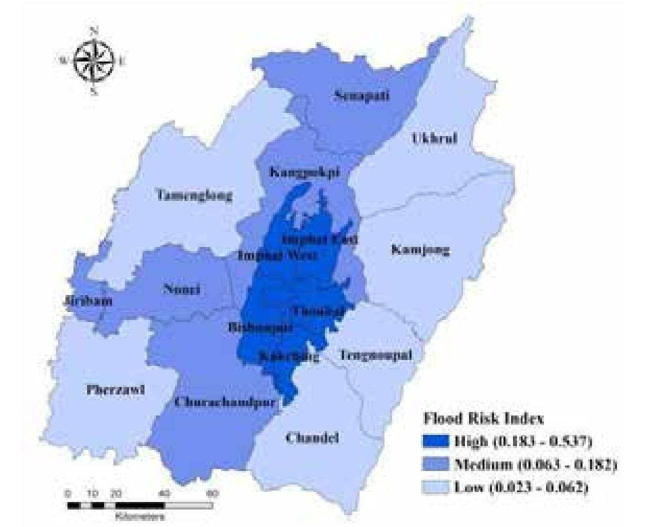


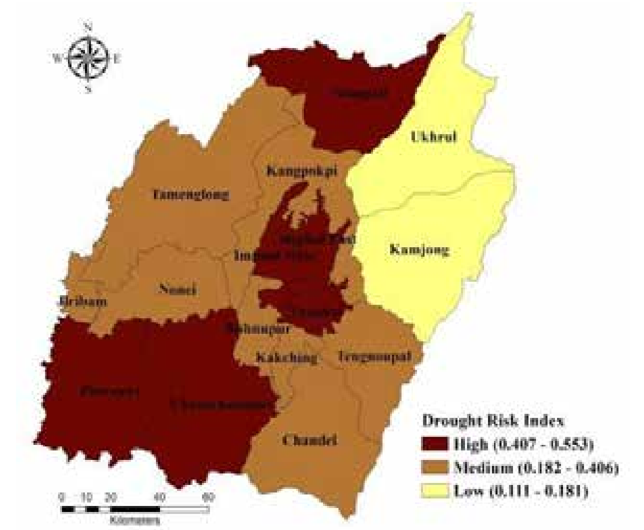
Flood Risk Index - Maharashtra	Drought Risk Index - Maharashtra



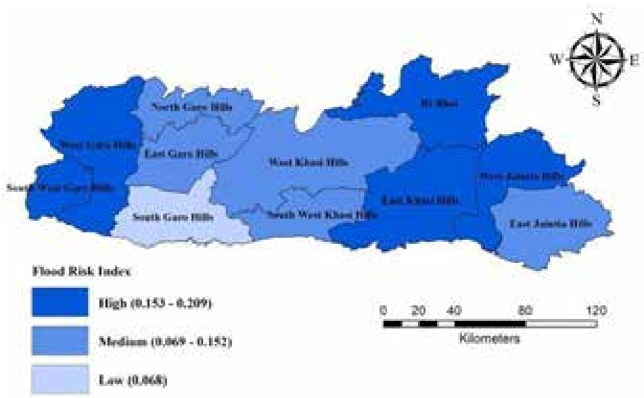


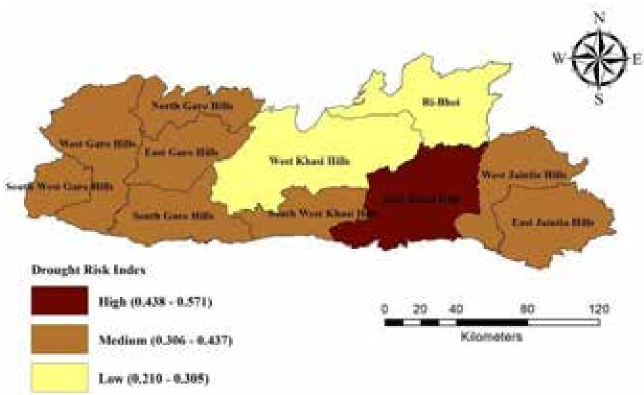
Flood Risk Index - Manipur	Drought Risk Index - Manipur



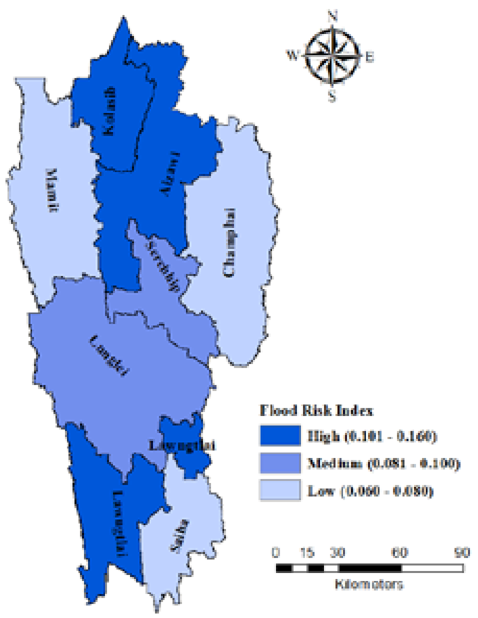


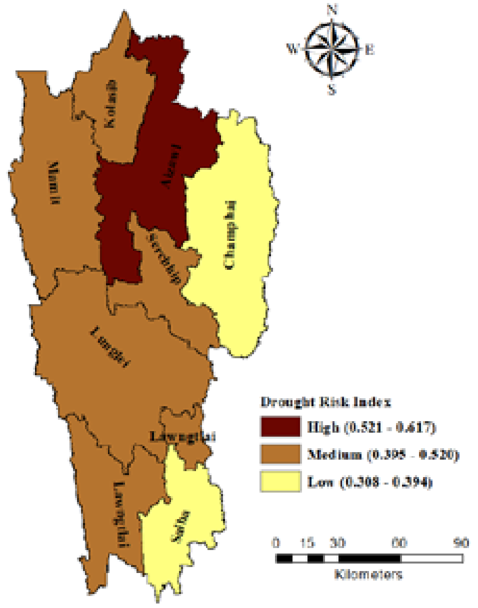
Flood Risk Index - Meghalaya	Drought Risk Index - Meghalaya



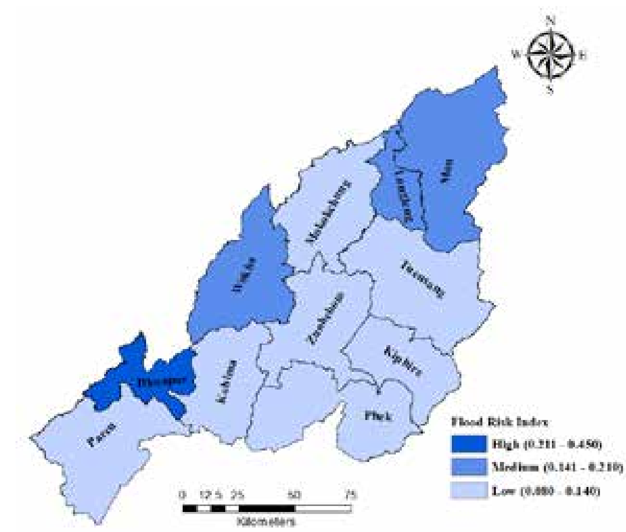


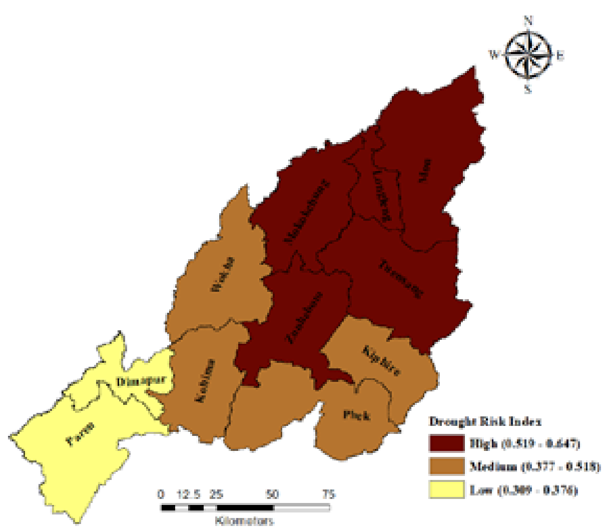
Flood Risk Index - Mizoram	Drought Risk Index - Mizoram



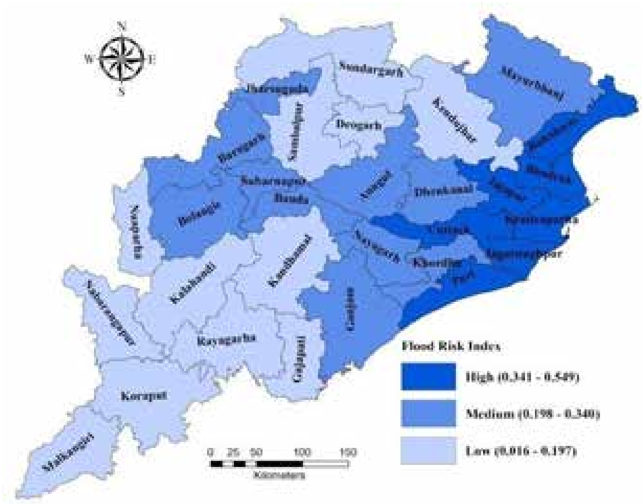


Flood Risk Index - Nagaland	Drought Risk Index - Nagaland

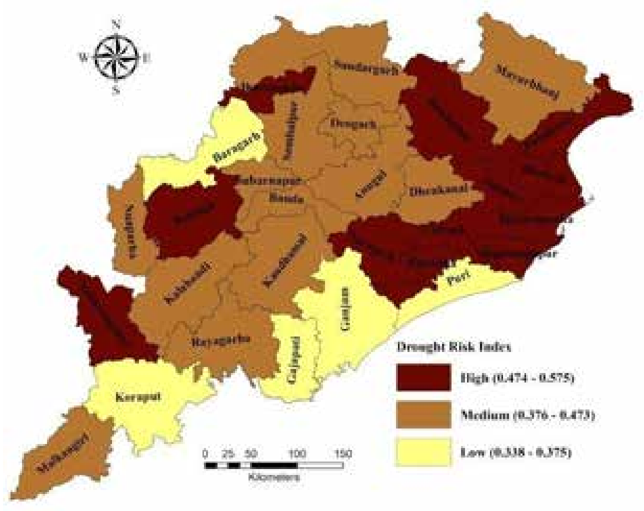




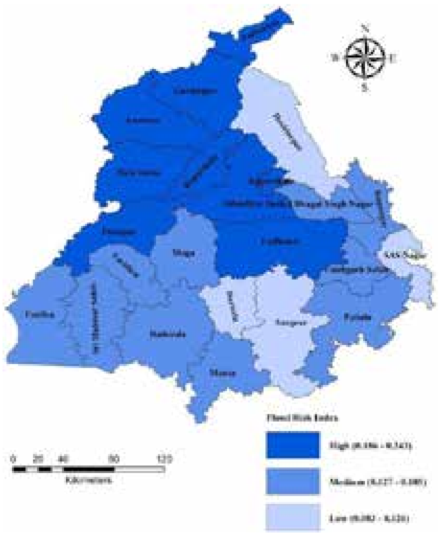
Flood Risk Index - Odisha



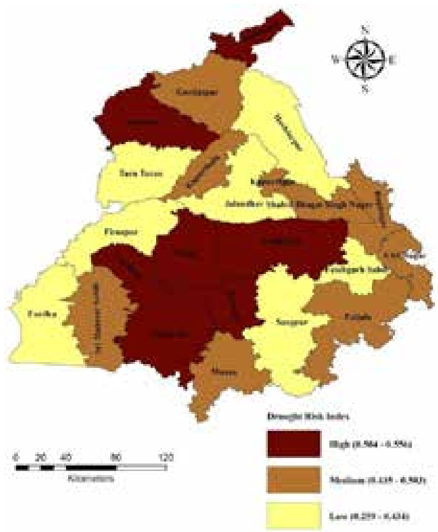
Drought Risk Index - Odisha



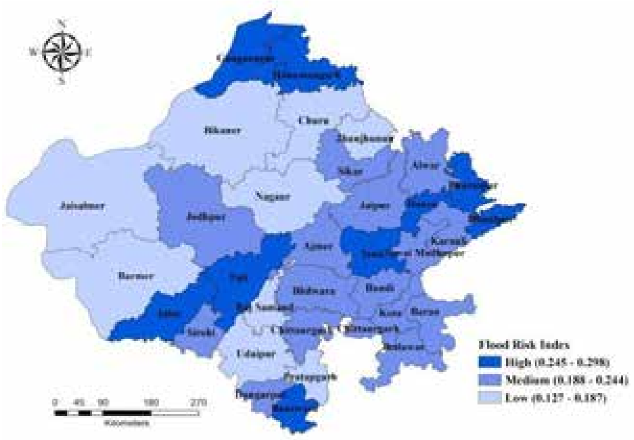
Flood Risk Index - Punjab



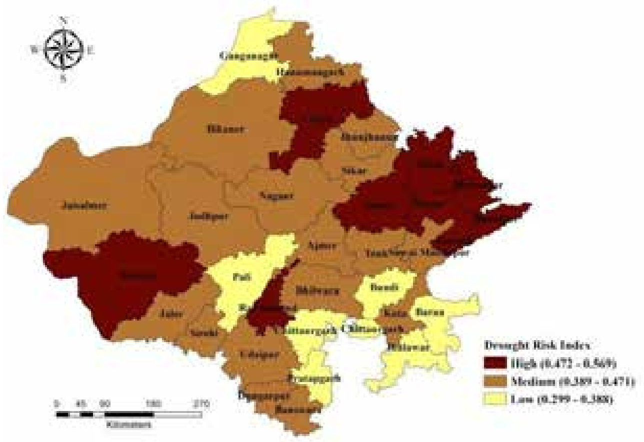
Drought Risk Index - Punjab



Flood Risk Index - Rajasthan



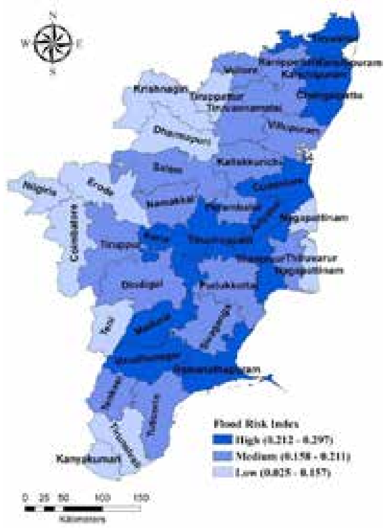
Drought Risk Index - Rajasthan



Flood Risk Index - Sikkim

Drought Risk Index - Sikkim

Flood Risk Index - Tamil Nadu



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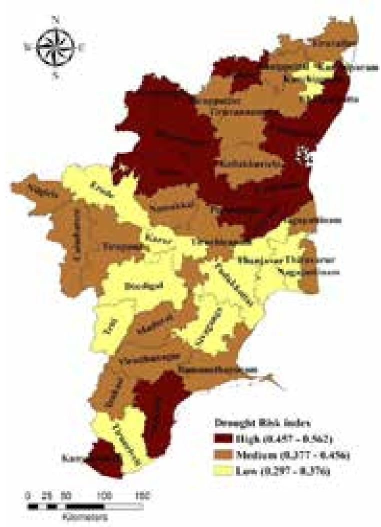
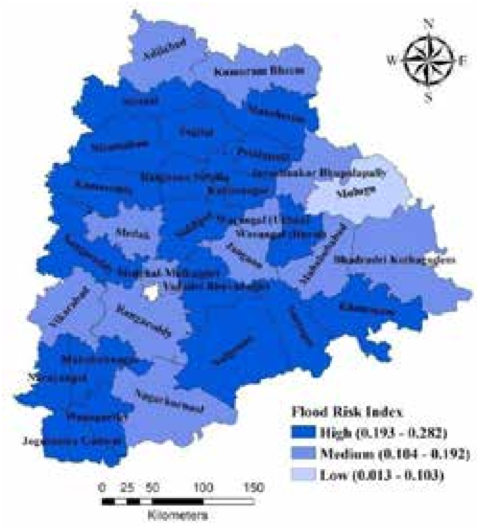
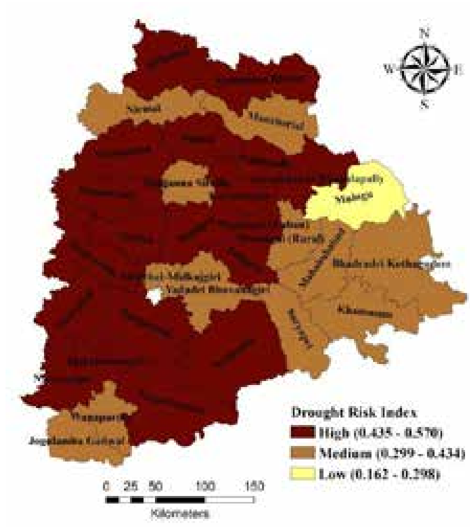


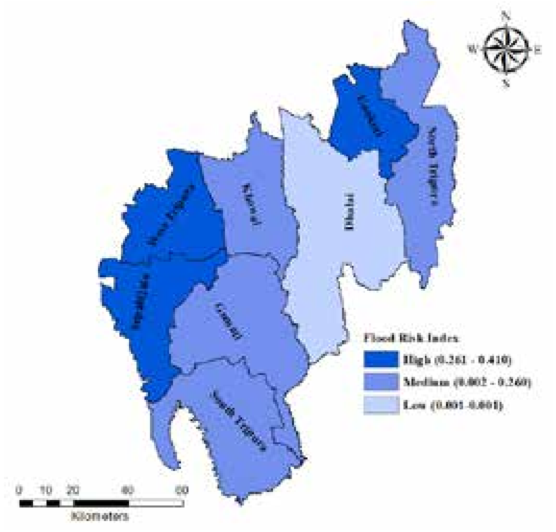
Flood Risk Index - Telangana



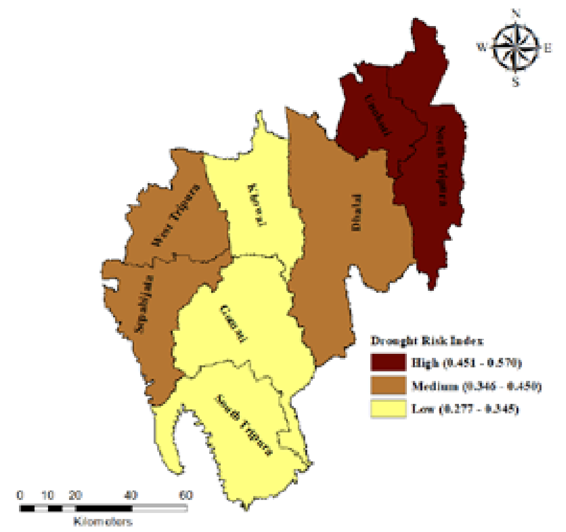
Drought Risk Index - Telangana



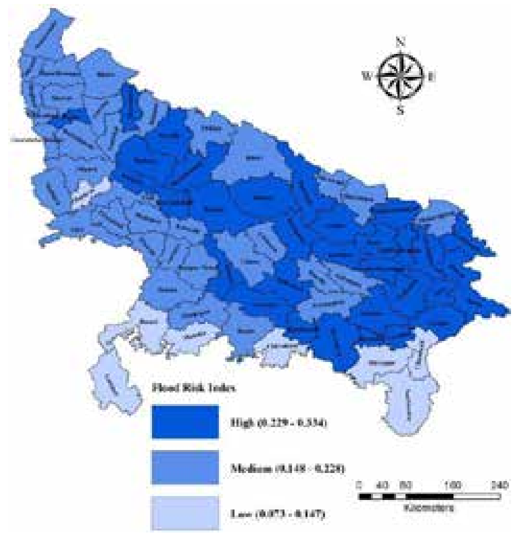
Flood Risk Index - Tripura



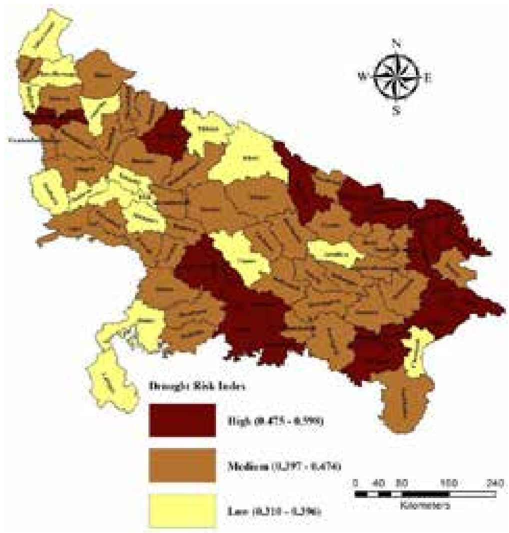
Drought Risk Index - Tripura



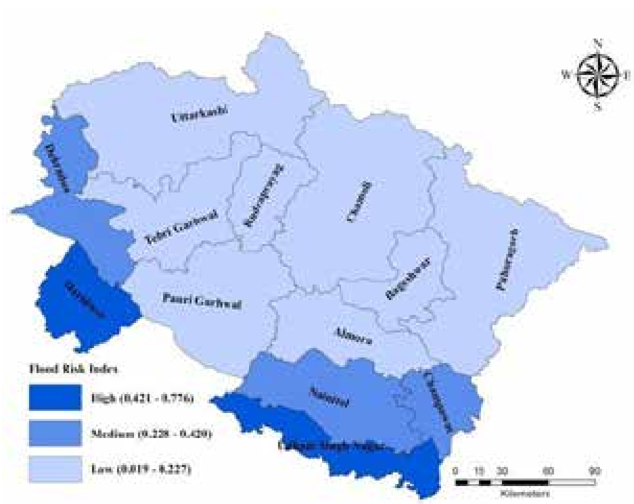
Flood Risk Index - Uttar Pradesh



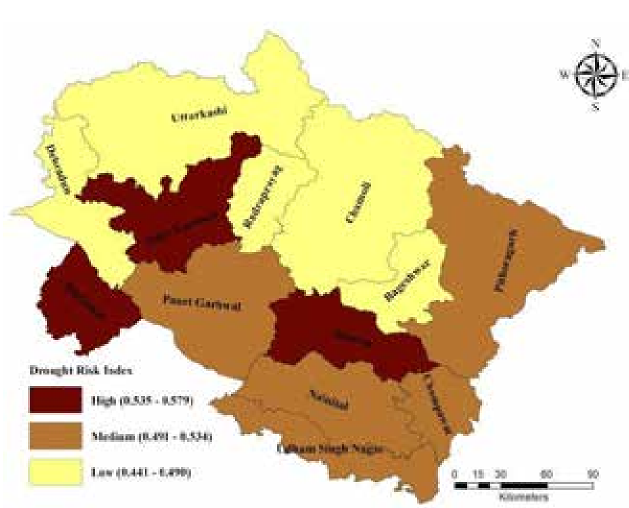
Drought Risk Index - Uttar Pradesh



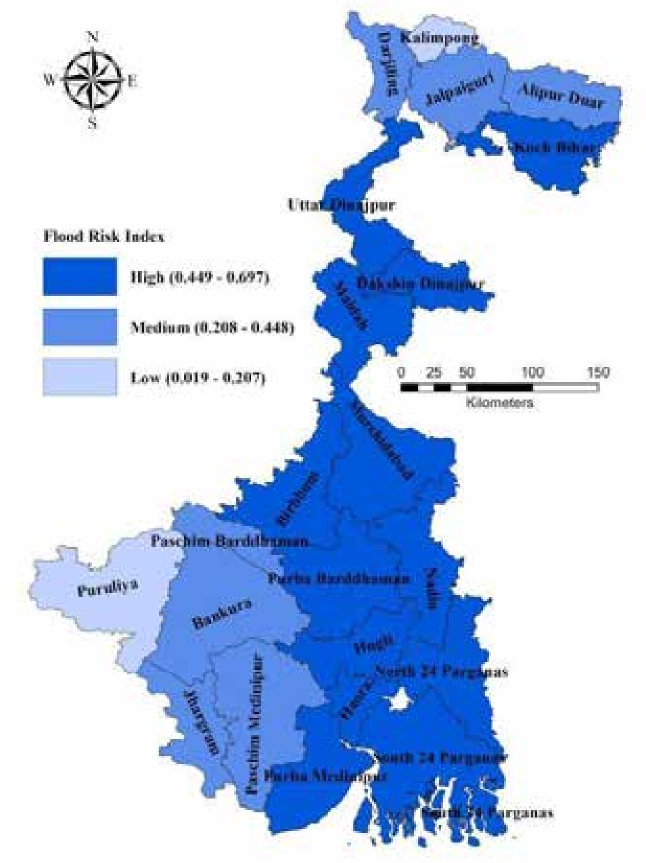
Flood Risk Index - Uttarakhand

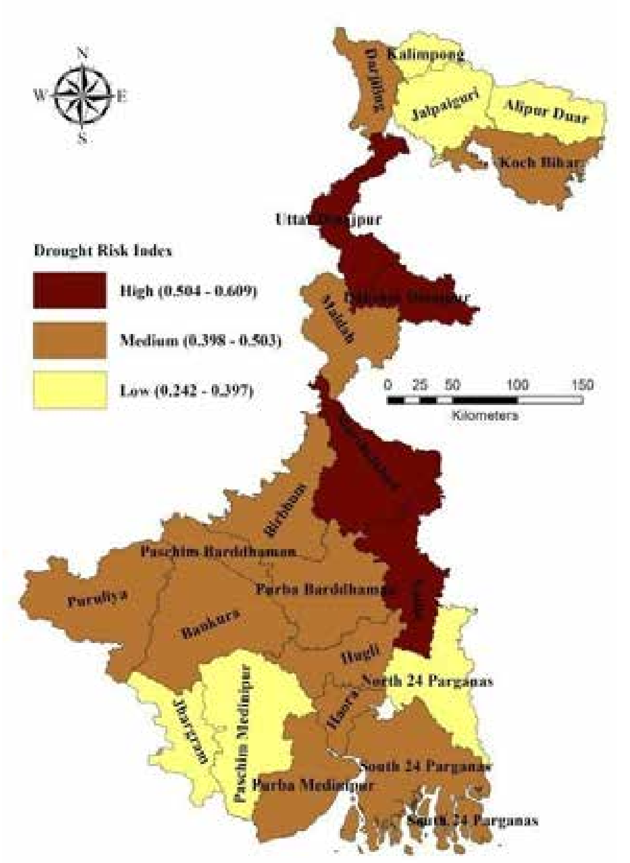


Drought Risk Index - Uttarakhand



Flood Risk Index - West Bengal	Drought Risk Index - West Bengal





PART III:

Utility and Way Forward

5. Utility and Way Forward

5.1. Utility of the report

Comprehensive Risk Mapping

- The development of risk maps for floods and droughts facilitates comparative analysis of districts within a state based on standardised indicators. These maps encompass flood and drought hazards, the degree of exposure to hazards, and overall vulnerability, fostering a holistic understanding of climate risks.

Determining Flood and Drought Risk Components

- Helps uncover the relative contribution of flood and/or drought hazards, exposure, and vulnerability within each district, facilitating identification of critical indicators that policymakers can utilise to prioritise interventions to mitigate or buffer the impacts of specific climate hazards.

Enhancing Government Preparedness and Policy Guidance

- Both state and central governments confront mounting pressure to deliver drought and flood assistance, driven by the rising frequency and intensity of extreme weather events. Risk assessments such as these, enable state governments to prepare proactively and allocate resources, staff and design programmes, fostering resilience in districts most affected by floods and droughts.

District-level Flood and Drought Risk Maps to Facilitate Prioritisation and Optimised Resource Allocation

- Hazard-specific risk profiles at district level help identify districts requiring urgent attention.
- Enable policymakers to identify entry points and interventions, and focus efforts and resources on critical districts to buffer and/or mitigate the impacts of specific climate hazards.
- Mainstreaming Climate Change Adaptation and Mobilising Climate Finance
- Provide valuable insights to policymakers for integrating into the State Action Plan on Climate Change (SAPCC). Periodic updates of these assessments based on evolving hazard occurrences ensure strategies remain relevant and effective, and are aligned with the goal of sustainable and adaptive governance.
- Facilitate the pursuit of climate finance by highlighting the urgency and significance of addressing identified risks, for implementation of adaptation strategies addressing climate hazards in various sectors.
- Risk indices, rankings, and maps support the preparation of adaptation projects, enhancing the credibility of funding proposals for national and international agencies, particularly in identified hotspot districts.

Community Empowerment

Empowers local communities and elected representatives to advocate for compensation or insurance measures in response to high drought and flood-related losses. Strengthens community resilience by fostering proactive measures at grassroots level.

5.2. Way forward

There exists significant potential for expanding risk assessment efforts at both national and state levels, leveraging the established framework and bolstered capacities developed during the current phase. They include:

1. **Sector-Specific Risk Index Development:** This involves the creation of risk indices tailored to specific sectors such as agriculture, horticulture, or coastal activities at state level. One specific example could be LULC and varying rainfall patterns on risk.

2. **Urban Risk Assessment:** Assessing flood and drought risks in districts, towns, and cities, with a focus on water supply.

3. **Standardised Methodology Application:** Utilising a common methodology to assess risks associated with various hazards like landslides, heat stress, and compound or cascading extreme events.

4. **Risk Assessment under Future Climate:** Addressing the imperative of conducting risk assessments under different climate change scenarios, recognising the evolving nature of environmental challenges.

This refined approach encompasses a diverse range of risk assessments, ensuring a comprehensive and adaptable framework to address various hazards and scenarios across different geographic scales.

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Appendix

1. Drought Hazard Index

$$DHI = (DWm \times DRm) + (DWs \times DRs) + (DWe \times DRe) \quad \text{Eq.1}$$

where DRm= ratings assigned to moderate droughts based on a percentage of occurrence; DWm= weight scores for moderate drought; DRs = ratings assigned to severe droughts based on a percentage of occurrence; DWs= weight scores for severe droughts; DRe= ratings assigned to extreme drought based on a percentage of occurrence; DWe= weight scores for extreme drought.

2. Flood Hazard Index

$$FHI = \begin{array}{l}(W_{slope} \times Slope) + (W_{elevation} \times Elevation) + (W_{geomorphology} \times Geomorphology) + (W_{DD} \times DD) + \\ (W_{DR} \times DR) + (W_{ST} \times ST) + (W_{TWI} \times TWI) + (W_{SPI} \times SPI) + (W_{LULC} \times LULC)\end{array} \quad \text{Eq.2}$$

where W = weight of respective indicators determines using Analytical Hierarchy Process (AHP); DD = drainage density; DR = distance to river; ST = soil texture; TWI = Topographic Wetness Index; SPI = Standard Precipitation Index; LULC = Land Use Land Cover.

3. Drought and Flood Exposure Indices

$$\text{Drought Exposure Index} = \frac{(E1_{NV} + E2_{NV})}{2} \quad \text{Eq.3}$$

$$\text{Flood Exposure Index} = \frac{(E1_{NV} + E3_{NV})}{2} \quad \text{Eq.4}$$

where E1 = population density, E2 = area under rainfed agriculture, and E3 = % land under agricultural use.

4. Drought and Flood Vulnerability

$$\text{Vulnerability Index} = \frac{(V1_{NV} + V2_{NV} + V3_{NV} + V4_{NV} + V5_{NV} + V6_{NV} + V7_{NV} + V8_{NV} + V9_{NV} + V10_{NV} + V11_{NV})}{11} \quad \text{Eq.5}$$

where V1 = multidimensional poverty index; V2 = proportion of marginal and small landholdings; V3 = yield variability of food grains; V4 = composite MGNREGA index; V5 = female literacy rate; V6 = forest area per hundred rural population; V7 = health infrastructure available per hundred square kilometres; V8 = livestock to human ratio; V9 = proportion of area under crop insurance; V10 = proportion of net sown area under horticulture; V11 = road density; NV = normalised value.

Case I: The indicator that has a + relationship with exposure/vulnerability
(Example: proportion of marginal and small landholdings)

$$\text{Normalized value} = \frac{(\text{Actual indicator value} - \text{Min indicator value})}{(\text{Max indicator value} - \text{Min indicator value})} \quad \text{Eq.6}$$

Case II: The indicator that has a - relationship with exposure/vulnerability
(Example: composite MGNREGA index)

$$\text{Normalized value} = \frac{(\text{Max indicator value} - \text{Actual indicator value})}{(\text{Max indicator value} - \text{Min indicator value})} \quad \text{Eq.7}$$

About DST

The Department of Science and Technology (DST) was established in May 1971, with the objective of promoting new areas of Science & Technology and to play the role of a nodal department for organising, coordinating and promoting S&T activities in the country. The Department of Science & Technology (DST) has been entrusted with the responsibility of coordinating two out of eight national missions launched under the National Action Plan on Climate Change (NAPCC). These are National Mission for Sustaining the Himalayan Ecosystem (NMSHE) and National Mission on Strategic Knowledge for Climate Change (NMSKCC).

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The Swiss Agency for Development and Cooperation (SDC) has been a partner of India for more than 60 years. Since 2011, SDC's engagement focuses specifically on climate change and other environmental issues. The office in India is part of SDC's Global Programme Climate Change and Environment (GPCCE). Other SDC Global Programmes like Food Security and Water also have ongoing activities in India, as part of their regional/global initiatives.

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