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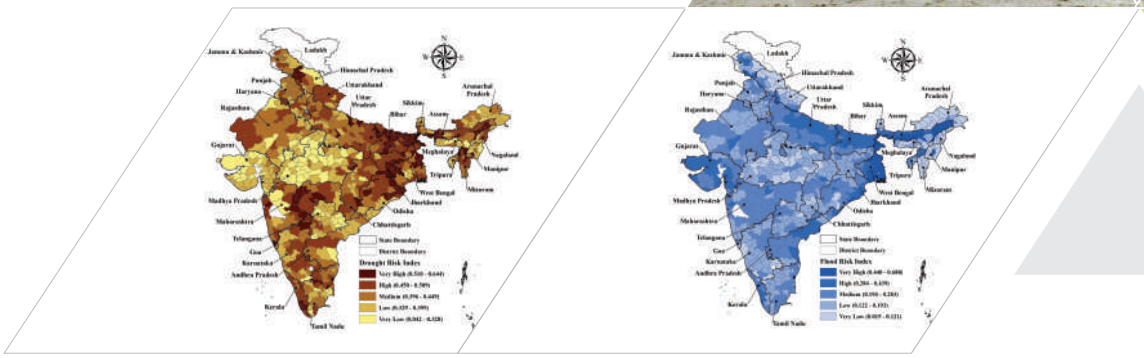
District-Level Climate Risk Assessment for India: Mapping Flood and Drought Risks Using IPCC Framework

EXECUTIVE SUMMARY



Indian Institute of Technology Mandi

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
Indian Institute of Technology Guwahati

CSTEP

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

Prepared under the DST and SDC funded project:

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

2024

Core Team

Shyamasree Dasgupta[1], Anamika Barua[2], Indu K Murthy[3]

Contributing Team

Priyam L. Borgohain[2], Triambak Baghel[1], Pooja Sankhyayan[1], Vidya S.[3], Himani Narwal[1], Aarifah Jan[1], Surbhi Vyas[2], Yashpal Luniwal[1], Shankar Ghosh[2], Tashina Madappa Cheranda[3], Mir Khursheed Alam[1], Sahil Mathew[3], Pradeep M.S.[3]

Advisor

N. H. Ravindranath
Retd. Professor, Indian Institute of Science, Bengaluru

Coordinated by

Susheela Negi and Swati Jain
Department of Science and Technology, Government of India, New Delhi

Divya Mohan
Team Leader, Strengthening Climate Change Adaptation in Himalayas (SCA-Himalayas),
Swiss Agency for Development and Cooperation (SDC), Embassy of Switzerland

The maps presented in this report are 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. They were empowered to generate risk maps at various scales, leveraging their in-house expertise and on-the-ground insights.

1. Indian Institute of Technology Mandi
2. Indian Institute of Technology Guwahati
3. Center for Study of Science, Technology and Policy, Bengaluru

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State Partners

Arunachal Pradesh

State Climate Change Cell, Dept. of Environment and Forest, Govt. of Arunachal Pradesh

Shri. D. Dohu Robin, Director.

Shri. Rinching T. Gonpapa, Project Scientist.

Shri. Licha Bida, GIS Expert.

Assam

Assam Climate Change Management Society, Govt. of Assam

Shri. Rizwan Uz. Zaman, Technical Consultant.

Smt. Dipima Sarma, Research Associate-III.

Shri. Arindam Goswami, Research Associate-II.

Smt. Priyanka Borah, Senior Research Fellow.

Smt. Bonanya Bora, Junior Research Fellow.

Smt. Jurishmita Bora, Junior Research Fellow.

Chhattisgarh

Chhattisgarh State Centre for Climate Change, Govt. of Chhattisgarh

Dr. Anil Kumar Shrivastava, Research Associate.

Shri. Abhinav Kumar Agrahari, Junior Research Fellow

Himachal Pradesh

Dept. of Environment, Science, Technology and Climate Change, Govt. of Himachal Pradesh

Dr. Suresh C. Attri, Chief Scientific Officer.

Shri. Duni Chand, Environment Officer.

Smt. Shilpa Sharma, Junior Scientist.

Smt. Monika Sharma, Junior Advisor.

Jammu and Kashmir

State Climate Change Cell, Department of Ecology Environment & Remote Sensing, Govt. of Jammu and Kashmir

Dr. Majid Farooq, Scientist/Coordinator.

Dr. Fayma Mushtaq, Geospatial Analyst.

Karnataka

Environmental Management & Policy Research Institute (EMPRI)

Dr. Pavithra P. Nayak, Research Scientist.

Dr. Shruthi B.V. Rajesh, Research Scientist.

Dr. Vanishri B.R., Research Associate.

Dr. Kiran K.C., Senior Research Fellow.

Smt. Poorvashree P., Project Associate.

Smt. Parul Singh, Project Associate.

Kerala

Directorate of Environment and Climate Change, Govt. of Kerala

Dr. Jude Emmanuel, Environmental Scientist.

Dr. Shiju Chacko, GIS Specialist.

Madhya Pradesh

Environmental Planning and Coordination Organization, Department of Environment, State Knowledge Management Center on Climate Change, Govt. of Madhya Pradesh

Smt. Sanjeev Singh, IAS Executive Director.

Smt. Lokendra Thakkar, Chief Scientific Officer & Coordinator.

Shri. Ramratan Simaiya, Subject Expert (Agriculture).

Shri. Ravi Shah, Subject Expert (Climate Change).

Manipur

Directorate of Environment and Climate Change, Govt. of Manipur

Dr. T. Brajakumar Singh, Director.

Shri. Yengkokpam Satyajit Singh, Junior Research Officer.

Dr. Sanoujam Manichandra Singh, GIS Consultant.

Meghalaya

Meghalaya Climate Centre, Govt. of Meghalaya

Dr. Marbakor Mary Lynrah, Project Scientist.

Shri. Vivek Lyngdoh, Junior Research Fellow.

Smt. Amica L. Nongrang, Programme Associate.

Smt. Tangwa Lakiang, Project Assistant.

Mizoram

Mizoram Science Technology and Innovation Council and State Climate Change Cell, Govt. of Mizoram

Er. H. Lalsawmliana, Chief Scientific Officer & Member Secretary.

Shri. Lalthanpuia, Project Scientist-II.

Dr. James Lalnunzira Hrahsel, Project Scientist-II.

Dr. H. Laldinpuii, Project Scientist-I.

Nagaland

Nagaland State Climate Change Cell, Govt. of Nagaland

Shri. Thsope Medo, GIS Specialist.

Shri. Kenilo Kessen, Research Fellow.

Shri. Meziwang Zeliang, Research Fellow.

Odisha

Climate Change Cell, Forest and Environment Department, Govt. of Odisha

Dr. Krushna Chandra Pal, Senior Scientist (Ecology and Environment).

Er. Sujeet Kumar Sahoo, Consultant.

Dr. Purna Chandra Mohapatra, Research Associate.

Punjab

Executive Director, Punjab State Council for Science & Technology, Chandigarh, Govt. of Punjab

Dr. Jatinder Kaur Arora, Executive Director.

Shri. Pritpal Singh, Additional Director.

Dr. Rupali Bal, Project Scientist-C.

Er. Maganbir Singh, Principal Scientific Officer.

Shri. Dhirendra Chauhan, Information Officer (GIS).

Dr. Kanchan Rawat, Project Associate.

Smt. Manjeet Kaur, Project Associate.

Tamil Nadu

Centre for Climate Change and Disaster Management, Anna University, Chennai

Prof. Kurian Joseph, Director.

Shri. Ahamed Ibrahim S. N., Research Associate-III.

Telangana

Environment Protection Training & Research Institute (EPTRI)

Smt. A. Vani Prasad, IAS, Principal Secretary to Government, Environment Forest Science & Technology Department, Govt. of Telangana, and Director General.

Dr. J. Sesha Srinivas, Senior Scientist.

Dr. J. Rajeswar, Climate Change Coordinator.

Dr. Anchal Rana, Research Associate.

Shri. M. Praveen, Senior Project Associate.

Smt. Sushmita Patel Kakatiya, Governance Fellow.

Shri. Sadhna Chaganti, Junior Research Fellow.

Sikkim

Sikkim Climate Change Cell (under NMSHE)

Dr. Dhiren Shrestha, Senior Scientific Officer, Department of Science and Technology.

Smt. Kalzen Dolma Tamang, Project Scientist.

Smt. Pema Yoden Bhutia, Project Associate-I.

Smt. Baichung Lepcha, Project Associate-I.

Tripura

Tripura University

Prof. Sabyasachi Dasgupta.

Tripura Climate Change Cell, Department of Science, Technology and Environment.

Shri. Susanta Banik, Scientific Officer.

Shri. Jain Souh Reang, Scientific Assistant.

Uttarakhand

State Environment Conservation & Climate Change Directorate, Govt. of Uttarakhand

Shri. S.P. Subudhi, Director.

Shri. Ankur Kansal, Joint Director.

Shri. Pankaj Semwal, Junior Research Fellow.

West Bengal

Department of Science and Technology and Biotechnology, Govt. of West Bengal

Smt. Subrata B Dutta, Senior Scientist.

Shri. Jyotibrata Chakraborty, Former Senior Research Fellow.

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

Climate change is a reality and a formidable challenge globally and in India. Across the world, there has been a rise in extreme climate events such as floods, droughts, and heatwaves. The severity and frequency of these extreme events are projected to escalate in the coming years (IPCC, 2022). These events not only endanger natural ecosystems but also pose substantial risks to human systems. However, it is crucial to recognise that the distribution of the impact of climate change is not equal across the world. It is dependent on different facets of socio-economic and demographic inequalities based on gender, age, class, race, ethnicity, (dis)ability, economic status, etc. (IPCC, 2014).

There is, therefore, an urgent need to assess and quantify climate risks, considering the probability of climate-hazards, and socio-economic and demographic disparities, and identify the underlying drivers of risk. Such an assessment is essential to move from a reactive stance to a precautionary approach. Consequently, conducting vulnerability and risk assessments tailored to specific regions becomes a fundamental initial step for effective adaptation strategies. In the face of escalating climate challenges, comprehensive climate risk assessment is a tool that can empower governments to prioritise and enhance preparedness by determining critical risk components.

During the initial phase of the project (2019–2021), the project team developed vulnerability maps at the district level. This was initially for the Indian Himalayan Region (Barua et al., 2019), and subsequently for all of India (Dasgupta et al., 2021). The team adopted a common framework of vulnerability assessment and a common set of indicators. This assessment identified and ranked districts vulnerable to climate change, indicating the urgent need for adaptation interventions that were also aligned to overall socio-economic development. While vulnerability assessments play a crucial role in prioritising adaptation efforts, evaluating climate risk is a natural progression toward gaining deeper insights into districts' relative risk to climate change.

Climate risk encompasses the probability of hazard occurrence, exposure to hazards, and vulnerability (IPCC 2014). Therefore, comprehending climate risks by mapping a common framework presents an opportunity to understand the entry points for adaptation planning. This study is an effort to integrate vulnerability assessment with proneness to two hazards: flood and drought, and exposure to these hazards, to gain a comprehensive understanding of risk, using the framework proposed by the Intergovernmental Panel on Climate Change (IPCC, 2014).

Objectives

The overarching aim of this study is to assess the risk associated with two prevalent climate hazards in India –drought and flood– in the context of historical and current climate conditions during 1970–2019. The focus on flood and drought stems from their widespread occurrence across the majority of Indian districts (Mujumdar et al., 2020). According to the Indian Meteorological Department (IMD), 87% and 30% of districts in India are respectively susceptible to drought and flood (IMD, 2022).

Specific objectives of the study include:

1. Develop district-level flood and drought hazard, exposure, and vulnerability maps, which will lead to the generation of comprehensive flood and drought risk maps for India.
2. Develop district-level flood and drought hazard, exposure, and vulnerability maps for the Indian states and UTs.
3. Building the capacity of State climate change cells and allied departments in climate change risk assessment for adaptation planning.

Relevant Work on Climate Risk

Studies have emerged assessing climate vulnerability and climate risk across different spatial and sectoral scales since the conceptualisation of the modified climate risk framework by the IPCC in its Fifth Assessment Report. The framework was also retained in the Sixth Assessment Report (Figure E.1). While the literature on climate-vulnerability assessment has grown over time, a comprehensive climate risk assessment still remains a challenge, 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, there are 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.). They offer comprehensive hazard mapping for the entire country.

There is also the Climate Risk Management Framework for India, developed by GIZ in collaboration with the Ministry of Environment Forest and Climate and NIDM (NIDM & GIZ, 2019). It is focused on mitigating potential loss and damage in specific climate-sensitive regions. The district-level assessment of risk and vulnerability of Indian agriculture to climate change by CRIDA, the Central Research Institute for Dryland Agriculture is another document in this context (Rama Rao et al., 2019).

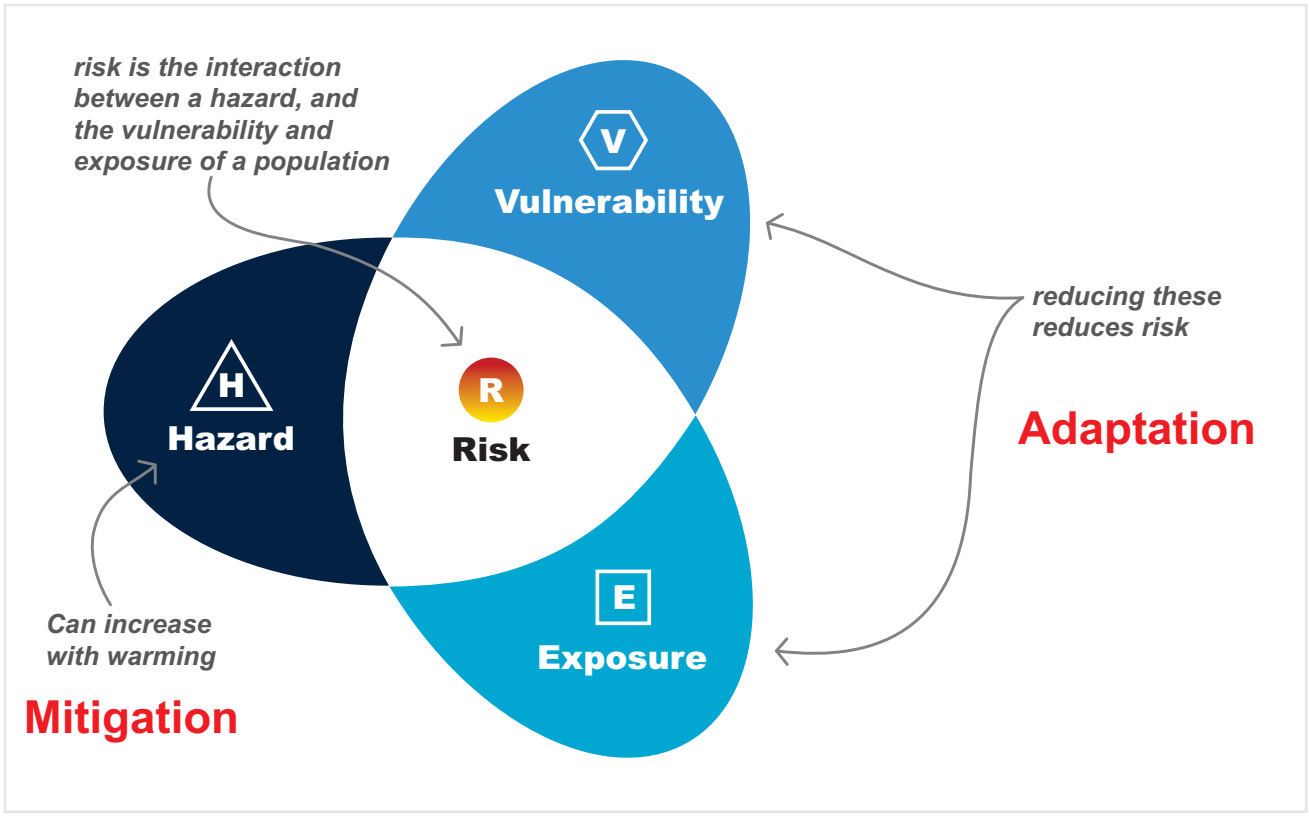

Figure E.1: Risks arising from climate change impacts results from dynamic interactions: adapted from IPCC Risk Framework (IPCC, 2014)

Salient Features

- **Focus on flood and drought:** The study focuses 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 hydrometeorological floods shaped by rainfall anomalies and topographical, geological, and hydrological factors.
- **Human-centric approach:** This study integrates exposure, vulnerability, and climatic hazards to evaluate flood and drought risk. The risk assessment thus explores the manner and extent to which climate hazards may impact people and livelihoods, considering hazard-specific exposure and inherent vulnerability.
- **Ex-ante approach:** It aligns with the Prime Minister's 10-point agenda (NDMA, n.d.) for Disaster Risk Reduction (DRR) as the current approach is rooted in the ex-ante DRR framework – prioritising proactive measures over relief-based strategies.
- **Spatial scale:** The assessment is carried out at the district level – an essential administrative unit for decision-making throughout India.
- **Temporal scale:** The assessment considers the current climate over a 50-year time period from 1970 to 2019.
- **Comparability:** The risk indices are relative and serve to rank districts within the country or a state/UT. A higher value of the 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 the state level have raised awareness of the utility and use of a risk assessment framework. States have been shared with a broad approach and common framework for risk assessment, thereby creating a knowledge network of state departments, academic institutions, and universities.

Methodology

The risk indices are developed based on the current/historical probability of flood and/or drought hazards, exposure to the hazard, and vulnerability. A schematic depiction of the methodology is provided in Fig. E.2. Drought hazard is calculated, based on the Standardized Precipitation Index (SPI 6) and utilizing gridded precipitation data from the IMD with a spatial resolution of 0.25 x 0.25 degrees, spanning the period 1970-2019 (50-years). The susceptibility of a particular area to flood hazards has been systematically assessed through the integration of GIS and Multi-Criteria Decision Analysis techniques and is based on nine key flood conditioning factors. Hazard, Exposure and Vulnerability indicators are converted to Hazard Index (HI), Exposure Index (HI) and Vulnerability Index (VI), respectively, and the risk index is calculated as their geometric mean. Based on the relative values of the risk indices, the districts are categorised as 'Very High', 'High', 'Medium', 'Low', and 'Very Low' risk-prone.

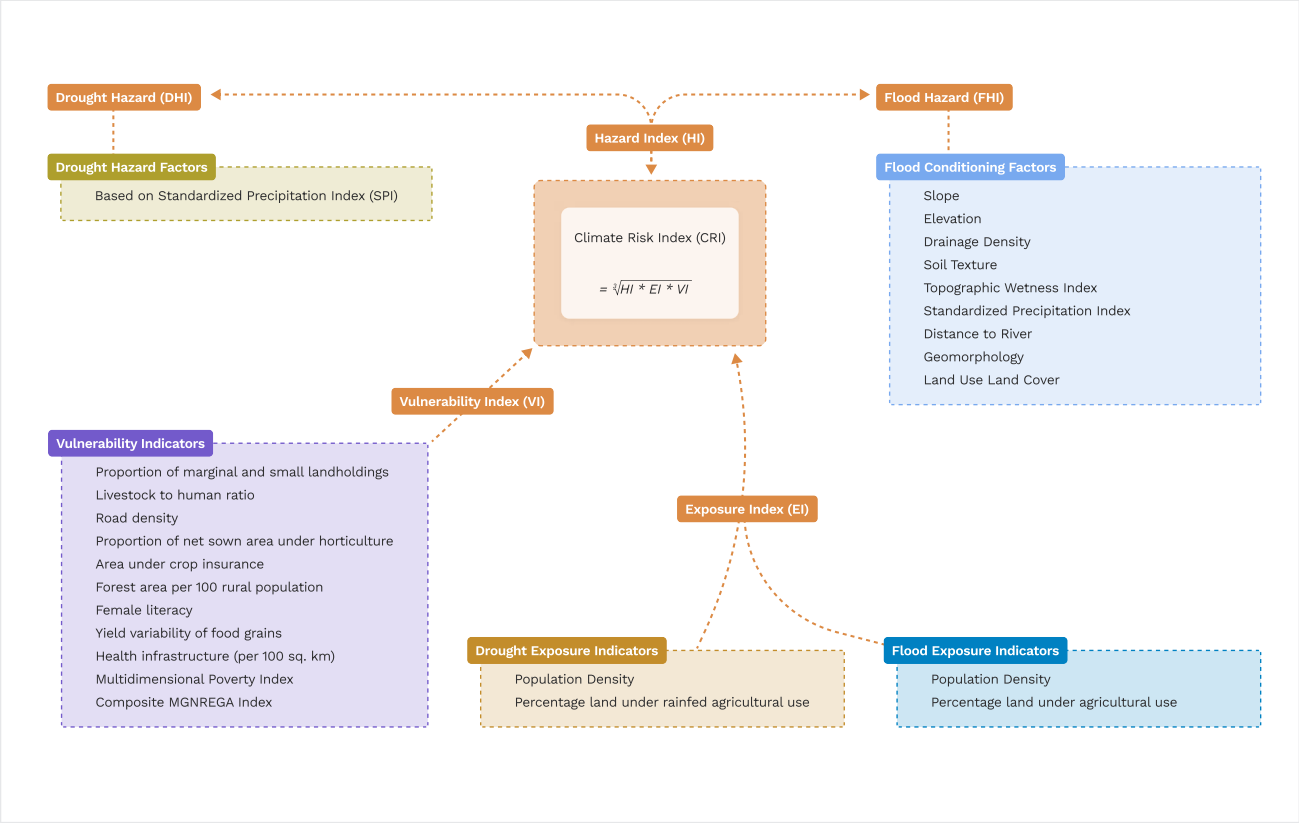

Figure E.2: schematic depiction of the methodology

Key Findings

Figures E. 3 and E. 4 present the district-level flood risk and drought risk maps for India, respectively.

Flood Risk Assessment

- The flood risk arises at the intersection of flood hazard, flood exposure, and vulnerability.
- The range of the flood risk index is from 0.015 to 0.688 for all India, indicating that flood risks vary extremely across districts of India.
- Fifty-one districts fall into the 'Very High' flood risk category (0.440–0.688), and another 118 districts fall into the 'High' flood risk category (0.284–0.439).
- About 85% of districts in the 'Very High' or 'High' flood risk category are located 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 drought risk index ranges from 0.042 to 0.644 for all India, indicating the variation in drought risk across districts of India.
- Ninety-one districts fall in the 'Very High' drought risk category (0.510–0.644) and another 188 districts in the 'High' drought risk category (0.450–0.509).
- More than 85% of 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

- Considering the top 50 districts with the highest flood risk and the top 50 districts with the highest drought risk, 11 districts are at 'Very High' risk of both 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.

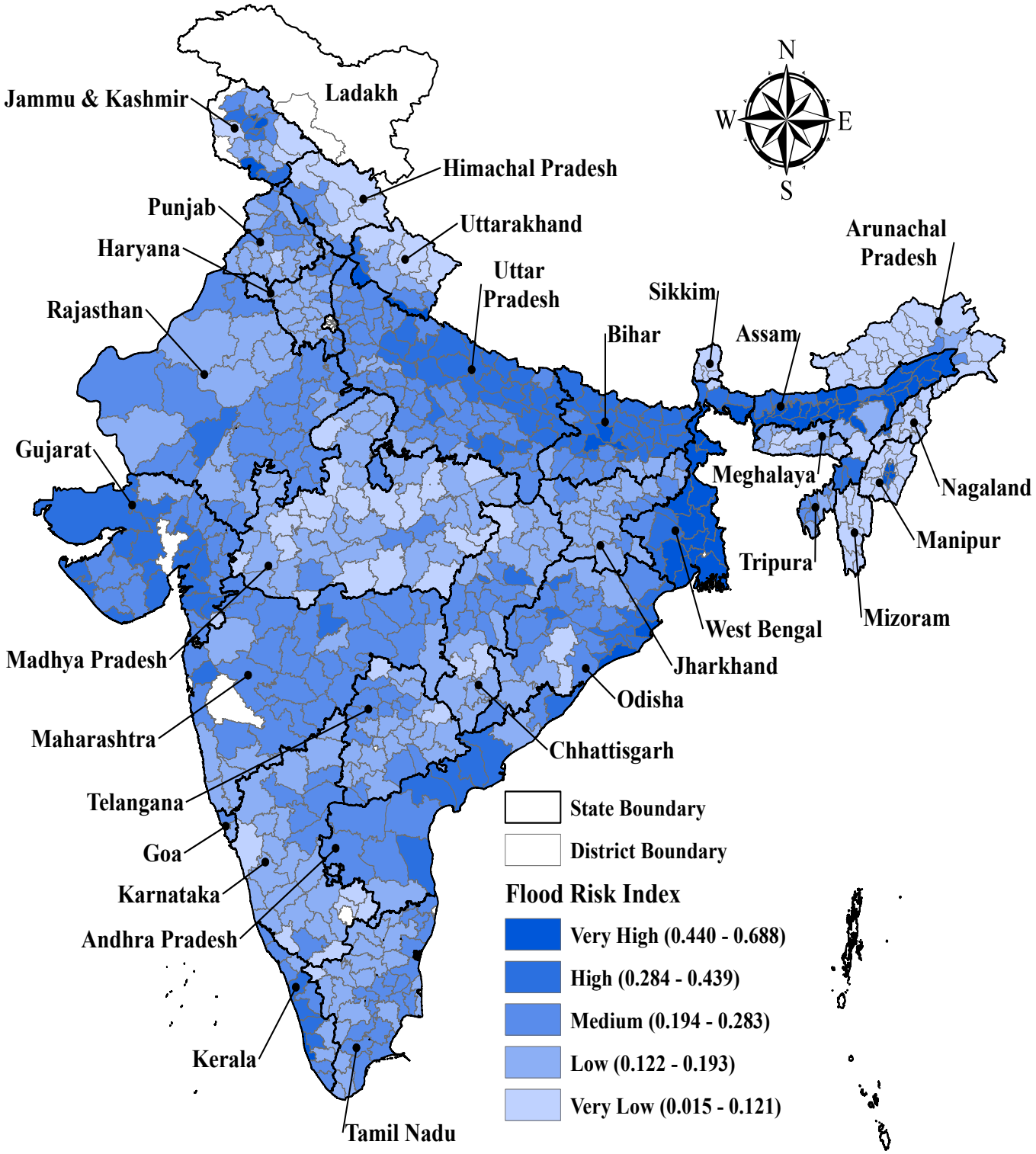

Figure E.3: District-level flood risk index in India (for the period 1970–2019)

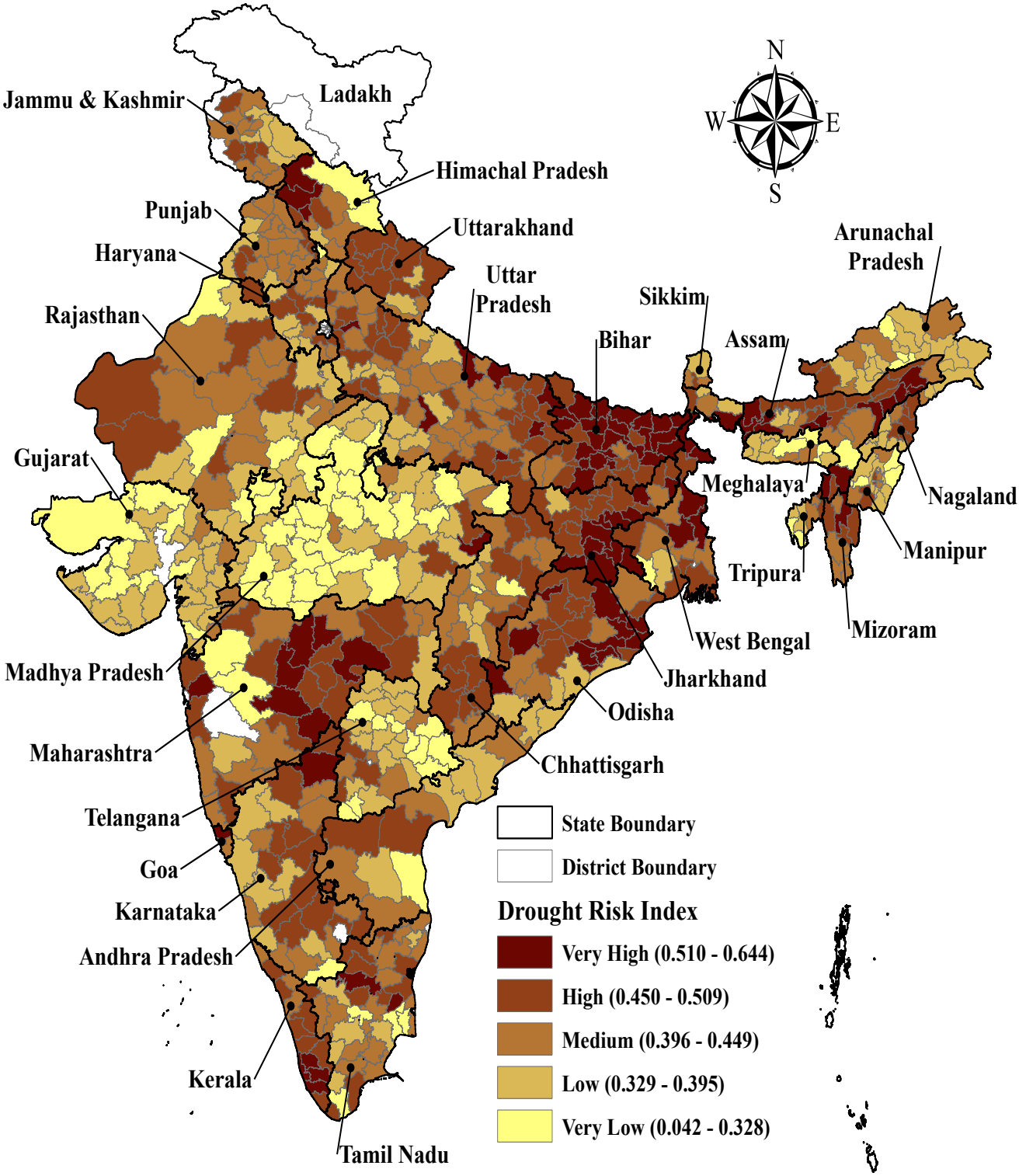

Figure E.4: District-level drought risk index in India (for the period 1970–2019)

Utility of the Report

- Comprehensive risk mapping for drought and flood, facilitating comparative analysis of districts, based on standardised indicators, enables prioritisation of locations for adaptation interventions.
- Determining risk components based on the relative contribution of flood and/or drought hazards, exposure, and vulnerability facilitates the identification of critical drivers that need to be addressed in adaptation planning.
- It provides valuable insights to policymakers for integration into the State Action Plan on Climate Change.

Way Forward

- **Multi-Scale and Sectoral Approach:** Adopt a multi-scale and sector-specific approach to assess risks for various sectors and at various levels, from local to regional and national scales.
- **Incorporating Emerging Risks:** Adapt risk assessment frameworks to address emerging risks such as landslides, heat stress, and compound extreme events.
- **Risk Assessment under Climate Change Scenarios:** Incorporate future climate scenarios in risk assessment for better preparedness for impending climate change.
- **Continuously Building Capacity:** Continuously enhance the capacity of development administrators at state and district levels to develop and apply risk and vulnerability assessments in adaptation planning.

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The Journey from Vulnerability Assessment to Risk Assessment with State partners

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).

About SDC

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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