How can India Make its Health Sector Climate Resilient?

A District-level Risk Assessment

Shreya Wadhawan, Aryan Bajpai, Vanya Pandey, and Dr Vishwas Chitale

Report | February 2025

Only 20% of assessed facilities met the required benchmarks for healthcare infrastructure as per a survey by Indian Public Health Standards in 2024 (IPHS 2024).

Image: Alamy

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भारत सरकार
राष्ट्रीय रोग नियंत्रण केन्द्र
(स्वास्थ्य सेवा महानिदेशालय)
स्वास्थ्य एवं परिवार कल्याण मंत्रालय, भारत सरकार
22, शाम नाथ मार्ग, दिल्ली - 110054

सत्यमेव जयते

Government of India
NATIONAL CENTER FOR DISEASE CONTROL
[Formally Known as National Institute of Communicable Disease (NICD)]
Directorate General of Health Services
Ministry of Health & Family Welfare, Government of India
22, Sham Nath Marg, Delhi-110054

Direct: 00-91-11-23913148
23922132, 23944035
Email: dirnicd@nic.in
Website: www.ncdc.gov.in
www.idsp.nic.in

Dr. AAKASH SHRIVASTAVA
MD, MPH,PhD
Additional Director & Head
Centre for Environmental & Occupational Health,
Climate Change and Health

Foreword

Health systems are a cornerstone of India's public policy landscape, reflecting the nation's commitment to ensuring equitable access to healthcare for all. Under the ambit of the National Health Mission (NHM), India has made significant strides in improving healthcare delivery, with a focus on strengthening infrastructure, enhancing workforce capacities, and addressing the health needs of vulnerable populations. Nonetheless, the increasing frequency and intensity of extreme climate events pose new and complex challenges to the resilience of our health systems.

Climate change coupled with the rising frequency and intensity of climate-induced extreme events such as floods, droughts, heat waves, and cyclones, poses a severe threat to water security, public health, and socio-economic development in India. Further, India's unique geography and socio-economic diversity make it particularly susceptible to climate-induced health impacts.

The National Programme on Climate Change and Human Health (NPCCHH), launched in 2019, strives to support State and District Health Departments in preparedness for climate induced extreme weather events and integrating climate-resilient measures into healthcare facilities.

In this context, the study *Assessing the Impacts of Extreme Climate Events on India's Health Systems* is both timely and critical. I appreciate CEEW and UNICEF's efforts in conducting a focused research on this issue and developing a scalable climate risk assessment framework aimed at assessing climate-induced risks to the health systems of India in the face of climate change. This study aims to provide evidence-based insights to strengthen climate resilience in the health sector and highlights the need for adaptive strategies that integrate climate risk considerations into health system planning, resource allocation, and service delivery.

The National Centre for Disease Control (NCDC), India has been at the forefront of efforts to address emerging public health challenges in India. This study complements the NCDC's mission by assessing the impacts of extreme climate events on Indian healthcare systems.

Awareness of climate-induced risks and fostering a shared understanding of health system resilience are crucial for implementing effective structural and operational measures. By leveraging research outcomes and shared expertise, India can set an example in addressing the challenges of climate-induced risk to the health systems, contributing significantly to the global challenge of building climate resilience. I am confident the study will provide critical insights and foresight to guide future policies and practices for developing climate-resilient health systems in India.

Aakash Shrivastava

(Aakash Shrivastava)

Foreword

Resilient health systems form the bedrock for health and sustainable development of a society and are intricately linked to the socioeconomic development of a country. In India, with its large population and diverse challenges in terms of climate induced disasters, the importance of resilient and adaptive health systems cannot be overstated. They serve as the first line of defence against a diversity of health risks, including those exacerbated by climate change and extreme weather events. The increasing frequency of extreme weather events, the rise in vector-borne diseases, and disruptions to health infrastructure pose significant challenges to healthcare access and delivery.

Over the past few decades, India, like elsewhere in the world, has been witnessing an alarming increase in the frequency and intensity of extreme climate events, ranging from devastating floods and cyclones to prolonged heatwaves and droughts. In early 2025, India Meteorological Department (IMD) reported 2024 being the hottest year on record for India. In addition, 2024 saw unprecedented rainfall events that disrupted lives, livelihoods, and critical infrastructure across the country. These events have had a profound impact on public health, manifesting in outbreaks of vector-borne diseases, malnutrition, heat-related illnesses, and mental health challenges, among others. The ripple effects of such crises place immense strain on health systems, particularly in vulnerable regions where resources are already stretched thin.

In this context, the study titled *Assessing the Risks from Extreme Climate Events on India's Health Systems* takes on vital significance. By examining the intersection of climate extremes and health system resilience, this study aims to provide actionable insights into the vulnerabilities and capacities of India's health systems. It seeks to identify gaps, highlight best practices, and recommend strategies to enhance preparedness and response mechanisms. Importantly, the findings will not only inform the policy and planning at the national and sub-national levels but also contribute to global discourses on climate-resilient health systems.

UNICEF is deeply committed to advancing child survival and development through resilient and responsive health systems, including in India. UNICEF's health programmes in India support the Ministry of Health and Family Welfare (MoHFW) and the state governments predominantly focusing on SDG 3: Good Health and Well-Being. It works to end preventable maternal, newborn and child deaths, particularly focusing on improving equity and gender-based imbalance. The objective is to reach every mother and child with life-saving health services. Recognising the critical intersection between climate change and health, this theme has remained central to UNICEF's mission, and the current study reflects this commitment.

I commend the collaborative effort of the Council on Energy, Environment and Water (CEEW) and the National Centres for Disease Control (NCDC), along with the UNICEF India team in producing this invaluable work. Together, we hope to drive meaningful change and underscore the urgent need to integrate climate resilience into the health sector. The findings of this study will undoubtedly serve as a cornerstone for informed decision-making and collective action in the years to come.

Vivek Singh

Dr Vivek Virendra Singh
Chief of Health a.i.
UNICEF, India

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We express our sincere gratitude to the United Nations Children's Fund (UNICEF) for their generous grant and partnership in supporting this study. Our special thanks to Dr Mainak Chatterjee, Dr Vivek Virendra Singh, Chehak Ahuja, and Dr Sandeep Thacker for their consistent feedback on the various elements of this work. We are indebted to the reviewers, especially the UNICEF review committee, Dr Abhiyant Tiwari of the Natural Resources Defense Council (NRDC), Dr Pranay Lal of the Health Systems Transformation Platform (HSTP), and Dr Arpan Patra of CEEW, for their insightful comments that helped improve the overall messaging of this study. We are also grateful to Dr Aakash Shrivastava and the National Programme on Climate Change and Human Health (NPCCHH) team at the National Centre for Disease Control (NCDC) and the state nodal officers, NPCCHH for their valuable time and input throughout the stakeholder consultation process.

We deeply appreciate our stakeholders' contribution to the questionnaire, which helped rank the indicators developed in this report. We extend our gratitude to Dr Pranay Lal, Senior Advisor at HSTP; Dr Nirmalya Mukherjee, Director at the Centre for Public Health Research (CPHR); Dr Purvi Patel, Senior Consultant at NCDC; Dr Poornima Prabhakaran, Director of the Centre for Health Analytics Research and Trends at Ashoka University; Dr Ratnesh Kumar, Lead at the Coalition for Disaster Resilient Infrastructure; Dr Vijendra Ingole, Principal Data Scientist (Climate and Health) at UK Civil Service, Office for Spatial Statistics; Niyati Gupta, Senior Program Associate at World Resources Institute; Dr Dharmesh Kumar Lal, Scientist-E at the Indian Council of Medical Research; Subhojit Goswami, Senior Program Manager at the Leprosy Mission Trust India; and Muneer Kutty, Consultant at World Bank. We would also like to thank members of UNICEF, including Dr Kaushik Ganguly, Dr Annapurna Kaul, Dr Sridhar P. Ryavanki, Anand Kanoo, Omkar Oneil Khare, Dr Brajesh Merta, Dr Vijay Agrawal, and Dr Mangesh Arun Gadhari, for their expert inputs on the questionnaire.

We acknowledge the support of Rohini Nilekani Philanthropy in facilitating the launch event for this report. We thank Ekansha Khanduja, Programme Associate, for co-leading the development of the risk assessment methodology. We are also grateful to Nitin Bassi, Senior Programme Lead at CEEW, for his guidance throughout the research process. We appreciate the contributions and support of Aditya Vikram Jain, Keerthana Anthikkat, Anushka Maheshwari, Ahana Chatterjee, and Ishita Gupta.

Thank you all for your generosity and support in this endeavour.

The authors

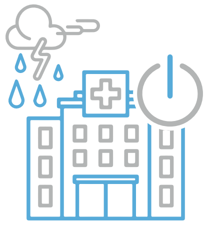
Contents

India experienced extreme weather events on 255 out of 274 days in the first nine months of 2024, i.e for 93% of the days (CSE 2024).

Image: Alamy

Executive summary

India is one of the world's most at risk nations from the impacts of climate change–induced events such as floods, cyclones, and droughts (Eckstein, Künzel, and Schäfer 2021). Between 2000 and 2019, India experienced an annual average of 17 floods, making it the second most flood-affected country in the world (CRED and UNDRR 2020). Furthermore, as of 2021, about 68 per cent of Indian districts were exposed to extreme droughts (Mohanty and Wadhawan 2021).



By 2100, 1 in 12 hospitals in the world are at risk of shutting down due to extreme weather events (XDI 2023)

The rising frequency and intensity of such extreme events cause damage to infrastructure and service interruptions in the health sector. By 2050, climate change is projected to cause an additional 14.5 million deaths globally, primarily due to extreme weather events such as floods, droughts, and heatwaves (WEF 2024). Moreover, vulnerable populations, especially in low- and middle-income countries (LMICs), are expected to bear a disproportionate share of the health impacts of climate change. UNICEF's Children's Climate Risk Index identifies India as a country where children are at very high risk with regards the adverse effects of climate change (UNICEF 2021a). Diseases sensitive to climate fluctuations, such as malaria and dengue, are predicted to spread into new areas, potentially putting an additional 500 million people at risk by 2050 (WEF 2024). The economic impact is also severe, with losses estimated at USD 12.5 trillion, alongside an additional USD 1.1 trillion burden on healthcare systems (WEF 2024). Furthermore, the economic losses in LMICs from non-communicable diseases (NCDs) are projected to exceed USD 7 trillion by 2025 (Bloom et al. 2011). Despite these challenges, there remains insufficient investment in addressing the social and environmental determinants of health in India.

Increasing investment in this area will improve the health sector's climate resilience and support the attainment of the United Nations Sustainable Development Goals (SDGs), thus ensuring universal access to adequate health services. Figure ES1 highlights the various SDGs that will be achieved while enhancing the health sector's climate resilience.

It is thus imperative for policymakers to prioritise the integration of climate adaptation strategies into health sector planning to safeguard the well-being of India's most vulnerable populations. According to the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), an investment of USD 1 in adaptation can lower the annualised average loss from extreme climate events, slow-onset hazards, and biological hazards by USD 5.5 (UNESCAP 2022). This necessitates conducting thorough and granular risk assessments across various sectors to identify the underlying key risk factors. In this study, we attempted to develop a national-level framework for assessing extreme events–induced physical climate risk to health sector in India.

Figure ES1 The SDGs achieved while building a climate-resilient health sector

3. Good Health and Well-being	3.1 Reducing Maternal Mortality	3.2 End all Preventable Deaths under 5 Years of Age	3.3 Fight Communicable Diseases	3.4 Reduce Mortality from Non-Communicable Diseases and Promote Mental Health
3.8 Achieve Universal Health Coverage	3.d Improve Early-Warning System for Global Health Risks	4.a Quality Education	5. Gender Equality	6.2 Sanitation and Hygiene
11.5 Reduce the Adverse Effects of Natural Disasters	13.1 Aspects of Climate Action	14.1 Aspects of Life Below Water	15.1 Aspects of Life on Land	

Source: Authors' compilation based on the 17 SDGs promoted by the UN's Division for Sustainable Development Goals

The Climate Health Risk Index developed in this study can support evidence-based programming under the National Program on Climate Change and Human Health, while also providing critical data for strengthening state and district-level action plans. By offering a strategic roadmap for long-term national adaptation planning, the risk index informs policies for addressing climate-linked health challenges, including non-communicable diseases (NCDs). Additionally, state and district governments can utilise this assessment to establish baseline risks and vulnerabilities associated with health impacts and disease burden patterns in the context of climate change, thereby guiding targeted interventions for 2030. It can also contribute to India's Nationally Determined Contributions (NDCs) by enabling targeted adaptation measures in the health sector.

Objectives of the risk assessment for the health sector in India

In this study, we developed a climate risk assessment framework that is contextualised to the health sector in India. It had the following three key objectives:

- To identify and finalise indicators for health risks due to climate extremes in India, with a special focus on women, children, and other vulnerable groups
- To compute district-level climate extremes–induced health risk index
- To identify district-level risk hotspots and the key driving factors

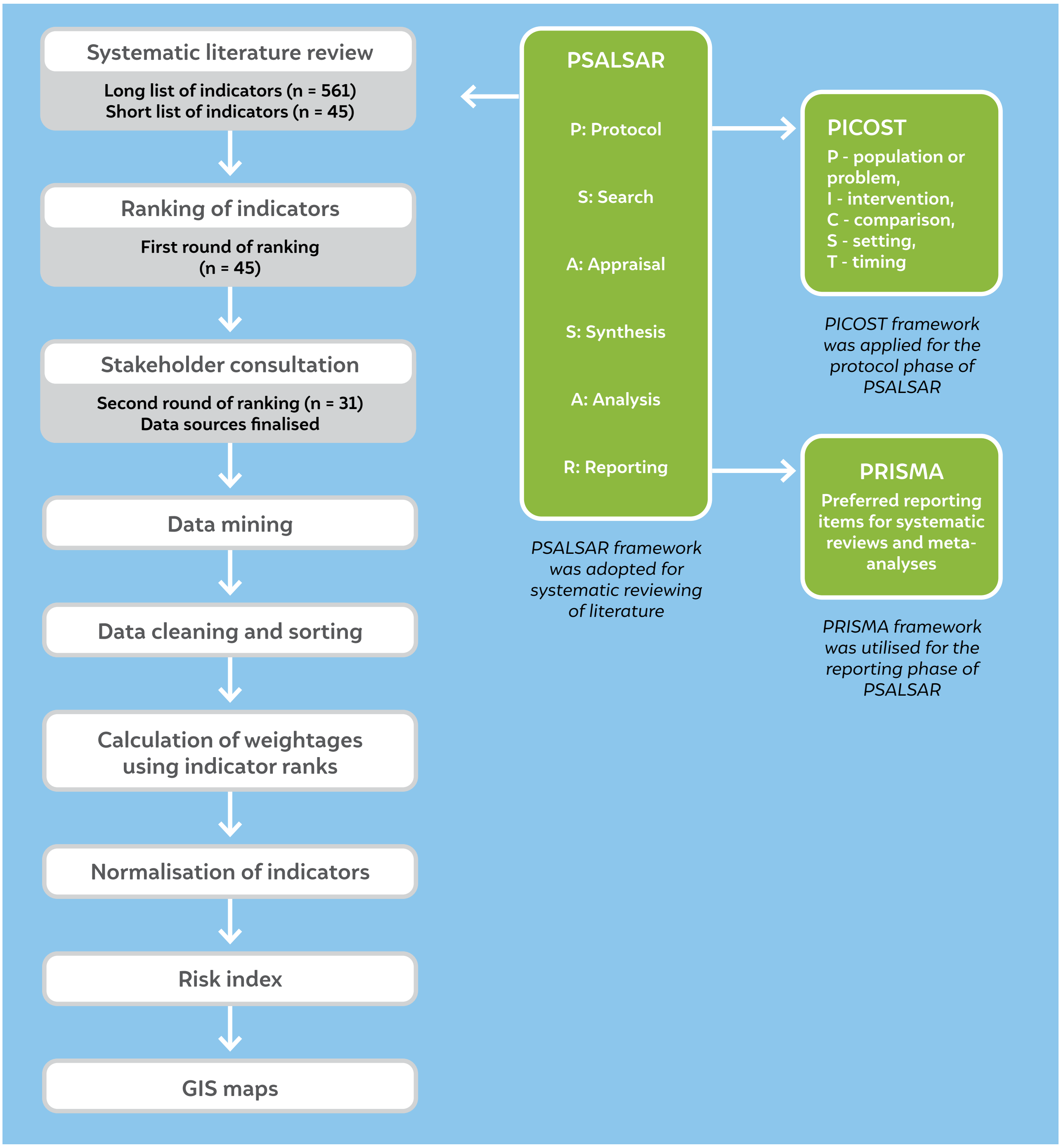
Methodology for development, computation, and representation of the risk index

In the current study, we define risk as per the Intergovernmental Panel on Climate Change's (IPCC) *Fifth Assessment Report* (AR5), where risk is defined as a product of hazard, exposure,[1] and vulnerability (adaptive capacity and sensitivity). The study consisted broadly of five steps, beginning with a systematic literature review (SLR) of 180 publications and reports from grey and non-grey literature and concluding with plotting geographic information system (GIS)–based maps highlighting the climate risk in the health sector in India, as depicted in Figure ES2.

1 Note: The study considers healthcare facilities (PHCs and SHCs) as an exposure component, with higher facility numbers linked to higher exposure-based risk. However, this does not imply that more healthcare facilities increase risk, as their role in enhancing adaptive capacity is accounted for separately.

The protocol, search, appraisal, synthesis, analysis, and report (PSALSAR) methodology served as a guiding framework for conducting the SLR, within which the population, intervention, control, outcomes, study design, and time frame (PICOST) model was used to define the research protocol. The results were reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Figure ES2 The research methodology used in this study

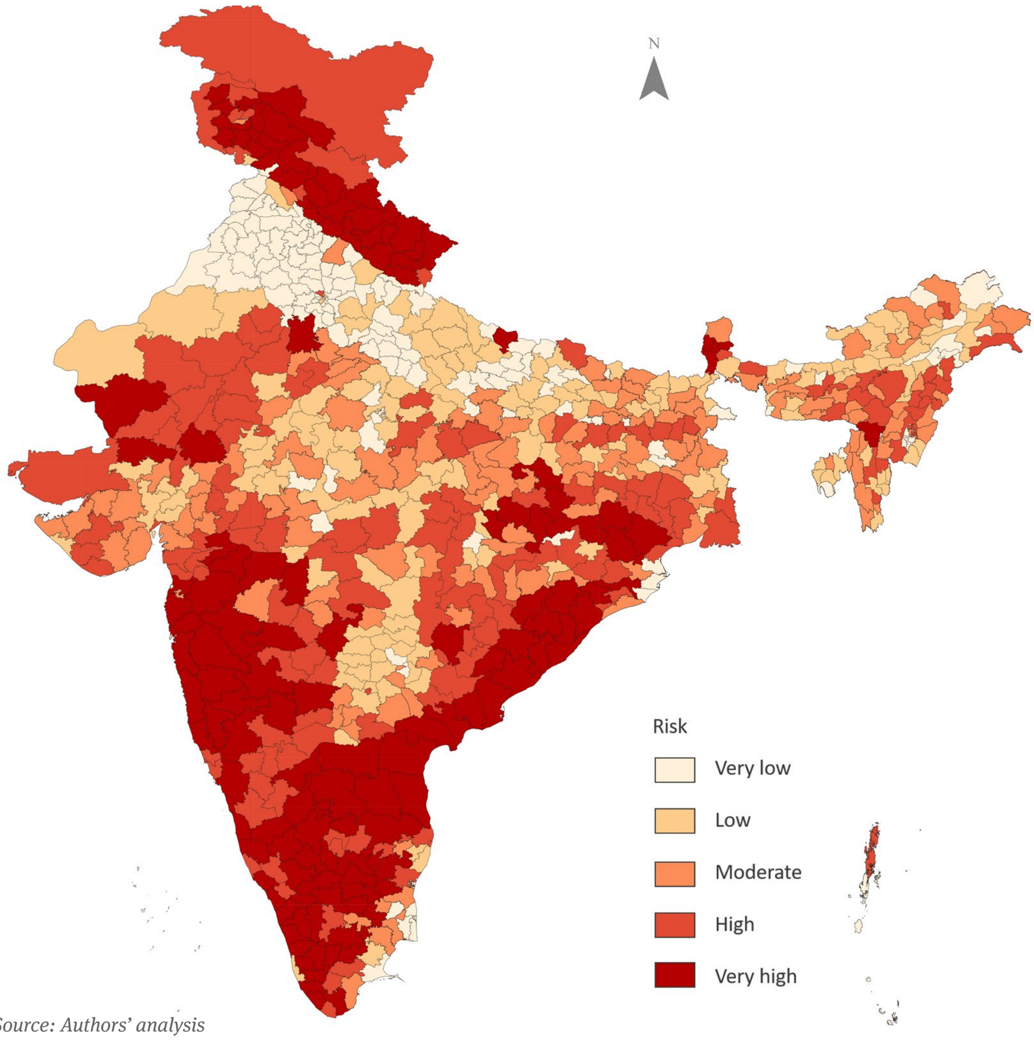


Source: Authors' analysis

Key findings

- **Hazard:** Most districts in states such as Karnataka, Tamil Nadu, Gujarat, Assam, Andhra Pradesh, Bihar, Maharashtra, Odisha, and Kerala fall under the very high hazard category. More than 50 per cent of the districts in Uttar Pradesh, Chhattisgarh, Jharkhand, West Bengal, and Himachal Pradesh belong to the high category.
- **Exposure:** More than 50 per cent of the districts in Andhra Pradesh, West Bengal, Maharashtra, Bihar, and Karnataka have very high exposure to extreme climate events.
- **Vulnerability:** The majority of districts in states such as Himachal Pradesh, Uttarakhand, Arunachal Pradesh, Jammu and Kashmir, Manipur, Mizoram, and Nagaland fall under the very high vulnerability category. Many districts in Chattisgarh, Jharkhand, and Tripura come under the high category. Twenty per cent of the districts in India are very highly vulnerable to extreme climate events, and an additional 19 per cent fall under the highly vulnerable category. States such as Arunachal Pradesh, Himachal Pradesh, Sikkim, and Nagaland show very high to high levels of vulnerability.
- **Risk:** More than 40 per cent of Indian districts have healthcare systems that face very high to high climate risk, whereas approximately 20 per cent have moderate risk, and 40 per cent have low to very low risk. The majority of the districts with very high risk are concentrated in Andhra Pradesh, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Odisha, Maharashtra, Sikkim, Tamil Nadu, and Uttarakhand. The high-risk category has a wide distribution across different regions of the country, including Chhattisgarh, Gujarat, Rajasthan, Madhya Pradesh, and West Bengal (See Figure ES3).

Figure ES3 Healthcare systems in more than 40% of Indian districts are at high climate-induced risk

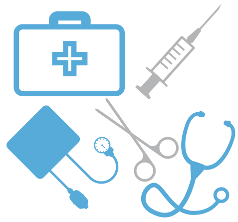


Source: Authors' analysis

Recommendations and the way forward

- **Mainstream sub-district level, interdisciplinary risk assessments of the health sector:** Detailed, sub-district risk assessments are crucial for quantifying the health sector's vulnerability to extreme climate events. These assessments should incorporate interdisciplinary factors such as governance, socioeconomic conditions, and public health infrastructure.
- **Establish data dashboards to facilitate assessments:** Developing an open-access, interactive data dashboard that hosts district-level climate vulnerability data is key to enabling healthcare institutions to assess physical climate risks. This dashboard should consolidate data from national surveys and extreme weather events and support physical risk assessments and resilience measures. Implementing this at the state and district levels through the state action plan on climate change and human health (SAPCCHH) and the district action plan on climate change and human health (DAPCCHH) will further enhance risk assessments and lead to informed policymaking. In addition to climate vulnerability data, the dashboard can also provide information on contextualised adaptation measures suited for the health sector; this will aid the health authorities in prioritising adaptation solutions in high- and very high-risk districts.
- **Assess and build the capacities of health sector professionals to conduct risk assessments:** Strengthening the skills, knowledge, and resources of government departments and institutions related to the health sector is essential for conducting effective climate risk assessments. Drawing on resources such as CEEW's capacity assessment framework (CAF), the Ministry of Health and Family Welfare (MoHFW) can assess the ability of state health departments to address climate change. The MoHFW could then use it to develop state- and national-level programmes for capacity building in the relevant stakeholders from government departments.
- **Maintain inter-ministerial and interdepartmental coordination for bringing health sector at the forefront of climate action:** Since health systems and climate change are managed by two different ministries – the MoHFW and the Ministry of Forest, Environment and Climate Change (MoEFCC) – it is critical to ensure coordinated assessments and policies across departments. Collaboration among ministries such as Health, Environment, Rural Development, and Home Affairs will support unified monitoring of climate and health indicators and foster coherent policy responses and climate readiness. While formulating a national adaptation plan for India, special emphasis should be placed on enhancing climate resilience in the health sector through an effective coordination mechanism between the MoHFW and the MoEFCC.
- **Provide climate health risk–based financing for health systems in India:** Allocating healthcare resources based on granular climate risk assessments will ensure that regions at high and very high risk due to climate-induced extreme events receive focused funding to strengthen their health systems. India can strengthen its health systems by integrating climate adaptation into national health policies, such as the National Health Mission (NHM) and the National Action Plan on Climate Change and Human Health (NAPCCHH). This integration could involve leveraging climate risk assessments to prioritise initiatives addressing climate-sensitive health concerns in medium- and long-term programme planning. For instance, similar efforts in other South Asian countries have focused on prioritising community-based interventions to address climate-induced vector-borne diseases (UNDRR 2018).

By prioritising these actions, India can make the health sector more resilient and capable of effectively addressing the challenges posed by climate change.



India's healthcare budget for 2025-26 increased by 9.46% compared to the FY25 budget estimate (Source: Ministry of Finance, Budget Division 2025)

One in five hospitals in Southeast Asia could be at risk of shutdown by the century's end (XDI 2023).

Image: iStock

1. Introduction

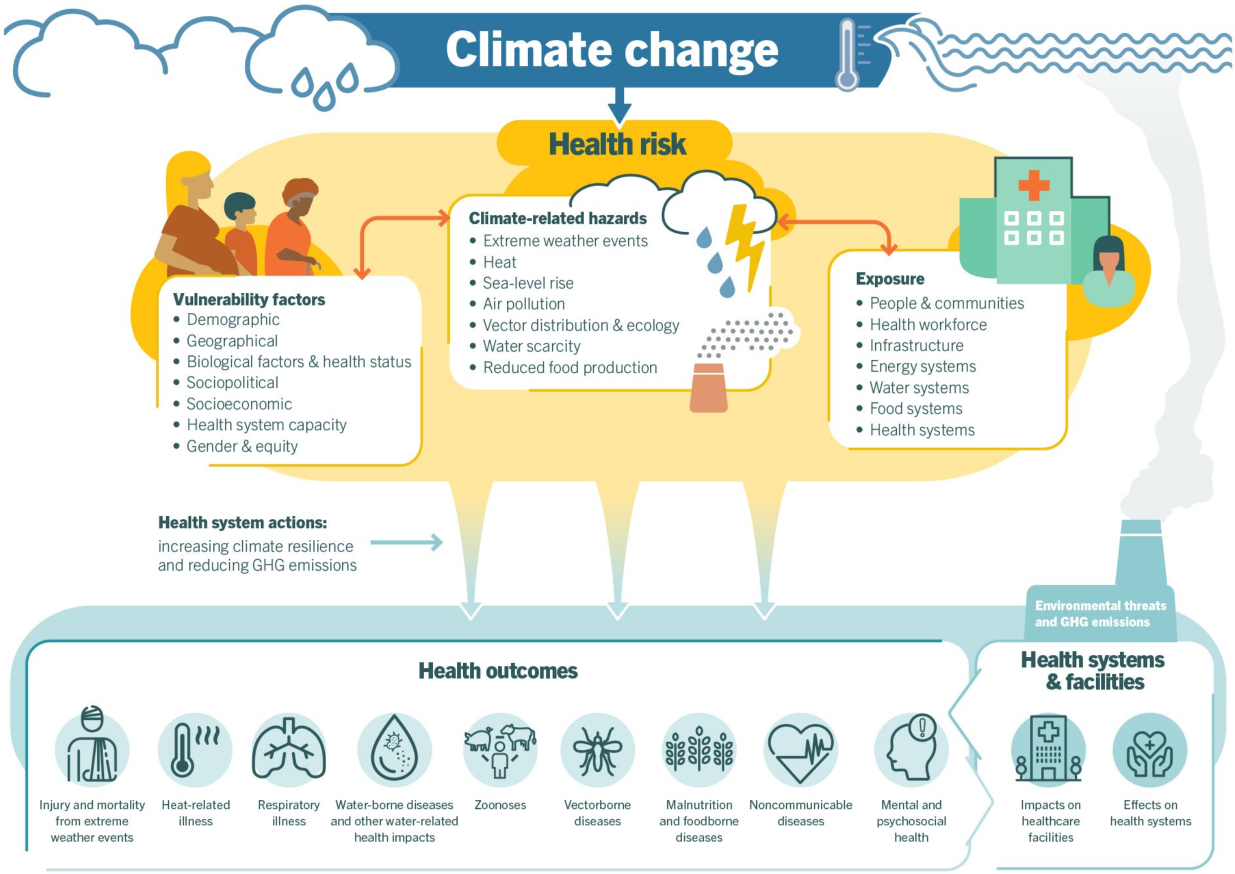
India's health sector is vulnerable to the growing impacts of climate change. As one of the most at-risk nations in the world (Eckstein et al. 2021), India's exposure to extreme climate events such as floods, cyclones, and droughts presents significant challenges to public health. A 2021 study by CEEW found that approximately 75 per cent of Indian districts are hotspots for these climatic extremes, with over 80 per cent of the population living in these vulnerable regions (Mohanty and Wadhawan 2021). This vulnerability is even more pronounced in children, with India ranking 26th out of 163 countries in UNICEF's Children's Climate Risk Index, underscoring the urgent need for targeted interventions to protect the nation's most vulnerable population (M. S. Swaminathan Research Foundation [MSSRF] 2024; UNICEF 2021a).

Between 2000 and 2019, India accounted for 10% of global flood events, making it one of the most flood-prone countries in the world (EM-DAT 2019)

In addition to the impacts of extreme weather events, water stress poses a serious challenge. India is currently ranked 13th globally in per capita water availability; projections suggest a sharp decline in the coming decades from 1,341 cubic metres in 2025 to 1,140 cubic metres by 2050, approaching the threshold of official water scarcity (NITI Aayog 2019). This escalating scarcity is driven by limited access to safe and clean water during floods and reduced availability during droughts. Additionally, climate change is expected to increase the incidence of vector-borne diseases as warmer temperatures and changing climatic conditions create more favourable environments for disease-carrying mosquitoes and pathogens. About 600 million children globally are at high risk for diseases such as malaria and dengue, and India's already vulnerable population may face even greater health risks in the future (UNICEF 2021a). Furthermore, extreme heat poses significant health risks, ranging from heat cramps and exhaustion to life-threatening heatstroke (NDMA 2024; WHO 2024). Vulnerable populations, including the elderly, children, and those with chronic conditions, face heightened risks due to their reduced ability to regulate body temperature (NDMA 2023; WHO 2024). Beyond individual health, heatwaves can disrupt essential services, strain healthcare systems, reduce productivity, and worsen air pollution, amplifying their societal impact (WHO 2024). Figure 1 below provides an overview of the climate change–induced health risks. This underscores the need to conduct comprehensive climate risk assessments to support the building of a resilient health sector across the country and inform policymaking at the national and state levels to achieve this goal.

A study by the World Health Organization (WHO) suggests that addressing environmental risks can prevent an estimated 26 per cent of deaths of children under 5 years (Prüss-Üstün et al. 2016). The Healthy Environments for Healthy Children: Global Programme Framework developed by UNICEF also identifies an 'improved understanding of climate risk for building resilience in healthcare facilities' as one of the targets countries should strive toward to improve the health of this vulnerable group (UNICEF 2021b).

Figure 1 An overview of climate change–induced health risks



Source: World Health Organization. 2023. Climate Change and Health

1.1 Understanding the physical impact of climate risk on the health sector

India's population is increasingly vulnerable to the physical risks posed by climate change, which impacts it in both direct and indirect ways. The rising frequency and intensity of extreme weather events, such as floods and cyclones, lead to increased mortality and morbidity while also exacerbating existing health inequities. The disproportionate impact on marginalised communities, such as low-income groups and those living in informal settlements, underscores the deepening of health inequities (WRI 2023; Choudhry 2023). These populations often lack access to adequate healthcare, clean water, and sanitation, making them more vulnerable to climate-related health risks like waterborne diseases and heat stress (IIED 2018). Between 2000 and 2019, India accounted for 10 per cent of global flood events, making it one of the most flood-prone countries in the world (Emergency Events Database [EM-DAT] 2019). According to a CEEW analysis, the frequency of associated flood events such as landslides, heavy rainfall, hailstorms, thunderstorms, and cloudbursts surged by over 20 times between 1970 and 2019 (Mohanty 2020). The impacts of floods include drowning, injuries, and outbreaks of waterborne diseases such as cholera, diarrhoea, and typhoid. For instance, the 2018 floods in the state of Kerala led to over 500 deaths and a surge in waterborne diseases, with nearly 3,000 cases of leptospirosis reported in its aftermath (MoHFW 2019). In addition, acute climate events severely threaten public health by causing damage to HCFs and infrastructure. During the 2022 floods in Assam, the destruction of medical equipment and power outages severely disrupted operations across several hospitals (Banik 2024).

Among chronic climatic events, heatwaves are one of the most significant direct physical impacts of climate change impacting the health sector worldwide. A study found that between 2018 and 2022, people experienced approximately 86 days of dangerously high temperatures each year (when temperatures exceeded healthy, safe levels); heat-related deaths increased above the 83.6th percentile of temperatures in 1986–2005 globally. **Climate change driven by human activities increased the frequency of extreme heat days in 60 per cent of world regions by two-fold** (Romanello et al. 2023). These impacts are particularly severe for vulnerable populations, including children, older adults, the poor, and marginalised communities. Between 2018–22 and 2000–04, heat-related deaths among people over 65 increased by 85 per cent, which is double the expected increase if temperatures had remained unchanged (Romello 2023). The impacts in India are no different. The country has experienced a significant rise in the frequency and intensity of heatwaves in recent decades, with 2022 witnessing one of the hottest March months in over a century (Srivastava, Kumar, and Mohapatra 2024). These heatwaves have led to increased cases of heat-related illnesses such as heatstroke and dehydration and exacerbated cardiovascular and respiratory conditions. According to the National Disaster Management Authority (NDMA), over 24,000 fatalities were attributed to heatwave-related deaths from 1992 to 2015 (NRDC 2020); in 2024, more than 42,000 suspected heatstroke cases were registered across India (Sharma and Das 2024).

India suffered economic losses of INR 12 trillion due to floods and storms between 1900 and 2023 (State Bank of India 2023)

Vector-borne diseases are another major concern since climate change influences the distribution and behaviour of vectors such as mosquitoes. Rising temperatures and changing precipitation patterns have expanded the geographical range and transmission season of diseases such as malaria, dengue, and chikungunya. Although India registered a drop of 14 million malaria cases between 2000 and 2019 (MoHFW 2020), India still accounts for 3 per cent of the global malaria cases and approximately 52 per cent of the deaths due to dengue annually (WHO 2021). **With climate models predicting a further increase in the number of months with higher temperatures and humidity – which are conducive to vector breeding – the burden of these diseases is expected to rise** (Caminade, McIntyre, and Jones 2018). In states such as Maharashtra and Odisha, the State Action Plan on Climate Change and Human Health (SAPCCHH) has recognised the growing incidence of vector-borne diseases such as dengue, Zika virus, leptospirosis, chikungunya, malaria, and Japanese encephalitis due to climate change; these states have conducted health and vulnerability assessments to understand the nexus between climate change and human health. A study states that the transmission potential of dengue by *Aedes aegypti* and *Aedes albopictus* increased by 42.7 per cent and 39.5 per cent since 1982, respectively. Additionally, 12.7 per cent of the global coastline is now more vulnerable to Vibrio transmission than it was during the period from 1982 to 2010, placing a record 1.4 billion people at risk (Romanello et al. 2023).

The indirect impacts of climate change on health are also profound – including food and water insecurity, and mental health deterioration. Climate-induced disruptions to agriculture adversely affect food security, potentially leading to malnutrition, particularly among children. Moreover, **the exacerbation of water scarcity due to climate change could worsen hygiene conditions, leading to a higher incidence of diarrheal diseases, which already cause over 100,000 child deaths annually in India** (UNICEF 2021a). Additionally, climate change contributes to the worsening of air quality, with increasing concentrations of particulate matter ($PM_{2.5}$ and PM_{10}) and other pollutants such as CO, O_3, NO_2, and SO_2 leading to respiratory and cardiovascular diseases, including stroke, ischaemic heart disease, chronic obstructive pulmonary disease, lung cancer, pneumonia, and cataract. According to the *Lancet Countdown on Health and Climate Change*, air pollution is responsible for nearly 1.67 million deaths annually in India, with climate change expected to further aggravate this health burden (Romanello et al. 2023). Figure 2 provides an overview of climate-induced health risks for women and children and the factors driving their vulnerabilities.

Figure 2 An overview of climate-induced health risks, exposure, and vulnerability pathways for women and children

Vulnerabilities

Factors that determine women and children's ability to cope and adapt:

- Geographical location
- Socioeconomic status
- Healthcare and education access
- Pre-Existing illness

Impacts

- Malnutrition in children
- Increased vulnerability to infectious and non-communicable diseases
- Neurodevelopmental and mental health issues
- Still births and congenital defects
- Infant mortality

Factors

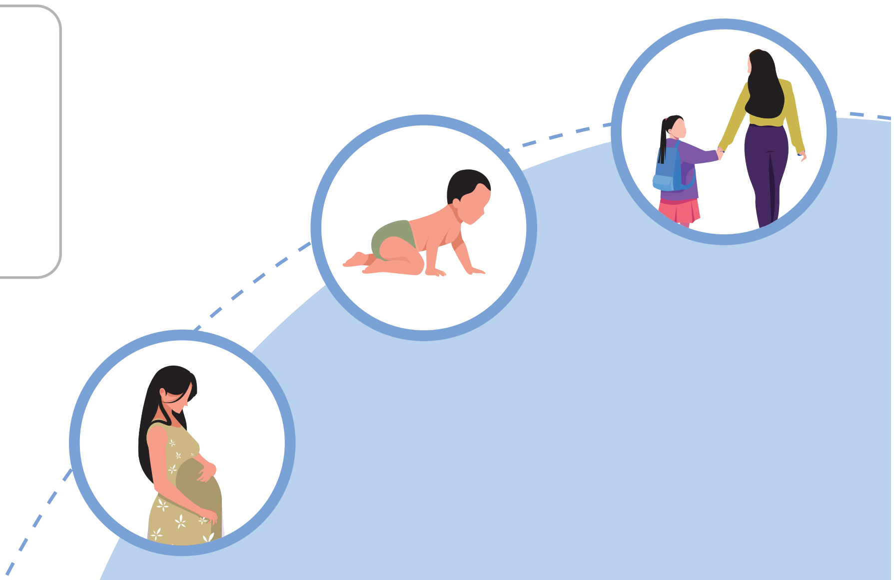
Factors leading to multiplied effects:

- Water scarcity and contamination
- Food insecurity and contamination
- Infrastructural damage
- Service disruption
- Displacement

Hazards

Climate-related hazards:

- Extreme heat
- Droughts
- Floods
- Cyclones
- Extreme precipitation



Source: CEEW compilation based on UNICEF. 2024. A Threat to Progress: The Impact of Climate Change on Children in Sub-Saharan Africa. United Nations Children's Fund

A review of existing climate risk and vulnerability assessments for the health sector in the country indicate that **currently no study utilises a risk assessment methodology for identifying the impacts of climate change on the health sector.** This study utilises a risk assessment methodology based on IPCC AR5 framework that captures the multifaceted impacts of extreme climate events on India's health sector. Policymakers must prioritise integrating climate adaptation strategies into health planning to safeguard the well-being of India's most vulnerable populations. Such efforts have already begun under the NAPCCHH.[2]

This study aims to further inform and strengthen these initiatives as local-level DAPCCHHs are developed. However, to effectively implement these strategies, it is essential to develop context-specific adaptation solutions tailored to the physical climate risks faced in different regions. This requires **identifying the underlying risk factors at a granular level through comprehensive risk assessments across sectors.** Such assessments can generate the scientific evidence administrators and policymakers need to enhance decision-making and prioritise adaptation planning. To aid this process, we developed **a novel and scalable risk assessment framework** designed to assist relevant decision-makers in prioritising geographies and populations that require urgent support in building resilience against climate change.

2 The National Action Plan on Climate Change and Human Health (NAPCCHH), launched in 2021 by the National Centre for Disease Control (NCDC), aims to strengthen healthcare services for all citizens of India, especially vulnerable populations like children and women, against climate-sensitive illnesses.

In order to implement NAPCCHH effectively and ensure timely implementation and adequate attention to local vulnerabilities, NCDC is also developing the District Action Plan on Climate Change and Human Health (DAPCCHH). It aims to provide guidelines to District Nodal Officers-Climate Change (DNO) and District Multisectoral Task Force (DTF), and to support districts in pre-planning the health sector's response to each climate-sensitive health issue and allocate resources (NCDC 2024).

1.2 Major initiatives taken by the Government of India to increase the health sector's resilience against climate extremes

The increasing frequency and intensity of extreme climate events have made it necessary to build the resilience of India's existing healthcare infrastructure and services. The Government of India (GoI) has emphasised the need to establish a well-prepared and responsive health system to combat the health risks posed by climate change in its national and state-level policies (Department of Science and Technology 2023; MoHFW 2018).

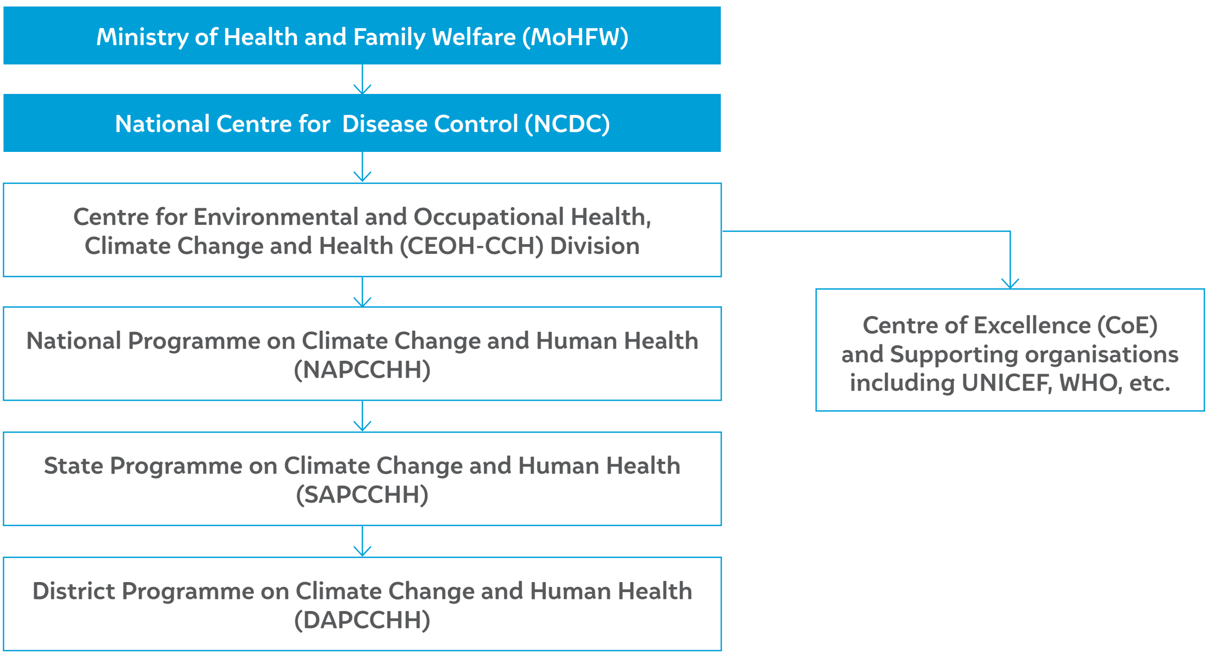
Annually, USD 9.2 trillion is required to close the global infrastructure gap, meet SDG targets, and achieve net zero missions by 2050 (CDRI 2023)

Institutional structure

India has a centrally-led structure for addressing the health impacts due to climate change. The National Centre for Disease Control (NCDC), being the technical-nodal agency for addressing the nexus between climate change and human health addresses health risk due to climate change through the development of national, state and district action plans on climate change and human health. These plans focus on addressing the health risk by building the capacity of states and districts to conduct vulnerability assessments, building human and technical capacity and allocating relevant resources for carrying out activities highlighted under the plans.

The NCDC collaborates with several other supporting health programmes and government departments such as the National Centre for Vector-borne Diseases Control (NCVBDC) that address the health risks by targeting a reduction in transmission of vector-borne diseases that is exacerbated in the case of extreme weather events. This is evident in the national and state action plans on climate change and human health that contain chapters on air pollution related illnesses, heat related illnesses, extreme weather events, vector borne diseases, and climate resilient healthcare. In addition to NCVBDC, NCDC also collaborates with the Ministry of Environment, Forests and Climate Change (MoEFCC) that acts as a technical advisor to the units under MoHFW to develop the understanding of climate change and extreme weather events.

Figure 3 Institutional structure in India for addressing the nexus between climate change and human health



Source: Authors' analysis based on MoHFW. 2021a. National Action Plan on Climate Change and Human Health. Ministry of Health and Family Welfare

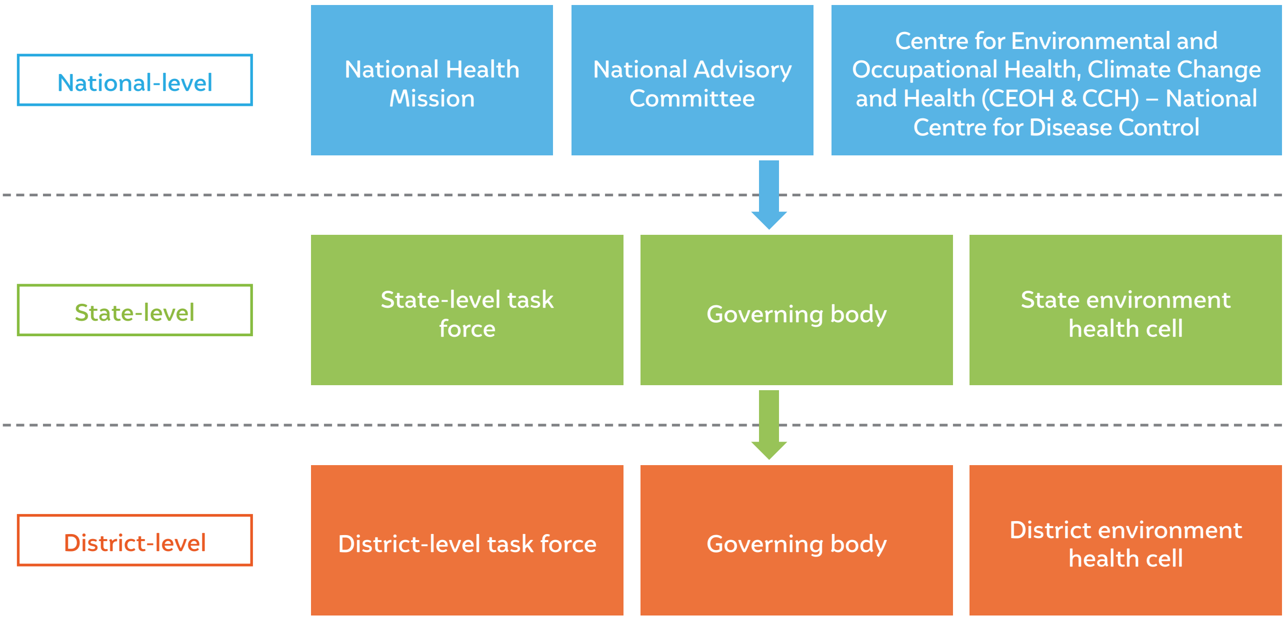
Existing central schemes, missions, and plans for addressing the health impacts of climate change

The NHM and the NAPCCHH: The MoEFCC's *National Action Plan on Climate Change* (NAPCC) consists of eight missions to address the growing concerns about climate change. In 2014, four new missions were added to the NAPCC after COP21,[3] one of them being the *National Health Mission* (MoHFW 2018). The NHM seeks to minimise climate-sensitive illnesses by collaborating with other missions under the NAPCC and through programmes implemented by different ministries.

Under the NHM, the MoHFW constituted the National Expert Group of Climate Change and Health to prepare an action plan consisting of strategies for mitigating the impacts of climate change in the healthcare sector and for building the resilience of its infrastructure and services. The expert group provided the first iteration of the NAPCCHH for India in 2018. The NAPCCHH aims to safeguard the health of citizens of India against climate-sensitive illnesses, especially vulnerable groups such as children, women, and marginalised communities, and to reduce morbidity, mortality, injuries, and health problems caused by climate variability and extreme weather events (MoHFW 2018).

The NAPCCHH is a comprehensive document that provides strategies to create awareness among the general population (especially vulnerable communities), healthcare providers, and policymakers regarding the impacts of climate change on human health by developing effective information, education, and communication materials. The document also highlights pathways to strengthen health preparedness and response by performing situational analyses at national, state, district, and sub-district levels. It calls for establishing monitoring and surveillance systems for climate-sensitive diseases and developing mechanisms for early warning and alerts during disasters and extreme weather events. Figure 4 outlines the organisational framework for implementing NAPCCHH.

Figure 4 Organisational framework for implementing NAPCCHH



Source: Authors' compilation based on MoHFW. 2021a. National Action Plan on Climate Change and Human Health. Ministry of Health and Family Welfare

3 COP21, or the 21st Conference of the Parties, refers to the United Nations Climate Change Conference held in Paris in 2015.

Under the guidance of the Centre for Environmental & Occupational Health, Climate Change & Health in the NCDC, every state government and union territory in India has prepared an SAPCCHH. This document presents detailed state plans to address climate sensitive illnesses in accordance with regional risks and includes plans for air pollution related illnesses, heat related illnesses, extreme weather events preparedness, vector borne diseases, and building green and climate resilient healthcare.

National Policy on Disaster Management: The NDMA launched this policy for managing disasters in 2009. It aims to promote disaster resilience at all levels and mainstream disaster management into the development planning process, bringing urban local bodies and gram panchayats into its gambit. Medical preparedness is a crucial component of this policy. The policy highlights collaboration between the NDMA, the MoHFW, and other institutions to formulate policy guidelines to enhance capacity in emergency medical response and mass casualty management. The policy also mandates the development of disaster management plans for hospitals, including training medical teams and paramedics, capacity building, trauma and psycho-social care, mass casualty management, and triage.

National Disaster Management Plan: The NDMA revised and updated this plan in 2019 to take forward the targets set by India under the Sendai Framework for Disaster Risk Reduction (2015–30), the SDGs, and the Paris Agreement on Climate Change (NDMA 2019). The plan underlines the principles of disaster risk reduction ensuing from sustainable and climate-resilient development. It identifies two health-specific objectives: (1) promoting resilient health systems to develop the capacities and resilience of communities and enable them to cope with and recover from disaster impacts and (2) enhancing the resilience of healthcare systems by integrating disaster risk reduction into all levels of healthcare.

The Budget 2025-26 proposes extending high-speed broadband connectivity to schools and primary healthcare centres (PHCs) through the BharatNet project

National Vector Borne Disease Control Programme (NVBDCP): In India, vector-borne diseases such as malaria, kala-azar, dengue, lymphatic filariasis, Japanese encephalitis, and chikungunya were traditionally addressed individually. However, in 2003, the GoI launched the NVBDCP, which subsumed these individual efforts to prevent and control vector-borne diseases in India (National Centre for Vector Borne Diseases Control [NCVBDC] 2022). The NVBDCP has been implemented under the overarching umbrella of the *National Rural Health Mission,* which has now been subsumed under the NHM along with the *National Urban Health Mission.*

The GoI has also established the **regional office for health and family welfare (ROHFW)** in 17 states, with one or more states or union territories under each office's jurisdiction. These regional offices play a critical role in monitoring NVBDCP activities in their respective states. Every state has a vector-borne disease control unit under its Department of Health and Family Welfare, headed by the state programme officer. At the district level, the district vector-borne disease control officer manages vector-borne diseases, including malaria.

The impact of climate change and extreme weather events on vector-borne diseases has been recognised by every state in its SAPCCHH. *The National Strategic Plan: Malaria Elimination 2023–27* also identifies the link between climate change and vector distribution patterns and behaviour in the case of malaria (NCVBDC 2023).

Integrated Disease Surveillance Programme (IDSP): The GoI initiated this decentralised disease surveillance in November 2004 to detect and generate early warnings of impending outbreaks and help initiate an effective response promptly (NCDC n.d.). Several vector-borne diseases, including malaria, dengue, and chikungunya, are reported under the IDSP. In light of advancements in mobile technology platforms and the supply of mobile phones to frontline health workers, the WHO helped redesign the IDSP platforms into the Integrated Health Information Platform (IHIP), a web-enabled near-real-time electronic system providing geospatial information. Subsequently, the GoI launched the *Ayushman Bharat Digital Mission* and the *Pradhan Mantri Ayushman Bharat Health Infrastructure Mission* (PM ABHIM) to scale up and integrate other surveillance systems with the IHIP.

National One Health Mission: Several initiatives spanning different ministries address the growing challenges related to health. In its 21st meeting, the Prime Minister's Science, Technology, and Innovation Advisory Council approved the establishment of the *National One Health Mission*. The mission aims to coordinate, support, and unify all the 'One Health' activities nationwide, addressing gaps as needed through a collaborative, cross-ministerial effort.

The mission seeks to coordinate efforts towards comprehensive pandemic preparedness and integrated disease control across the human, animal, and environmental sectors. This includes establishing early-warning systems through integrated surveillance and ensuring effective and timely responses to outbreaks of endemic diseases and emerging epidemic or pandemic threats. To enhance response readiness, the mission emphasises key preparedness areas, including R&D for vaccines and diagnostics, clinical care readiness, streamlined data access, and community participation (Office of the Principal Scientific Adviser to the Government of India n.d.).

G20 Health Ministers' Meeting: The 2023 G20 Health Ministers' Meeting identified threats to human health due to the increasing frequency and intensity of extreme weather events. It recognised the need to enhance the resilience of health systems against the impacts of climate change. The members stressed the importance of developing climate-resilient health systems and strengthening existing infectious disease surveillance systems using a risk-based approach. They also highlighted the role of an inclusive 'One Health' approach that addresses the nexus between climate change and human health.

The Union Budget 2025-26 allocates INR 99,858.56 crore to the Ministry of Health and Family Welfare, marking a 191% rise since and a 9.78% rise from 2024-25

Major announcements by the GoI in Budget 2024–25

Between 2012–13 and 2023–24, the budget for the Department of Health and Family Welfare has consistently grown at an annual rate of 12 per cent, increasing from INR 25,133 crore (USD 2.93 billion) in 2012–13 to INR 86,175 crore in 2023–24 (USD 10 billion) (PRS Legislative Research 2024). The 2024 Interim Health Budget further increased the total allocation to INR 90,171 crore (USD 10.54 billion) (1.87 per cent of the total budget), with notable allocations to the PM ABHIM, preventive healthcare, and initiatives such as cervical cancer vaccination and the U-WIN platform[4] (MoHFW n.d.). The *National Health Policy* of 2017 set a target of 2.5 per cent of the gross domestic product for public health expenditure. In Budget 2024–25, India's health expenditure reached INR 80,518 crore (USD 9.41 billion), representing 2.3 per cent of the total revenue expenditure. This indicates that the actual health expenditure has nearly reached the target set by the *National Health Policy;* however, the allocation to the MoHFW needs to be increased for initiatives addressing climate change as a critical public health concern.

4 A digital platform that maintains records of all vaccinations of children and pregnant women under the *Universal Immunization Programme.*

1.3 Purpose and scope of the study

The purpose of this study is to develop a comprehensive climate risk assessment framework for the health sector in India. **This framework aims to assess and quantify the impacts of acute and chronic climate events at the district level, providing a granular understanding of how different regions are affected by climate-related risks.** This district-level analysis will help identify specific vulnerabilities and risk factors currently impacting the health sector in India that require contextualised adaptation solutions to strengthen the sector's climate resilience across the country.

India's healthcare budget for FY25 is 1.9% of our national GDP

The scope of this study encompasses the evaluation of a wide range of climate-related hazards, including extreme climate events such as heatwaves, floods, droughts, and cyclones, as well as long-term shifts in climate patterns, such as in temperature and rainfall, which can exacerbate public health challenges. The framework is designed to integrate scientific data, risk models, and socioeconomic factors to create a unified, scalable tool that can be utilised by policymakers, administrators, and health professionals. The goal is to provide actionable insights to inform the development of targeted adaptation strategies, ensuring that India's health sector is equipped to withstand the increasing threats posed by climate change.

Research questions

1. What are the various physical, social, economic, and institutional factors that influence the risk induced by climate extremes in the health sector in India?
2. What are the most crucial indicators that must be monitored and managed to make the health sector resilient to climate extremes?
3. How can the climate risk assessment framework help improve decision-making on building a climate-resilient health sector?

Objectives of the study

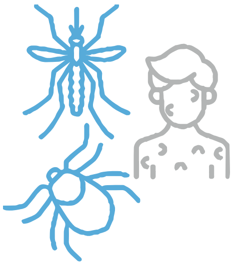
1. To identify and finalise indicators for health risk due to climate extremes in India, focusing on children, women, and vulnerable groups
2. To compute district-level climate extremes–induced health risk index
3. To identify at risk district level hotspots the key driving factors

Every USD 1 invested in adaptation against extreme events could reduce India's annual disaster losses by USD 5.5 (UNESCAP 2022).

Image: Alamy

2. Methodology

This chapter outlines the various inclusion and exclusion criteria used in this study. Figure 7 summarises the findings using PRISMA. From an initial 583 indicators, we prepared a shortlist of indicators, which we then ranked using the Delphi method in both online and offline modes. The ranking was based on a relevance scale from 0 to 4, with 0 indicating not relevant, 1 indicating less relevant, 2 indicating moderately relevant, 3 indicating highly relevant, and 4 indicating very highly relevant. Table 3 shows the finalised list of 29 indicators. The ranks were used to compute the risk index for each district in the country, and GIS maps were then created for each layer (Section 2 and Annexures 4–8 offer more details on the methodology).



Maharashtra and Odisha's SAPCCHH highlights rising vector-borne diseases like dengue, Zika, and malaria due to climate change

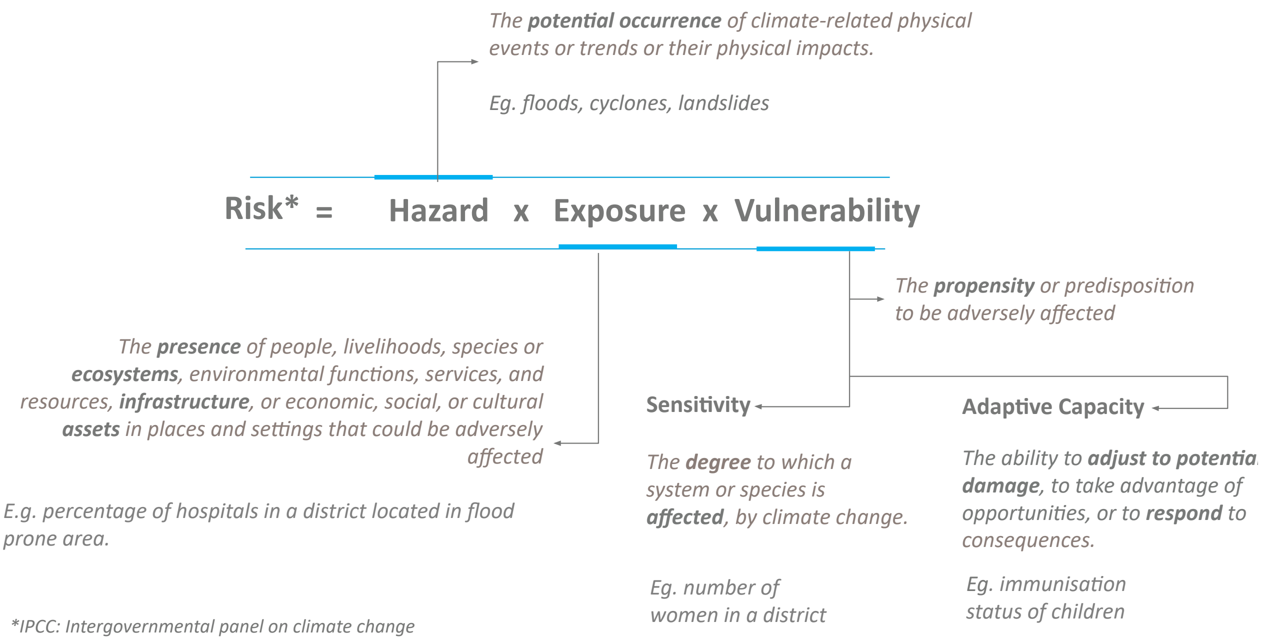
2.1 Development of the risk index

Existing studies exploring the relationship between climate change and human health use vulnerability assessments based on the IPCC's AR4. However, given recent advances in our understanding of climate change impacts, the risk to the health sector in India stemming from extreme events exacerbated by climate change can be expressed more accurately in the form of a risk index. A risk index is a composite measure that integrates various factors contributing to overall hazard, exposure, and vulnerability within a system.

The risk index for this study was developed using the methodology given in the IPCC's AR5, according to which risk results from hazard, exposure, and vulnerability (Figure 5). The framework defines risk as

> *"The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, infrastructure, health and wellbeing, economic, social, and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species (IPCC 2015)."*

Figure 5 Risk assessment equation



Source: Authors' compilation based on IPCC. 2015. "AR5 Synthesis Report: Climate Change 2014." Edited by Rajendra K. Pachauri and Leo Meyer. Intergovernmental Panel on Climate Change

2.2 A systematic review of the literature

The primary aim of a Systematic Review of Literature (SLR) is to provide a thorough analysis of a subject by adhering to a structured process. This results in an unbiased summary of the available literature. The SLR offers dual benefits – it facilitates a methodological understanding of the subject matter and presents findings robustly through a reporting structure

There is a wide variety of SLR approaches based on the research objective and the intended output of a study. Framework-based SLRs are domain-specific reviews that target a particular research topic within a broader area of study (Paul et al. 2021). These SLRs employ a well-structured approach to draw key insights, highlight research gaps, and provide directions for future studies.

The problem or intervention under consideration in an SLR can be simple or complex. Complex interventions involve multiple components and causal pathways, feedback loops, mediators, etc. They may target multiple groups (population complexity), require varied adoption strategies (implementation complexity), and function in dynamic environments (contextual complexity) (Kelly et al. 2017).

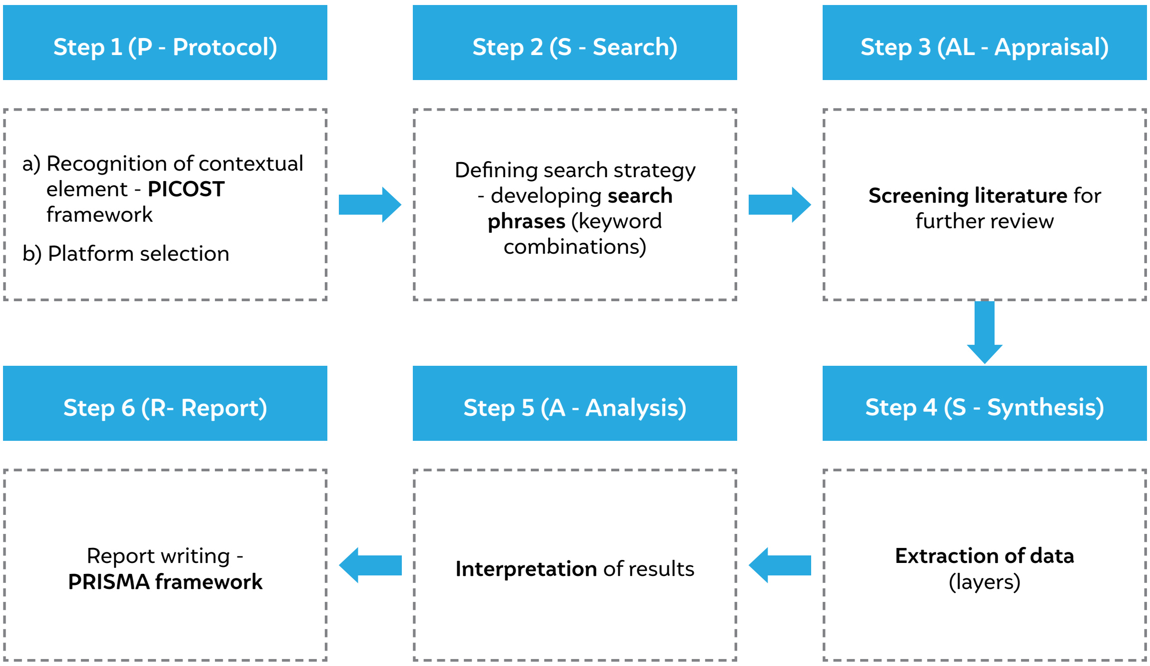
The SLR used in this study aims to identify suitable indicators to understand and explain climate risk in the health sector in India, where the problem exhibits intervention, pathway, population, and contextual complexities. To demonstrate the risk, its four sub-components (hazard, exposure, sensitivity and adaptive capacity) must be mapped separately, and infrastructural and people-specific lenses must be considered. This highlights the intervention complexity of the problem. The sub-components of risk interact with each other, creating multiple feedback loops and synergies, which contributes to pathway complexity; for example, people living in urban heat islands, floodplains, and coastal areas have higher exposure to risks, while socioeconomically disadvantaged groups may not only experience greater exposure but also have limited capacity to adapt. For this study, population complexity stems from the specific focus on various vulnerable groups, including women, children, and scheduled caste communities. The environment within which health systems operate in India is dynamic, as indicated by the different levels of governance, the multiple ministries involved, and the interaction of government with non-government space. This illustrates the contextual complexity of the problem. The comprehensive approach used to conduct the SLR for this study is explained below in detail.

2.2.1 Research protocol: The PSALSAR framework

A research protocol is crucial for a literature review. It ensures systematic, replicable, and transparent results through an extensive literature search (Mengist, Soromessa, and Legese 2020). Furthermore, the protocol minimises bias by developing search criteria to enable a systematic analysis. Therefore, the first step in the SLR conducted for this study was to establish and define the research protocol.

We adopted the six-step PSALSAR framework (Mengist, Soromessa, and Legese 2019), which is an extension of the more commonly used SALSA framework (Grant and Booth 2009; Mengist, Soromessa, and Legese 2019). Figure 6 presents the updated PSALSAR methodology we used for conducting our SLR.

Figure 6 The PSALSAR framework adopted for the SLR



Source: Authors' representation of the PSALSAR framework adopted for the study from Mengist, Wondimagegn, Teshome Soromessa, and Gudina Legese. 2019. Method for Conducting Systematic Literature Review and Meta-analysis for Environmental Science Research

The six steps of the PSALSAR framework are elaborated in detail below.

Step 1 – protocol (P)

The first step is to define the research protocol and establish the scope of the study. While several models are available in the literature for this purpose, for the kind of concepts this study entails, we employed PICOST, a variant of the well-known PICO framework (BMJ Global Health 2023; Davies 2011; Mengist, Soromessa, and Legese 2019; Sarri et al. 2020). PICOST provides a comprehensive understanding of the research protocol for this study, as outlined in Table 1.

Table 1 Detailed explanation of the PICOST framework to understand the research protocol for this study

Concept	Definition in the literature	Application for this study
P: population/ problem	The specific patient population that will be studied in the trial, considering their baseline sociodemographic and clinical characteristics: The selection criteria will be defined to minimise biases arising from patient selection or attrition	The research will help identify and map indicators to assess risks to the health sector from climate extremes. The search phrases used were developed from the following concepts (see Annexure 1 for details): • Components of health – includes health infrastructure, healthcare workforce, human resources, water and sanitation, and access to HCFs • Geographical boundary – the scope is regional (South Asia) and country-specific (India) • Hazards – include climate change–induced extreme events such as floods, cyclones, and droughts, climate change, climate risk, extreme event, extreme climate event, flood, extreme flood, cyclone, extreme cyclone, drought, extreme drought, heat, extreme heat, hydro-meteorological disaster, and weather shocks • Vulnerabilities or vulnerable groups – include women, children, low-income groups, and scheduled castes • Deployment of infrastructural lens
I: intervention	The technique or method employed to address the identified problem	Research studies (a) addressing risks to one or more health components, (b) from the specified causes or hazards mentioned above, (c) with a global, regional, country-specific, or sub-national focus, (d) that may or may not explicitly address the outlined vulnerabilities, and (e) can be viewed through an infrastructural and/or people-specific lens were included (Annexure 1 provides more details)
C: comparison	The placebo or active control comparator	There is no placebo or active control comparator for this study
O: outcome	The planned outcome or result that is measured and analysed to evaluate the effect of an intervention or condition, as defined in the protocol	Includes a list of indicators that elucidate risks to the health sector in India at the district level: this involves segregating and analysing the indicators based on components of risk such as hazard, exposure, sensitivity, adaptive capacity, and occurrence, as identified in the shortlisted literature
S: setting	The setting (primary, speciality, inpatient, nursing home, or other long-term care) where the study is conducted	The identified indicators will be utilised for climate risk computation within the health sector in India while also comparing with similar studies from South Asia Studies capturing health sector risks in other world regions will also be included if they meet the established criteria
T: timing	The time frame of treatment	The time frame for the study is 2010–23, encompassing India's NAPCC, launched in 2008, which outlines strategies for climate mitigation and adaptation in the country, highlighting eight key national missions, including the newly proposed Mission on Health post-COP21 to tackle the health impacts of climate change through a comprehensive, multifaceted approach

Source: Authors' analysis based on Hartmann, Katherine E., David B. Matchar, and Stephanie M. Chang. 2012. Assessing Applicability of Medical Test Studies in Systematic Reviews. In Methods Guide for Medical Test Reviews, chap. 6. Rockville, MD: Agency for Healthcare Research and Quality

Step 2 – search (S)

Step 2 involves defining the search strategy, including grey and non-grey literature that we considered for this study. Non-grey literature primarily consists of publications from journals and books. **We chose ScienceDirect and PubMed to search for and review non-grey literature**. Grey literature comprises research reports from leading organisations working in the domain of climate change–induced risk to the health sector. We selected reports by think tanks and multilateral organisations that aligned with the objectives of our study. (Annexure 4 presents more detailed information.)

Step 3 – appraisal (A)

In this stage, we screened both non-grey and grey literature for their relevance to the study's objectives (Mengist, Soromessa, and Legese 2019):

- First, we shortlisted the non-grey literature and reports for a full reading. This was done in two parts:
  - Out of the 314 search phrases initially used across both platforms (ScienceDirect and PubMed) for non-grey literature, we decided to select a reduced number due to time constraints. From the 'individual terminology' category, we selected one phrase. Of the remaining categories, we chose one phrase related to climate change from 'geography – India', 'social category – children', 'social category – women', 'income category – low income', and 'infrastructure'. We made this selection to ensure that we comprehensively covered all aspects in the SLR with optimal usage of time.
  - Based on steps 1 and 2 (P and S), we developed the inclusion and exclusion criteria detailed in Table 2.

Table 2 Development of criteria for inclusion and exclusion from the study

S. No.	Criteria	Decision
1.a	The pre-defined combinations of keywords exist at least in the title, keywords, or abstract of the paper (non-grey literature)	Included
1.b	The title, summary (if available), and table of contents speak of risk to health systems, access, and governance from extreme climate events in general or specifically those defined for this research (grey literature) or The title, summary (if available), and table of contents speak of health systems, access, and governance concerning the vulnerabilities of women, children, and scheduled caste communities (grey literature)	Included
2.	The literature is published in a scientific, peer-reviewed journal (non-grey literature)	Included
3.	The literature is written in the English language (grey and non-grey literature)	Included
4.	The literature is a review of literature or meta-data work (grey and non-grey literature)	Included
5.	The literature was published before 2010 or after 2023 (grey and non-grey literature)	Excluded
6.	The literature is not peer-reviewed (grey and non-grey literature)	Excluded
7.	The literature is not accessible through open access (grey and non-grey literature)	Excluded

Source: Authors' compilation

Note: Inclusion criteria 1–3 had to be met for a work to be included in the SLR. If any exclusion criteria were met, the literature was excluded.

- Second, we eliminated duplicates within the non-grey literature. This process included removing duplicates within the same search phrase on a single platform, across different search phrases on the same platform, and between the two platforms. While ScienceDirect (n.d.) automatically provides results without duplicates, the duplicate removal feature must be selected with each search for PubMed. To remove duplicates between search phrases (inter-phrase) and between different platforms (inter-platform), we utilised the reference management software EndNote after compiling the references. Figure 7 and Annexure 2 present the results of all the duplicate removal stages.
- Third, we determined the eligibility of the literature for full-text reading. The non-grey literature was examined by reading the abstract. For the grey literature, this was done by reading the summary and the table of contents. A total of 180 works were identified for inclusion in the literature review.

Step 4: synthesis (S)

This step includes extracting and classifying relevant data from selected papers to identify the climate risk indicators, understand their significance, and derive conclusions (Mengist, Soromessa, and Legese 2019). After reading the literature, we organised the information into the following categories: title, in-text citation, author(s), year of publication, objective, methodology adopted, variables identified, and the rationale behind the variables (Refer to Annexures 1–4 for details).

Step 5: analysis (A)

This step encompasses evaluating the synthesised data and analysing it further to extract meaningful information to answer the research questions (Mengist, Soromessa, and Legese 2019). The objective of this SLR was to identify the indicators that can capture the risk to the health sector in India. This was done in the following way. We classified or reclassified the variables identified from the 180 selected works under four categories: hazard, exposure, adaptive capacity, and sensitivity. This initially yielded a long list of indicators, with 75 indicators under hazard, 20 under exposure, and 463 under vulnerability (sensitivity/adaptive capacity) (Refer to Annexure 3 for details).

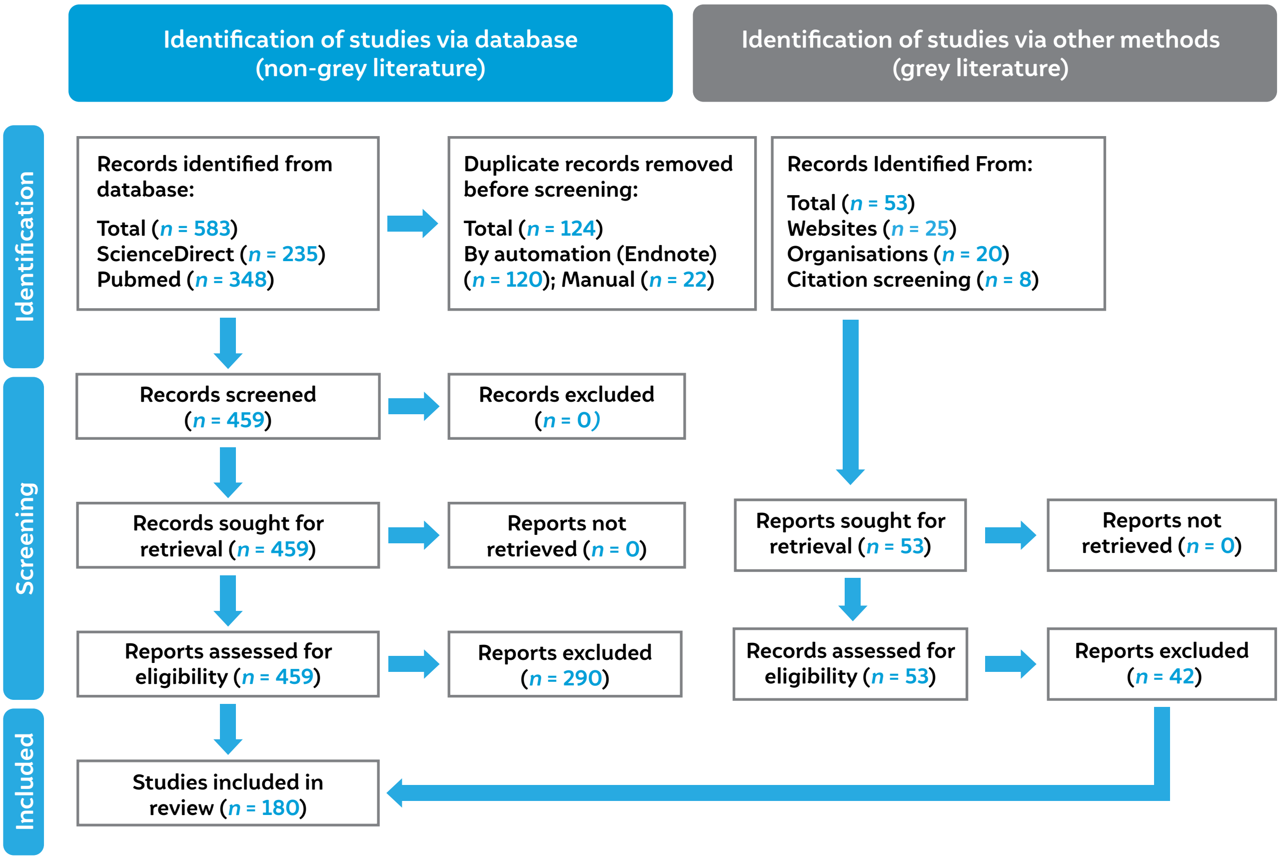
We then reduced this long list of indicators to produce a final shortlist using frequency analysis and our comprehension of the indicators' relevance to the Indian context. Eventually, we arrived at a total of 48 indicators. Their spatial scale and data sources were also finalised (Refer to Annexure 3 for details). These indicators were further ranked and revised at the stakeholder consultation, details of which are given in Section 2.3.

Step 6: reporting (R)

This step of the literature review involves describing and presenting the steps taken and the methods used to obtain the results. We adopted the PRISMA framework, one of the most widely used approaches in the literature for systematic reviews and meta-analyses. The PRISMA framework provides an evidence-based, minimum set of items to ensure clarity and transparency in reporting. Figure 7 shows the results from various stages of this SLR using the PRISMA framework. This figure is derived from the PRISMA 2020 flow diagram for new systematic reviews, which entails searches across databases, registers, and other sources (PRISMA 2020).

The objective of this systematic literature review was to identify the indicators that can capture the risk to the health sector in India

Figure 7 Reporting the SLR using the PRISMA framework



Source: Authors' analysis based on PRISMA. 2020. PRISMA Flow Diagram. British Medical Journal Publishing Group.

2.3 Computation of the risk index

After finalising the indicators for all the sub-components of risk and their sources, the next step was to compute the risk index. This consisted of three steps detailed in Sections below.

Ranking of the indicators

We ranked all the indicators identified through the SLR, excluding those for hazard, according to their relevance in assessing the risk to the health sector in India. **We used a 5-point Likert scale ranging from 0 to 4, where 0 indicates not relevant, 1 is less relevant, 2 is moderately relevant, 3 is highly relevant, and 4 is very highly relevant.** In all, 48 indicators were ranked based on the Likert scale, while the hazard indicators were assumed to have equal relevance and, hence, equal weightage.

For ranking these indicators, we followed a two-step Delphi process:

- The first step was to rank the indicators using an online mode. We developed a questionnaire and shared it with 50 experts in the government and non-government space, ranging from mid- to senior-level positions, who had experience and knowledge in fields related to the health sector. These also included stakeholders with varied areas of expertise other than health, such as diseases, gender, climate science, disaster management, and finance (Annexure 5 provides the details of the questionnaire). Of the total of 31 attendees, 19 responded. We gave the respondents the choice of suggesting potential new indicators and their data sources. We calculated the mode for each indicator and applied it in the subsequent step.

- The second step was to invite all the stakeholders for an in-person consultation, during which they were presented with a simple mode of rank for each indicator from the previous round and asked to re-rank them on the same scale of 0–4. Figure 8 shows the representation at the stakeholder consultation. We ensured that the responses from the Delphi round were anonymised. We then conducted a facilitated discussion using a mentimeter tool to garner new rankings for the indicators. Fifteen stakeholders attended the consultation (Annexure 7 for details).

  We based the final rank given to an indicator on the weighted average of all the ranks given to the indicator by all the stakeholders. This was the consensus criterion (discussed in the next section). The ranks obtained in this round were the finalised ranks. A total of 35 indicators obtained a different rank (based on the statistical mode) from their previous one. We revised the list of indicators based on suggestions made at the consultation. This was followed by finalising the data sources of the indicators. We excluded indicators lacking publicly available information; they are reported separately in the sections below. This ensured that the approach adopted prioritised the latest publicly available datasets at the district level for risk computation.

Figure 8 **Participants from the stakeholder consultation held in New Delhi**

Source: CEEW image

Representatives from CEEW, UNICEF, and various government and non-government stakeholders at the consultation workshop to finalise the indicators, their ranks, and data sources for the risk index of the health sector, conducted on 9 July 2024 at the India Habitat Centre, New Delhi.

Findings from the stakeholder consultation

Representatives from non-governmental organisations such as the Health Systems Transformation Platform (HSTP), Centre for Public Health Research (CPHR), MS Swaminathan Research Foundation (MSSRF), The Leprosy Mission Trust India, UNICEF state offices, and Ashoka University participated, while the state nodal officers from various states and representatives from National Centre for Disease Control (NCDC) were involved in the second consultation.

Following the consultation, we analysed and compiled the final ranking of the exposure, sensitivity, and adaptive capacity indicators by taking the weighted average of the ranks given by the stakeholders. Subsequently, we determined the final impact and feasibility scores of the identified adaptation strategies. We discuss this in further detail in Annexure 8. Table 3 lists the indicators shortlisted for climate risk assessment.

Table 3 Indicators and their sources for computation of the risk index

S. No.	Indicator	Component of risk	Spatial scale	Time period of dataset	Source of the indicator	In-text citation
1	Number of flood events	Hazard	District	1970–2023	CEEW analysis based on the EM-DAT database (updated per the state disaster management plans [SDMP])	EM-DAT (n.d.b)
2	Number of meteorological drought events	Hazard	District	1970–2023	CEEW analysis based on the EM-DAT database (updated per SDMP)	EM-DAT (n.d.b)
3	Number of cyclone events	Hazard	District	1970–2023	CEEW analysis based on Indian Monsoon Data Assimilation and Analysis (IMDAA) and India Meteorological Department data (updated per SDMP and Cyclone Dala)	EM-DAT (n.d.b)
4	Change in the number of extreme hot days over the past 10 years (99th percentile)	Hazard	District	2012–2022	CEEW analysis based on IMDAA and Coordinated Regional Downscaling Experiment – South Asia models	National Centre for Medium Range Weather Forecasting (NCMRWF n.d.; WCRP Cordex n.d.)
5	Change in the number of heavy rainfall days (October–December) in the past 10 years compared with the climatic baseline	Hazard	District	2012–2022	CEEW analysis based on IMDAA data	NCMRWF (n.d.)
6	Change in the number of heavy rainfall days (June–September) in the past 10 years compared with the climatic baseline	Hazard	District	2012–2022	CEEW analysis based on IMDAA data	NCMRWF (n.d.)
7	Total labour population	Exposure	District	2011	Census 2011	Ministry of Housing and Urban Affairs (MoHA n.d.b)
8	Population density in 2022	Exposure	District	2001 and 2011	CEEW analysis based on Census 2001 and Census 2011	MoHA (n.d.a, n.d.b)
9	Number of healthcare facilities (HCFs)	Exposure	District	2022	Rural Health Statistics	MoHFW (2023)
10	Slope	Sensitivity	District	2023	United States Geological Survey (USGS)	USGS (n.d.)
11	Elevation	Sensitivity	District	2023	USGS	USGS (n.d.)
12	Percentage of population aged ≤5 years or ≥65 years in 2022	Sensitivity	District	2001 and 2011	CEEW analysis based on Census 2001 and Census 2011	MoHA (n.d.a, n.d.b)
13	Stage of groundwater extraction	Sensitivity	District	2023	*National Compilation on Dynamic Ground Water Resources of India*	Central Ground Water Board (CGWB 2023)
14	Percentage of population with disability compared to the total population	Sensitivity	District	2001 and 2011	CEEW analysis based on Census 2001 and Census 2011	MoHA (n.d.a, n.d.b)
15	Number of women in a district	Sensitivity	District	2001 and 2011	CEEW analysis based on Census 2001 and Census 2011	MoHA (n.d.a, n.d.b)

S. No.	Indicator	Compo-nent of risk	Spatial scale	Time period of dataset	Source of the indicator	In-text citation
16	Number of adolescent girls in a district	Sensitivity	District	2001 and 2011	CEEW analysis based on Census 2001 and Census 2011	MoHA (n.d.a, n.d.b)
17	Household members with pre-existing illnesses or chronic medical conditions, including the following: a. Percentage of women aged 15-49 years who are anaemic b. Percentage of men and women with high or very high blood sugar c. Percentage of men and women with elevated blood pressure	Sensitivity	District	2021	National Family Health Survey (NFHS 2019–21)	MoHFW (2021b)
18	Nutritional status of children, including the following: a. Percentage of children under 5 years who are stunted (height-for-age) b. Percentage of children under 5 years who are wasted (weight-for-height) c. Percentage of children under 5 years who are underweight (weight-for-age) d. Percentage of children under 5 years who are overweight (weight-for-height)	Sensitivity	District	2021	NFHS (2019–21)	MoHFW (2021b)
19	Average out-of-pocket expenditure per delivery in a public health facility (in INR)	Adaptive capacity	District	2021	NFHS (2019–21)	MoHFW (2021b)
20	Percentage of women aged between 15 and 49 years with ≥10 years of schooling	Adaptive capacity	District	2021	NFHS (2019–2021)	MoHFW (2021b)
21	Percentage of households owning a vehicle (four-wheeler)	Adaptive capacity	District	2011	Census 2011	MoHA (n.d.b)
22	Percentage of children aged between 12 and 23 months who are fully vaccinated based on information from either vaccination centre or mother's recall	Adaptive capacity	District	2021	NFHS (2019–21)	MoHFW (2021b)
23	Percentage of households with any usual member covered under a health insurance or financing scheme	Adaptive capacity	District	2021	NFHS (2019–21)	MoHFW (2021b)

S. No.	Indicator	Compo-nent of risk	Spatial scale	Time period of dataset	Source of the indicator	In-text citation
24	Human resource gap in healthcare institutions	Adaptive capacity	District	2022	Rural Health Statistics	MoHFW (2022)
25	Percentage of households having exclusive access to water which is sufficiently available throughout the year from an improved source of drinking water located in the household premises	Adaptive capacity	District	2021	Multiple Indicator Survey, National Sample Survey (NSS) 78th round	Ministry of Statistics and Programme Implementation (MoSPI 2023)
26	Percentage of rural schools and *anganwadis* with drinking water available through tap connection	Adaptive capacity	District	2024	Format F26: Status of Pipe Water Supply in School, *Jal Jeevan Mission* (JJM) reports	Ministry of Jal Shakti (MoJS n.d.)
27	Percentage of rural households having individual household latrines	Adaptive capacity	District	2024	Format ER 77 (A): *Swachh Bharat Mission* target vs achievement based on Detail Entered (Entry Status), *Swachh Bharat Mission (G)* Phase II Management Information System (MIS)	MoJS (2024)
28	Percentage of rural schools and *anganwadis* having running water in toilets and urinals at the district level	Adaptive capacity	District	2024	Format F26: Status of Pipe Water Supply in School, *Jal Jeevan Mission* Reports	MoJS (n.d.)
29	SAPCCHH analysis: a. Number of states having health adaptation plans for the following components: i. Heat-related illnesses ii. Climate-resilient HCFs iii. Disaster management iv. Vector-borne diseases v. Extreme events b. Number of states having specific components as part of the budget of SAPCCHH: i. Infrastructure – civil works ii. Capacity building, including training iii. Information, Education, and Communication activities (IEC) and printing iv. Planning, monitoring and evaluation v. Surveillance, research, review, and evaluation	Adaptive capacity	State	2024	Database of SAPCCHH maintained by the Centre for Environmental & Occupational Health, Climate Change & Health, NCDC	NCDC (2024)

Source: Authors' compilation

Normalisation and reclassification of the indicators

We normalised all the indicators by bringing them to a common scale. For this, we used the min-max normalisation technique to make them unit-free. The normalisation is based on the functional relationship of the indicators. For positively related indicators, that is, where risk increases with an increase in the value of the indicator, we used the following formula:

$$X_{ij}^{P} = \frac{X_{ij} - Min_i\{X_{ij}\}}{Max_i\{X_{ij}\} - Min_i\{X_{ij}\}}$$

For negatively related indicators, that is, where risk decreases with an increase in the value of the indicators, we used the following formula:

$$X_{ij}^{N} = \frac{Max_i\{X_{ij}\} - X_{ij}}{Max_i\{X_{ij}\} - Min_i\{X_{ij}\}}$$

After normalisation, the indicator's risk score ranged between 0 and 1, where 1 corresponds to a district with maximum risk, and 0 corresponds to a district with minimum risk.

Sub-indices and index computation

Once the indicators were normalised as per their relation to risk, we calculated the sub-indices by adding the product of each indicator and its weightage. We did this for each district to compute the hazard, exposure, and vulnerability (sensitivity/adaptive capacity).

After calculating the sub-indices, we estimated the risk by calculating the product of the three sub-indices. **To maintain uniformity, the risk scores were again normalised and classified into five categories – very low, low, moderate, high, and very high.**

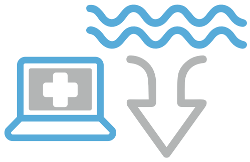
We used the equal quantile break method using ArcGIS Pro software for this categorisation. Annexure 8 details the process and the assigned weights. Finally, we computed the composite risk scores for each district using the risk equation and classified them into five categories – very high, high, moderate, low, and very low (Figure 9).

Figure 9 Schematic representation of the stepwise approach to compute the physical risk index

Source: Authors' analysis

2.4 Limitations of the study

The study has certain limitations due to its objectives and larger design and scope. Other limitations arise from data availability and risk computation. These two categories of limitations are explained below.



Climate proofing the health sector is essential for achieving SDG targets 3, 4, 5, 6, 13, 14, and 15, ensuring universal access to adequate health services

Limitations of the study design

- The SLR did not identify all the groups that are considered vulnerable in the literature as vulnerable populations. For example, genders other than women and other such identities were not considered in the systematic review of literature categories.
- We used ScienceDirect and PubMed to search for relevant literature. Insights from works in other databases are thus lacking in this study.
- The study excluded literature published in languages other than English and works not freely available in the public domain. Therefore, we omitted insights from research that did not meet these criteria.
- The scope of the study is limited to hydro-meteorological disasters and weather events, which include floods, droughts, cyclones, heatwaves, and extreme rainfall. Other kinds of natural disasters, such as geological, biological, and extra-terrestrial events, have not been considered in the study.
- The study includes the presence of healthcare facilities, such as primary healthcare facilities (PHCs) and secondary healthcare facilities (SHCs), in a district as a component of exposure. Since exposure contributes to risk, districts with a higher number of HCFs are assigned a higher risk. However, this should not be interpreted to mean that having more HCF increases risk. These facilities also offer services that enhance the district's adaptive capacity, which has been accounted for separately under adaptive capacity indicators in this study.

Limitations of the data for computing indicators

The following are the imitations related to the data for computing indicators.

a. Some of the datasets used for computing the indicators are not from the most recent time period, as indicated by the following examples.

- The district boundary shapefile for India is available for the year 2022. Hence, we brought down all the indicators from 2023 and 2024 to the level of administrative boundaries for the year 2022.
- We acquired the data for the indicators – namely *total labour population, population density, percentage of the population above 65 years and below 5 years of age, number of women in a district, number of adolescent girls in a district, percentage of the population with disability, and percentage of households with a vehicle,* as seen in Table 3 – from the census survey for population data conducted by the GoI in 2011. We extrapolated the population data using the compound annual growth rate method. However, extrapolation was not possible for the indicators of the total labour population and percentage of households with a vehicle due to data discrepancies in the previous census (Census 2011) conducted by the GoI. Annexure 8 provides more details.
- The indicator *percentage of households at the district level having exclusive access to water, which is sufficiently available throughout the year from an improved source of drinking water located in the household premises* is at the 2021 level. The latest data are only on functional household tap connections, as captured by the live dashboard of India's JJM. However, this information could not be used since it does not cover all aspects of safely managed drinking water services for households.

b. Some datasets overlap due to the nature of data collection. The following example holds true:

- The indicator *number of women in a district* was estimated by considering the number of women aged 18 years and above. The *number of adolescent girls in a district* was estimated by considering the population of girls aged between 10 and 19. Hence, there is a slight overlap in the data for the two indicators as they both include women aged 18 and 19.

c. Some datasets used for computing the indicators do not capture all the aspects necessary for formulating a holistic understanding of the indicator. The following examples hold true:

- The indicator *percentage of households having exclusive access to water which is sufficiently available throughout the year from an improved source of drinking water located in the household premises* does not capture all aspects of safely managed drinking water services for households. (Refer to Annexure 8 for more details).
- The indicator *percentage of rural schools and anganwadis with availability of drinking water through tap connection* does not cover all aspects of basic drinking water services for education facilities. (Refer to Annexure 8 for more details).
- The indicator *percentage of households at the district level with hand-washing facilities available within the premise* does not capture all elements of basic sanitation for households. (Refer to Annexure 8 for more details).
- The indicator *percentage of rural schools and anganwadis at the district level having hand-washing facilities* does not cover all aspects of basic hygiene requirements for education facilities. (Refer to Annexure 8 for more details).

Image: iStock

19 out of 36 districts in Maharashtra lack structural and functional capacities and record low expenditures on healthcare system strengthening, with only 8 accredited hospitals present across 19 districts (CEEW 2024)

3. Results and findings

Image: Alamy

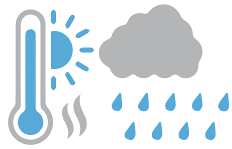
This chapter presents the key findings of our study, based on an integrated climate risk assessment using the IPCC AR5 framework. We followed a composite index–based approach, which provides a detailed explanation at a granular level of why the health sector of some districts of India are more vulnerable and at risk due to climate-related impacts. Furthermore, the framework serves as a reference model for creating a detailed climate risk assessment specifically for India's health sector.

The study evaluates hazard, exposure, vulnerability (sensitivity and adaptive capacity), and overall climate risk at the district level in India. Following the risk framework, we computed the risk index for all the districts. We then imported the risk scores to GIS to create maps for the sub-indices and the final risk index. Using ArcGIS Pro software, we divided the scores into five categories based on the equal count (percentile) method. The five categories of risk were very low, low, moderate, high, and very high.

The chapter also illustrates the major drivers of risk in specific states and districts of India; we identified the top five contributing indicators under the category "exposure, sensitivity, and adaptive capacity". This was done by accounting for the total number of districts falling under the range formed by the maximum score and half of the maximum score obtained for that indicator. The findings of the study are described in the following section.

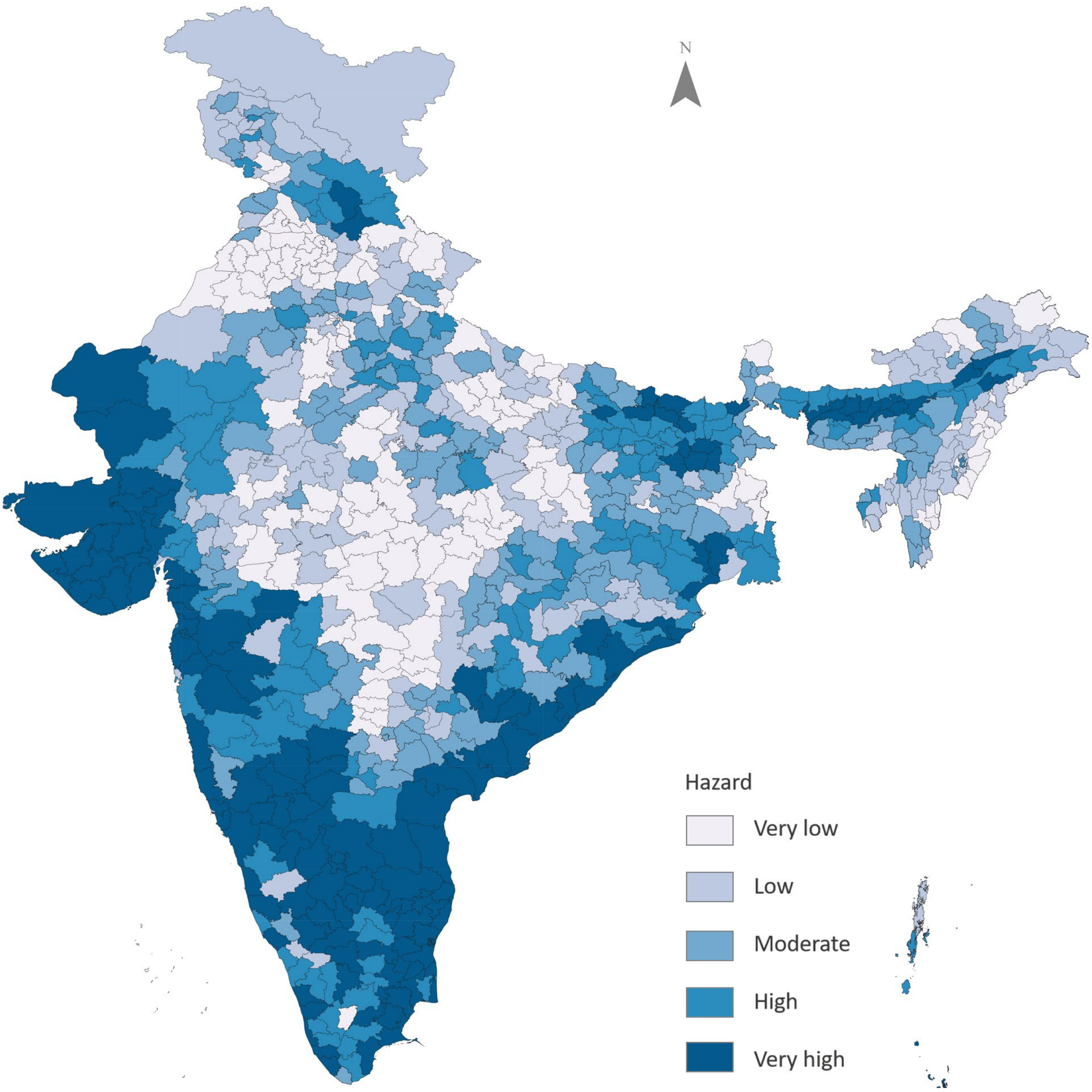
3.1 State of hazards

The frequency and intensity of extreme events across India, such as heatwaves, floods, droughts, and cyclones, have been increasing over the past few years. Findings from a pentad decadal analysis of extreme hydro-meteorological disasters by CEEW show that more than 75 per cent of Indian districts are hotspots for floods, droughts, and cyclones and their associated events (Mohanty 2020). Even more alarming, more than 40 per cent of these districts show a swapping trend – flood-prone areas are becoming drought-prone, and vice versa (Mohanty 2020). Recent data show that the occurrence of heatwaves in India has nearly doubled over the last two decades, with the coastal and northern states being more vulnerable (Saranya et al. 2022). Similarly, extreme rainfall events have increased in frequency and unpredictability, disrupting agriculture, infrastructure, and livelihoods. According to a study, the monsoon patterns have shifted significantly, leading to excessive rainfall in shorter time frames and longer dry spells, exacerbating water scarcity and soil degradation across India's agrarian belts (Prabhu and Chitale 2024).



The study considers the number of extreme floods, meteorological droughts, cyclone events, and changes in the number of extreme hot and heavy rainfall days as hazards

Figure 10 **Health sector in districts along India's eastern and western coasts is impacted by a very high frequency of hazards**



Source: Authors' analysis

The current study finds that more than 80 per cent of districts in states such as Andhra Pradesh and Karnataka, more than 60 per cent of districts in Tamil Nadu and Gujarat, and more than 45 per cent of districts in Assam and Bihar fall under the very high hazard category. More than 50 per cent of districts in Kerala and Himachal Pradesh fall under the high category. However, districts in Madhya Pradesh, Punjab, Haryana, and Jammu and Kashmir are in the low to very low range for hazards.

High to very high levels of hazards are witnessed in districts located in the eastern and western coastal belts of India (Figure 10). This can be attributed to the fact that these districts face an increasing number of multiple hazards, such as floods, cyclones, and droughts, which compounds the total hazard score for these districts. The changing patterns of monsoons and an increasing number of hot days further intensify the hazard levels. Table 4 provides the district-level hazard hotspots for each zone in India. A detailed table with hazard score for each district can be found in the annexure 8.

Table 4 Hazard hotspots in India

Zone	District hotspots
East	Sri Potti Sriramulu Nellore, East Godavari, Puri
North	Kullu, Bhagalpur
Northeast	South Salmara-Mankachar, Dhubri, Darrang
South	Chennai, Bijapur, Belgaum
West	Navsari, Gir Somnath, Kachchh, Surat, North Goa, Thane, Ratnagiri

Source: Authors' analysis

Table 5 Top five districts with highest hazard score

State	District	Top drivers of hazard	
Tamil Nadu	Chennai	Number of cyclone events	Change in number of extreme warm nights
Karnataka	Bijapur (Vijayapur)	Number of meteorological drought events	Change in number of extreme warm nights
Andhra Pradesh	Sri Potti Sriramulu Nellore	Number of cyclone events	Change in number of extreme warm nights
Gujarat	Navsari	Change in number of extreme hot days	Change in number of extreme warm nights
Gujarat	Gir Somnath	Change in number of extreme hot days	Change in number of heavy rainfall days (JJAS)

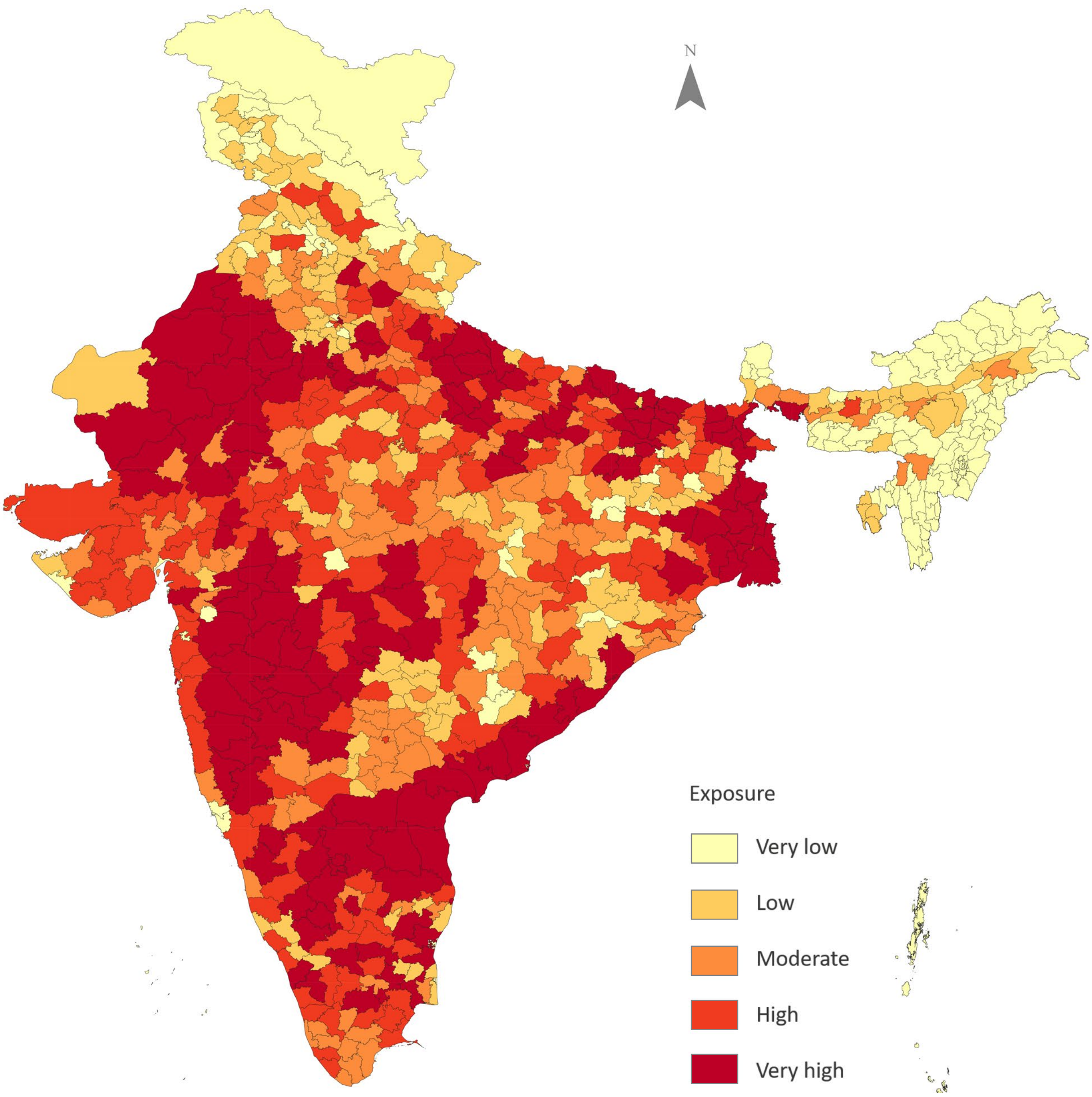
Source: Authors' analysis

Our findings are in line with the findings of a recent research paper that highlights that more than 50 per cent of India's population is at high risk from climate change–induced health impacts (Chaudhary and Mukhopadhyay 2023). Moreover, many studies have shown that high-risk areas are typically those already facing challenges such as resource scarcity, environmental degradation, high levels of infectious disease, weak infrastructure, and overpopulation (Patz et al. 2005; Wiley and Gostin 2009). Tropical regions, in particular, are expected to see significant shifts in human–pathogen dynamics due to climate change (Sattenspiel 2001). Additionally, changes in temperature and rainfall patterns also impact health by altering the ecology of vector-borne diseases, including malaria, dengue, chikungunya, Japanese encephalitis, kala-azar, and filariasis.

3.2 State of exposure

The sharp rise in the frequency and intensity of extreme climate events in India poses a significant challenge to the country's densely populated regions, where the health sector is especially vulnerable. The higher population density and larger number of HCFs in these areas lead to increased exposure to climate-related disasters, which damage the infrastructure and disrupt critical services.

Figure 11 The health sector in more than 50% of districts of Andhra Pradesh, West Bengal, Maharashtra, Bihar, and Karnataka is very highly exposed to extreme events



Source: Authors' analysis

Our analysis shows that health sector in districts in the states of Andhra Pradesh, West Bengal, Maharashtra, Rajasthan, Bihar, Karnataka, Uttar Pradesh, Tamil Nadu, and Kerala are very highly exposed to the impacts of extreme climate events (Figure 11). More than 90 per cent of districts in Andhra Pradesh face very high exposure to extreme events. Furthermore, districts in Gujarat, Madhya Pradesh, Uttar Pradesh, Himachal Pradesh, and Odisha fall under the high exposure category.

We identified the following two indicators as the top drivers of exposure:

a. **Total labour population:** In districts with a large labour population, particularly in agriculture and construction, labourers are more exposed to climate-related hazards due to outdoor work and limited access to social safety nets at the onset of extreme events such as floods, very heavy rainfall, or heatwaves.

b. **Population density:** High population density amplifies exposure because more people are affected by extreme climate events, straining local resources and emergency response systems.

Table 6 provides the district-level exposure hotspots for each zone in India. A detailed table with exposure score for each district can be found in the annexure 8.

Table 6 Exposure hotspots in India

Zone	District hotspots
East	East Godavari, Guntur, Chittoor, Kurnool, West Godavari, Anantapur, Prakasam, Krishna, Murshidabad, South 24 Paraganas
North	Purba Champaran, Madhubani, North-east Delhi, Sitapur
South	Belgaum, Tumkur
West	Nashik, Ahmadnagar, Pune, Jalgaon, Nagaur, Banas Kantha, Alwar

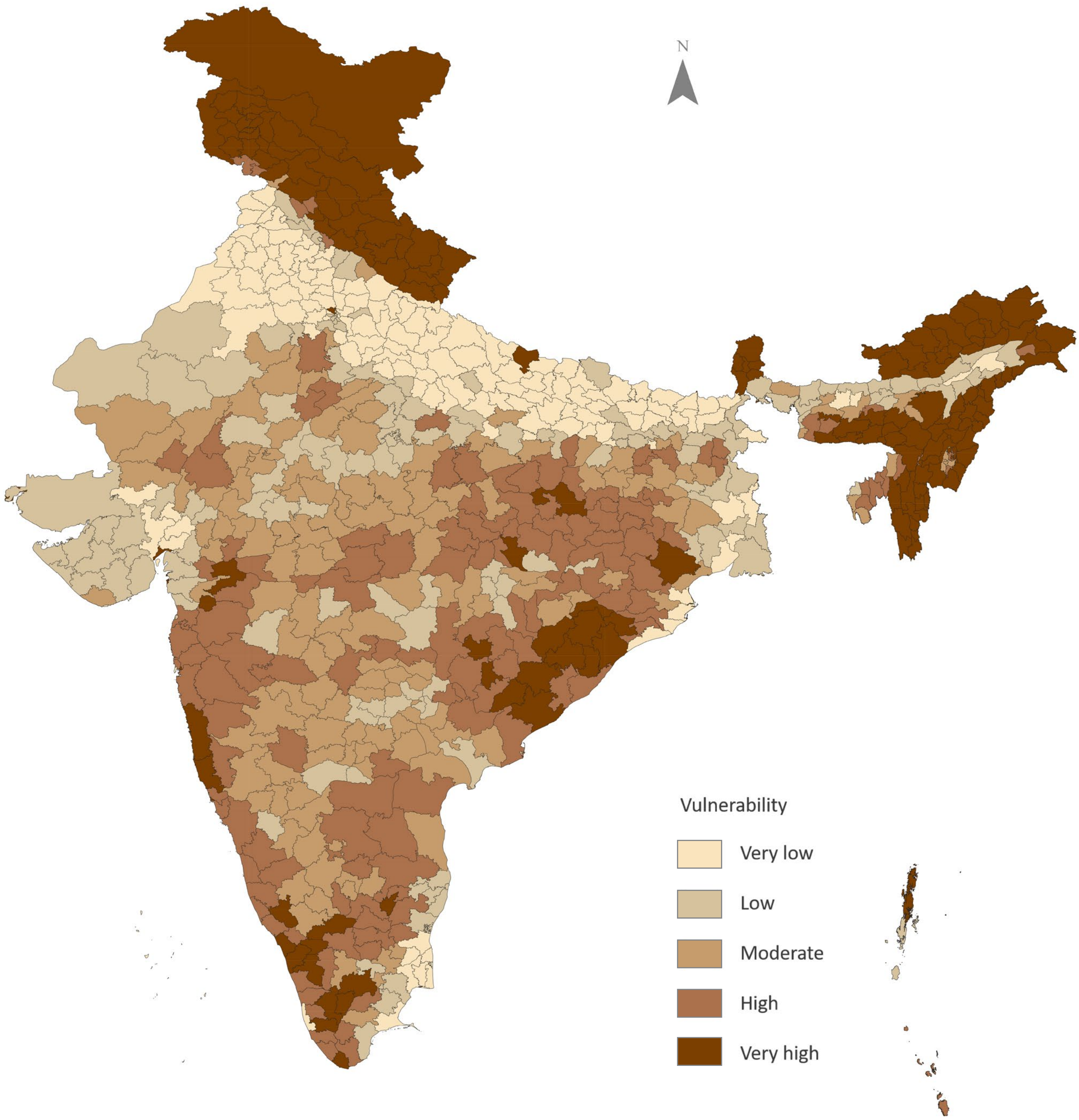
Source: Authors' analysis

The results align with the findings of a recent report, which states that India's annual temperatures are expected to increase by 1.7–2.2°C by 2030, and more people will be exposed to extreme heat and other extreme weather events. This could lead to a rise in acute incidents such as heat strokes and heat exhaustion, as well as an elevated risk for chronic diseases (MSSRF 2024; WHO 2024). The US Global Change Research Program's *National Climate Assessment* also highlights that extreme weather events can heighten exposure to harmful environmental conditions (NIH n.d.). For example, cyclones and coastal storms produce debris and projectiles, which can cause injuries during the event while also increasing the spread of hazardous chemicals and waterborne and vector-borne pathogens through damaged facilities, storm surges, and flooding. Furthermore, flood events and rising sea levels can contaminate water sources with harmful bacteria and viruses, leading to food-borne and waterborne diseases (Bolan et al. 2024).

3.3 State of vulnerability

The low resilience of healthcare systems, when combined with the growing severity of extreme weather events, presents a dire challenge. The high sensitivity and low adaptive capacity of HCFs, many of which are ill-prepared for climate-induced shocks, further exacerbate the situation. Districts with health systems that have a low adaptive capacity often struggle to recover or rebuild quickly after a disaster, leaving communities even more exposed to future extreme events.

Figure 12 **20% of the districts in India are highly vulnerable to extreme climate events**



Source: Authors' analysis

Figure 12 depicts the high variability of vulnerability in districts across the different Indian states. Districts in Uttarakhand, Himachal Pradesh, Arunachal Pradesh, Sikkim, Mizoram, Ladakh, Jammu and Kashmir, Manipur, and Nagaland show very high to high levels of vulnerability. The majority of Indian districts fall under the category of moderate vulnerability, with low vulnerability in West Bengal, Telangana, Rajasthan, Odisha, Madhya Pradesh, and Karnataka and very low in Uttar Pradesh and Punjab.

We identified the following five indicators as the top drivers of sensitivity:

a. **Altitude (elevation) of a district:** At lower altitudes, the health infrastructure and services are more vulnerable to disruptions due to extreme climate events such as heavy rainfall, cyclones, and floods.

b. **Percentage of the population above 65 years and below 5 years of age:** A higher percentage of older people and young children increases sensitivity as these groups are more vulnerable to health risks from extreme climate events.

c. **Number of women in a district:** A larger female population indicates higher sensitivity since women, especially from rural areas, often face greater health challenges from climate change impacts due to higher gendered vulnerabilities.

d. **Household members with pre-existing non-communicable illnesses:** The presence of individuals with chronic conditions such as diabetes or heart disease increases sensitivity, as they are more susceptible to climate-related health impacts.

e. **Malnourishment in children under 5:** High rates of malnourishment make young children more sensitive to health risks, particularly during disasters, due to weakened immune systems and poor health conditions.

Districts with low health system adaptive capacity struggle to recover from disasters, increasing future vulnerability

Furthermore, our analysis shows that most districts in Punjab, Tamil Nadu, Gujarat, and Karnataka score high on adaptive capacity, reducing their health sectors' overall risk during extreme climate events. Table 7 lists the districts with the maximum adaptive capacity. A detailed table with adaptive capacity score for each district can be found in the annexure 8.

We identified the following seven indicators as the top drivers of adaptive capacity:

a. **Average out-of-pocket expenditure per delivery in public health facilities:** Lower out-of-pocket maternal healthcare costs improve access, increasing adaptive capacity by reducing financial barriers during crises.

b. **Percentage of children aged 12–23 months who are fully vaccinated:** Higher vaccination rates among children boost overall health resilience, reducing vulnerability to climate-induced disease outbreaks.

c. **Human resource gap in healthcare institutions:** Large gaps in healthcare staffing weaken adaptive capacity by limiting the availability of skilled professionals during emergencies.

d. **Percentage of functional tap connections within households:** Access to reliable water sources at home increases adaptive capacity, especially during extreme weather events when water supply chains may be disrupted.

e. **Percentage of rural schools and *anganwadis* with tap water:** Availability of clean drinking water in schools and *anganwadis* enhances community health and resilience and protects children from disease outbreaks during extreme events.

f. **Percentage of schools and *anganwadis* with safely managed sanitation:** Proper sanitation in schools and *anganwadis* improves public health outcomes and reduces the spread of diseases during climate-related disasters.

g. **The SAPCCHH:** Implementing SAPCCHH strengthens adaptive capacity by integrating climate-resilient practices into healthcare policies and infrastructure.

Table 7 Top five districts with the highest adaptive capacity

State	District	Top drivers of adaptive capacity	
Punjab	Pathankot	% of schools and anganwadi having safely managed sanitation facilities at district level	% of rural schools and anganwadi with availability of drinking water through tap connection, at the district level
Tamil Nadu	Kanyakumari	% of schools and anganwadi having safely managed sanitation facilities at district level	% of households having safely managed sanitation facilities at district level
Punjab	Shahid Bhagat Singh Nagar	% of schools and anganwadi having safely managed sanitation facilities at district level	Human resource gap in healthcare institutions
Punjab	Jalandhar	% of schools and anganwadi having safely managed sanitation facilities at district level	% of functional tap connection within the premises of households, at district level
Punjab	Hoshiarpur	% of schools and anganwadi having safely managed sanitation facilities at district level	% of rural schools and anganwadi with availability of drinking water through tap connection, at the district level

Source: Authors' analysis

On the other hand, the majority of healthcare systems in the districts of Sikkim, West Bengal, Arunachal Pradesh, and Chhattisgarh have low adaptive capacity to cope with the impacts of extreme climate events. Table 8 lists the districts with the least adaptive capacity scores.

Table 8 Top five districts with the lowest adaptive capacity

State	District
Sikkim	West District
Sikkim	North District
Sikkim	South District
Sikkim	East District
Maharashtra	Mumbai Suburban

Source: Authors' analysis

Both Sikkim and Maharashtra have common indicator drivers leading to least adaptive capacity:

- Percentage of functional tap connection within the premises of households, at district level
- Percentage of rural schools and Anganwadi with availability of drinking water through tap connection, at the district level
- Percentage of households having safely managed sanitation facilities at district level
- Percentage of schools and Anganwadi having safely managed sanitation facilities at district level:

  Specific indicator driver for Mumbai Suburban:

  - Percentage of children aged between 12- and 23 months who are fully vaccinated, based on information from either vaccination cards or mother's recall

West District, North District, South District, and East District of Sikkim; and Mumbai Suburban of Maharashtra are the top 5 districts with least adaptive capacity score because of unavailability of data for the indicators mentioned above. **This lack of data is a significant factor contributing to the low adaptive capacity for the above districts.**

Table 9 below provides the district-level vulnerability hotspots for each zone in India. A detailed table with vulnerability score for each district can be found in the annexure 8.

Table 9 Vulnerability hotspots in India

Zone	District hotspots
East	Kalimpong, Gajapati, Bilaspur, Dima Hasao, Rayagada, Darjeeling
North	Kinnaur, Kishtwar, Chamoli, Ganderbal, Pithoragarh, Rudraprayag, Kargil, Uttarkashi, Ramban, Doda, Chamba, Shimla
Northeast	Sikkim East District, Sikkim South District, Shi Yomi, Sikkim West District, Sikkim North District, Upper Siang, Anjaw, Kra Daadi, Kiphire, Siang, Phek
South	Idukki, Palakkad, Theni, Pathanamthitta, Kanyakumari, Dindigul, Kodagu
West	Nandurbar, Ratnagiri, The Dangs

Source: Authors' analysis

Many other studies have also identified similar drivers which exacerbate the existing vulnerabilities of women and children in India. People at the extremes of age and those with pre-existing health conditions are especially vulnerable (Kenny et al. 2010; Meade et al. 2020; WHO 2024). Pregnant women face significantly higher health risks from prolonged heat exposure, which can lead to negative reproductive outcomes such as preterm birth, gestational hypertension, and pre-eclampsia (MSSRF 2024; Rekha et al. 2023). Furthermore, women working in the informal sector are particularly at risk due to prolonged exposure to heat and unfavourable working conditions (Integrated Research and Action for Development [IRAD] n.d.; MSSRF 2024). The lack of climate resilience in health and educational facilities further compounds the problem (Govind, Velmurugan, and Mariyam 2022; Sheffield et al. 2017).

3.4 State of overall climate risk

In this section, we present the findings from our composite risk indexing of all Indian districts using spatio-temporal analysis. We calculated the risk index by aggregating the values of the individual risk components – that is, hazard, exposure, sensitivity, and adaptive capacity. Hazard, exposure, and sensitivity positively correlate with risk, while adaptive capacity negatively correlates with risk. This means that a decrease in the adaptive capacity of the health sector will increase their risk, while a decrease in hazard, exposure, and sensitivity will decrease the risk to the health sector. The risk index characterises risk into five categories using the percentile method and the ArcGIS pro software. Table 10 gives the risk scores and categories. A detailed table with physical climate risk score for each district can be found in the annexure 8.

Table 10 Risk categories with their respective range of scores

Risk category	Range of scores
Very low	0.000–0.0009
Low	0.0009–0.002
Moderate	0.002–0.0037
High	0.0037–0.0085
Very high	0.0085–0.1057

Source: Authors' analysis based on quantile interval distribution

According to our analysis, health sector across more than 40 per cent of Indian districts faces very high to high climate risk, whereas in approximately 20 per cent of districts, health sector faces moderate risk, and in around 40 per cent of districts, they are at low to very low risk. Figure ES3 illustrates the risk levels for health sector across all the districts in India.

Health systems across more than 40% of Indian districts face very high to high climate risk (CEEW 2025)

Most of the districts with very high risk are located in Maharashtra, Karnataka, Tamil Nadu, Jammu and Kashmir, Andhra Pradesh, Odisha, Kerala, Sikkim, Himachal Pradesh, and Uttarakhand (Figure 13). The high-risk category is widely distributed across different regions of the country, including Rajasthan, Madhya Pradesh, Gujarat, West Bengal, and Chhattisgarh.

This can be attributed to the following reasons:

a. **High sensitivity** is observed in districts of states such as Sikkim, Uttarakhand, Jammu & Kashmir and Himachal Pradesh because of high slope.

b. **Low adaptive capacity** is observed in districts of states such as Maharashtra, and Sikkim because of lack of data availability for a few indicators.

c. **Odisha has high hazard** occurrence in few districts because of increase in flood, cyclone, and drought events.

d. High hazard occurrence is observed in few districts of states like Kerala, Odisha, and Andhra Pradesh. Andhra Pradesh also observes high exposure due to high labor population.

In the moderate-risk category, the central region of India is predominant, which includes the states of Madhya Pradesh, Gujarat, and Jharkhand. In the low- and very low-risk categories, northern states such as the National Capital Territory (NCT) of Delhi, Punjab, Haryana, and Uttar Pradesh stand out; there are also a few districts from the northeastern states of Assam, Arunachal Pradesh, and Tripura.

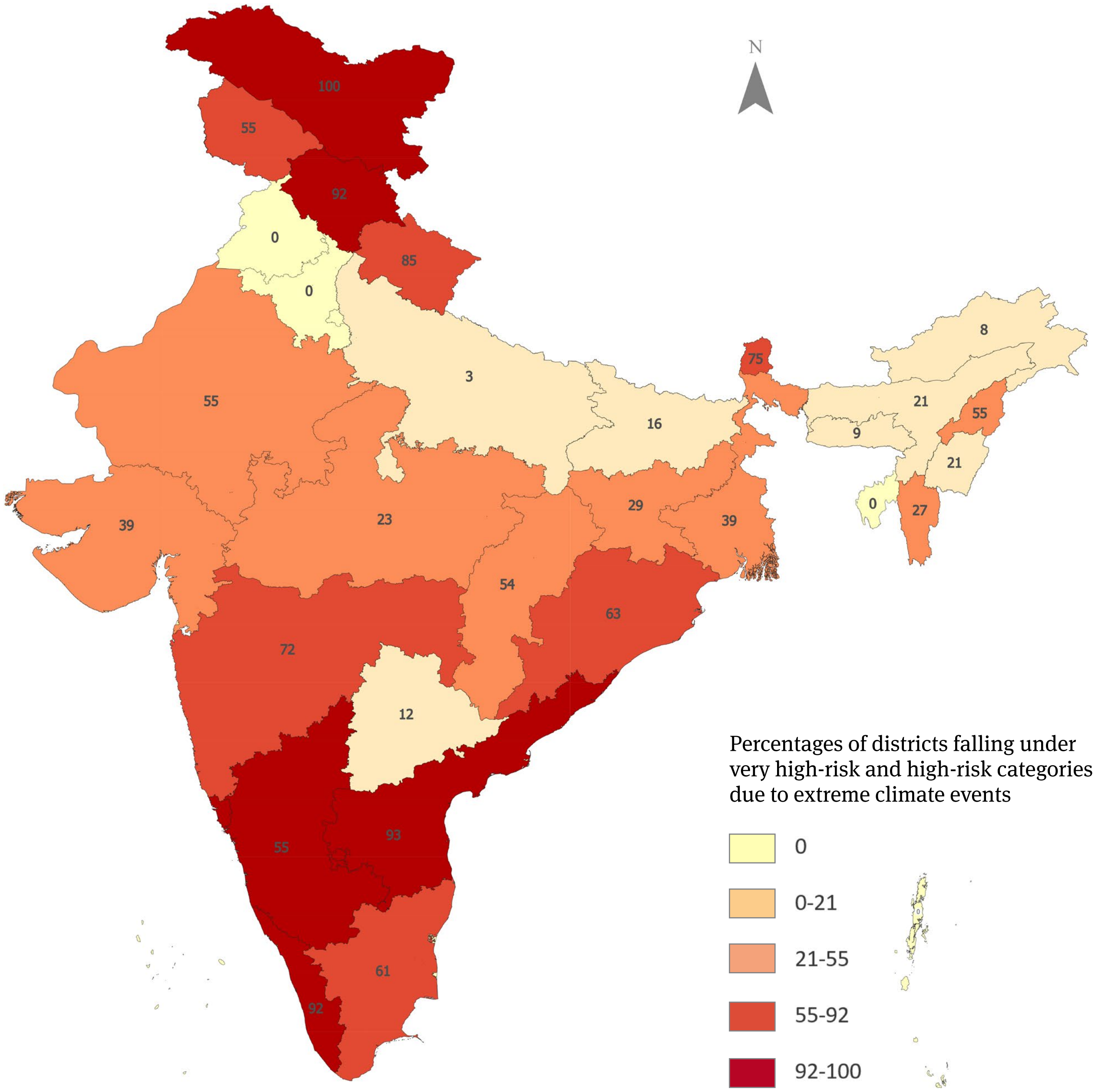
We calculated the total number of districts in each category to estimate the proportion of very high-risk and high-risk districts in each state. Andhra Pradesh, Kerala, Uttarakhand, Himachal Pradesh, and Jammu and Kashmir emerged as the states with the highest number of districts in the very high and high-risk categories, followed by Sikkim, Karnataka, Maharashtra, Ladakh, Tamil Nadu, and Odisha with more than 60 per cent of districts in these categories.

In contrast, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Puducherry, Punjab, Telangana, Tripura, and Andaman and Nicobar Islands had the lowest percentage of districts in the very high-risk and high-risk categories. This can be attributed to the following reasons:

- The low density of primary, secondary, and tertiary HCFs in the region
- Low exposure to extreme climate events such as floods, droughts, and cyclones
- Low population density
- Robust health policies being developed and implemented in the region

Table 11 provides more details.

Figure 13 **Andhra Pradesh, Kerala, Uttarakhand, Himachal Pradesh, and Jammu and Kashmir emerge as states with the highest number of districts falling under very high-risk and high-risk categories due to extreme climate events.**



Source: Authors' analysis

Table 11 More than 60% of districts in Andhra Pradesh, Kerala, Uttarakhand, Himachal Pradesh, and Jammu and Kashmir fall under very high-risk and high-risk categories due to extreme climate events

State/union territory	Number of districts				
	Very high risk	High risk	Moderate risk	Low risk	Very low risk
Andaman and Nicobar Islands	–	–	–	–	3
Andhra Pradesh	13	–	–	–	1
Arunachal Pradesh	–	2	8	10	5
Assam	1	6	7	13	6
Bihar	–	6	14	12	6
Chandigarh	–	–	–	–	1
Chhattisgarh	4	11	7	5	1
Dadra and Nagar Haveli	–	–	1	–	–
Daman and Diu	–	–	–	–	2
Goa	–	2	–	–	–
Gujarat	2	11	13	7	–
Haryana	–	–	–	–	21
Himachal Pradesh	9	2	1	–	–
Jammu and Kashmir	15	3	1	1	–
Jharkhand	1	6	10	6	1
Karnataka	18	12	–	–	–
Kerala	11	2	–	1	–
Ladakh	1	1	–	–	–
Lakshadweep	–	–	–	–	1
Madhya Pradesh	–	12	15	20	5
Maharashtra	19	7	5	5	–
Manipur	–	3	6	2	5
Meghalaya	–	1	7	2	1
Mizoram	–	3	3	5	–
Nagaland	–	6	3	2	–
NCT of Delhi	–	–	–	2	9
Odisha	12	7	5	1	5
Puducherry	–	–	–	–	3
Punjab	–	–	–	1	21
Rajasthan	3	15	7	6	2
Sikkim	3	–	1	–	–
Tamil Nadu	17	6	7	3	5
Telangana	–	4	9	18	2
Tripura	–	–	2	4	2
Uttar Pradesh	1	1	6	29	38
Uttarakhand	10	1	–	–	2
West Bengal	1	8	8	5	1

Source: Authors' analysis

4. Recommendations

Image: Alamy

The GoI is actively working on enhancing the status of the healthcare infrastructure and delivery of healthcare services across the country. For instance, the NAPCCHH under the *National Programme on Climate Change and Human Health*, launched by the MoHFW, is a part of the broader NAPCC, launched in 2008 to deliver India's contribution to global climate action. The NAPCCHH focuses on strengthening the resilience of the health sector, improving surveillance and response mechanisms, and promoting research and capacity building to mitigate the health risks associated with climate change. The plan emphasises a multi-sectoral approach, integrating the efforts of various government ministries and departments to protect vulnerable populations and ensure sustainable development in the face of increasing climate change impacts. In the current context of escalating impacts of extreme events, there is significant scope for improving the resilience of health infrastructure and service delivery mechanisms. A crucial step in this direction is the climate risk assessment of the health sector, which adopts an interdisciplinary approach. This study sought to address this need at the national level. Based on our findings, we propose the following recommendations:

- **Mainstream sub-district level, interdisciplinary risk assessments of the health sector:** Considering the increasing intensity and frequency of extreme climate events in India, there is an urgent need to conduct detailed and sub-district level risk assessments of the health sector to understand its risk and its vulnerability to these hazards. As highlighted in this study, the factors contributing to climate risk in the health sector are diverse and encompass a wide range of governance areas. These include economic conditions, educational attainment, gender vulnerabilities, public health infrastructure, allocation of funds, land use patterns, and frequency of climate hazards. Since geographic and microclimatic conditions and governance mechanisms vary at the local level, conducting climate risk assessments at the sub-district or block level is pertinent. Additionally, natural factors influencing these indicators may also vary significantly at the local level. Therefore, it is essential to conduct local-level risk assessments that consider these interdisciplinary factors. Mandating such assessments within the government framework will be pivotal in building a climate-resilient health sector.

An open-access, interactive data dashboard designed for health institutions and healthcare facilities (HCFs) can enhance data-driven decision-making and resource allocation

Above all, to enhance the quality of climate risk assessments, it is essential to **establish an integrated data system** that combines primary and secondary data sources while addressing current gaps in data availability. A robust, centralised infrastructure should enable cross-sharing of relevant data across ministries and programmes, supported by a comprehensive monitoring and evaluation (M&E) framework. This system would track progress, ensure real-time data exchange, and improve decision-making for climate-resilient health strategies.

- **Establish data dashboards to facilitate assessments:** As health authorities formulate action plans on climate change and human health, we recommend developing an open-access, interactive data dashboard tailored for health institutions and HCFs. This dashboard should integrate data from relevant schemes, policies, and datasets, including those from the census, NFHS, and NSS, as well as information on extreme weather events and future climate projections. The dashboard would enable HCFs to assess their physical climate risks effectively and implement resilience measures accordingly. Additionally, the MoHFW should mainstream this physical climate risk assessment exercise for the health sector and recommend its implementation by each state through its SAPCCHH. This will ensure consistent application across the health sector and enhance climate resilience nationwide. These assessments can then further trickle down to the district level under the DAPCCHH to provide more granular information for informed policymaking.
- **Assess and build the capacities of health sector professional to conduct risk assessments:** To effectively conduct climate risk assessments in the health sector, it is essential to systematically evaluate and build the capacities of government institutions and the workforce. This capacity building should encompass various dimensions, including enhancing perception, knowledge, and assessment skills; incorporating enabling provisions in government policies and mandates; strengthening monitoring and evaluation capabilities; fostering innovative and participatory planning and implementation; promoting inter-agency collaboration; improving information dissemination; ensuring adequate financing mechanisms; and developing both technical and non-technical skills within human resources (Abraham et al. 2024). A study by CEEW developed and employed a CAF comprising a comprehensive set of indicators and sub-indicators to assess the institutional capacities of state departments across different sectors (Abraham et al. 2024). The assessment evaluated the departments' ability to advance climate goals, identify gaps, and prioritise opportunities and interventions for driving large-scale climate action. Similar frameworks could be developed and implemented by the MoHFW to identify the capacities and needs of the state health departments in understanding and addressing climate change and its impacts.

- **Ensure inter-ministerial and inter-departmental coordination to bring health sector at the forefront of climate action:** Since health systems and climate change are managed by two different ministries – the MoHFW and the MoEFCC – it is critical to ensure that assessments and policies are coordinated across departments. Collaboration between ministries such as Health, Environment, Rural Development, and Home Affairs will support unified monitoring of climate and health indicators and foster coherent policy responses and climate readiness. While formulating a national adaptation plan for India, special emphasis should be placed on enhancing climate resilience in the health sector through an effective coordination mechanism between the MoHFW and the MoEFCC.

  Inter-ministerial action could also boost the adaptive capacity of the health sector. For instance, key drivers of adaptive capacity, such as access to tap water connections and safe sanitation, fall outside the direct purview of the health sector. In this context, the health department can play a pivotal role in identifying such drivers and advocating for these measures. By engaging with task forces and governing bodies at the national, state, and local levels, the health department can influence policy decisions and drive budgetary allocations to improve the overall resilience of the health sector.

- **Promote climate risk–based financing for health systems in India:** Allocating healthcare resources based on granular climate risk assessments will ensure that regions that face high and very high risk due to climate-induced extreme events receive focused funding to strengthen their health systems. India can build more resilient health systems by taking appropriate steps and actions to implement climate adaptation strategies through national health policies, such as the NHM and NAPCCHH.

To enhance the adaptive capacity of India's health sector and address climate-related vulnerabilities, the following measures are recommended:

- **Integrate Climate Risk Assessments into Health Policies:** Embed climate risk findings into programme planning and implementation to prioritise initiatives that mitigate health impacts of climate change. For instance, focus on strengthening primary healthcare systems in regions with high climate vulnerability and fostering partnerships to improve infrastructure resilience.

- **Address Human Resource Gaps:** Develop targeted strategies to bridge the human resource gap in the health sector, particularly in climate-vulnerable regions. This could include incentives for healthcare workers to serve in underserved areas, enhanced training on climate-sensitive health issues, and leveraging telemedicine to extend healthcare access.

- **Reduce Out-of-Pocket Expenditures:** Strengthen financial protection mechanisms under existing schemes such as Ayushman Bharat Pradhan Mantri Jan Arogya Yojana (PMJAY). Expand the coverage of climate-sensitive health conditions and improve awareness about entitlements to reduce the financial burden on vulnerable populations.

These steps would ensure a more robust, equitable, and climate-resilient health system, better prepared to manage emerging risks.

Acronyms

AR5	Fifth Assessment Report
CAF	capacity assessment framework
CGWB	Central Ground Water Board
CPHR	Centre for Public Health Research
DAPCCHH	*district action plan on climate change and human health*
EM-DAT	Emergency Events Database
GIS	geographic information system
GoI	Government of India
HCFs	healthcare facilities
HSTP	Health Systems Transformation Platform
IDSP	*Integrated Disease Surveillance Programme*
IHIP	Integrated Health Information Platform
IMDAA	Indian Monsoon Data Assimilation and Analysis
IPCC	Intergovernmental Panel on Climate Change
IRAD	Integrated Research and Action for Development
JJM	*Jal Jeevan Mission*
LMIC	low- and middle-income country
MoEFCC	Ministry of Forest, Environment and Climate Change
MoHA	Ministry of Housing and Urban Affairs
MoHFW	Ministry of Health and Family Welfare
MoJS	Ministry of Jal Shakti
MoSPI	Ministry of Statistics and Programme Implementation
MSSRF	M. S. Swaminathan Research Foundation
NAPCC	*National Action Plan on Climate Change*
NAPCCHH	*National Action Plan on Climate Change and Human Health*
NCDC	National Centre for Disease Control
NCVBDC	National Centre for Vector Borne Diseases Control
NCMRWF	National Centre for Medium Range Weather Forecasting
NCT	National Capital Territory
NDMA	National Disaster Management Authority
NFHS	National Family Health Survey
NHM	*National Health Mission*
NRDC	Natural Resources Defense Council
NSS	National Sample Survey
NVBDCP	*National Vector Borne Disease Control Programme*
PICOST	population, intervention, control, outcomes, study design, and time frame

PM ABHIM	*Pradhan Mantri Ayushman Bharat Health Infrastructure Mission*
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-analyses
PSALSAR	protocol, search, appraisal, synthesis, analysis, and report
ROHFW	regional office for health and family welfare
SAPCCHH	state action plan on climate change and human health
SDMP	state disaster management plan
SLR	systematic literature review
SDGs	Sustainable Development Goals
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNICEF	United Nations Children's Fund
USGS	United States Geological Survey
WEF	World Economic Forum
WHO	World Health Organization

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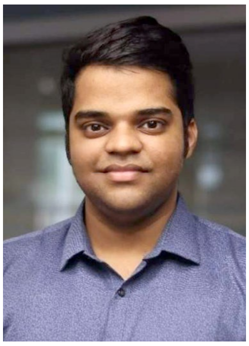
The authors

Shreya Wadhawan
shreya.wadhawan@ceew.in | @Shreya_Wadhawan

Shreya is a Programme Associate with the Climate Resilience team at CEEW. Her work focuses on spatio-temporal analysis, which helps design decision-making tools for effective policymaking on the intricacies of climate change risks, sustainability, and environmental resource management. Her research actively contributes to mainstream adaptation strategies across the Indian landscape and actions to mobilise finance for locally led adaptation.



Aryan Bajpai
aryan.bajpai@ceew.in

Aryan is a Research Analyst with the Climate Resilience team at CEEW. His work primarily focuses on analysing policies from a socioeconomic perspective, contributing to people-centric adaptation strategies. Prior to working at the Council, Aryan interned with several organisations, including CPR, ORF, Jan Sahas, and Tata Trusts, where he explored the intersection between climate change and topics such as land rights, health, migration and displacement, urban development, education, and livelihoods.

Vanya Pandey
vanya.pandey@ceew.in

Vanya is a Research Analyst with the Climate Resilience team at CEEW. Her research focuses on assessing the risks associated with extreme climate events and building tools to evaluate adaptation capabilities and increase resilience. She brings together science, policy, and practice to mainstream climate action.

Dr Vishwas Chitale
Vishwas.chitale@ceew.in | @Vishchi

Vishwas leads the Climate Resilience team at CEEW, where his work focuses on assessing risks and building resilience. He has over 15 years of experience developing and implementing digital solutions for climate change risk reduction and resilience building in various South Asian countries. Previously, he worked on AI for climate change and assessed the vulnerability of forest ecosystems. He holds a PhD in 'Assessing Climate Change Impacts on Biodiversity Hotspots in India' from the Indian Institute of Technology Kharagpur. He has published over 35 peer-reviewed articles, over 10 blogs, and several book chapters.

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United Nations Children's Fund (UNICEF)
UNICEF House, 73 Lodi Estate
New Delhi – 110 003, India,
+ 91 11 2469-0401, + 91 11 2469-1410

Council on Energy, Environment and Water (CEEW)
ISID Campus, 4 Vasant Kunj Institutional Area
New Delhi – 110070, India
+91 11 4073 3300
info@ceew.in | ceew.in | @CEEWIndia | ceewindia

COUNCIL ON ENERGY, ENVIRONMENT AND WATER (CEEW)

ISID Campus, 4 Vasant Kunj Institutional Area
New Delhi - 110070, India
T: +91 11 4073 3300

info@ceew.in | ceew.in | @CEEWIndia | ceewIndia

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