Emerging research priorities for climate change and health in India

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Climate change presents significant health challenges in India, a country with a diverse geography and population. This paper explores the existing and evolving research priorities, effects, and policy implications of climate change on human health in India. The study finds that India's susceptibility to climate change is heightened by several factors, such as a large population, diverse regions, and expanding urban heat islands, among others. The National Action Plan on Climate Change (NAPCC) and the National Mission on Strategic Knowledge for Climate Change (NMSKCC) are key Government initiatives aimed at increasing resilience and reducing the impact of extreme weather events.

The study identifies several key research priorities of the Government, such as climate modeling, understanding extreme events, urban climate dynamics, aerosol impacts, and Himalayan ecosystem preservation. The study also delves into the adverse health effects of climate change in India, which include heat stress, pollution-related illnesses, vector-borne diseases, and food insecurity. The paper also highlights obstacles to climate change and health research in India, such as low priority, lack of trained personnel, and inconsistent funding.

Four key emerging priorities are outlined for enhancing climate resilience in India's healthcare sector, including developing comprehensive climate impact archives, improving environmental surveillance, encouraging interdisciplinary research, and expanding partnerships for coordinated strategies.

Policy implications of this priority re-alignment include increasing research funding, conducting vulnerability assessments, investing in operational research for climate-resilient health systems, and establishing inter-ministerial monitoring mechanisms to effectively implement climate change policies. By prioritizing research, enhancing resilience, and implementing evidence-based policies, India can mitigate the adverse health impacts of climate change and build a sustainable future.

Keywords: climate change, climate resilience, environmental health, health research, health research priorities

Introduction

Climate change has been linked to various adverse health outcomes, and India, with its diverse geography and population, is particularly vulnerable.

On a global level, WHO reports that approximately 3.6 billion people are already at risk of climate change due to their location. Meanwhile, the damages caused to health and linked sectors till 2030 are approximately USD 2-4 billion per annum.1 In India, the scale is a more significant challenge given the tremendous population, diversity of regions, and growing urban heat islands. To map the extent of the impact, it is vital to understand the themes India chose as research priorities.

The Department of Science and Technology (DST), Government of India launched the National Action Plan on Climate Change (NAPCC) in 20082 to enable India to become more climate-resilient and to develop the capacity to mitigate the impact of extreme events.

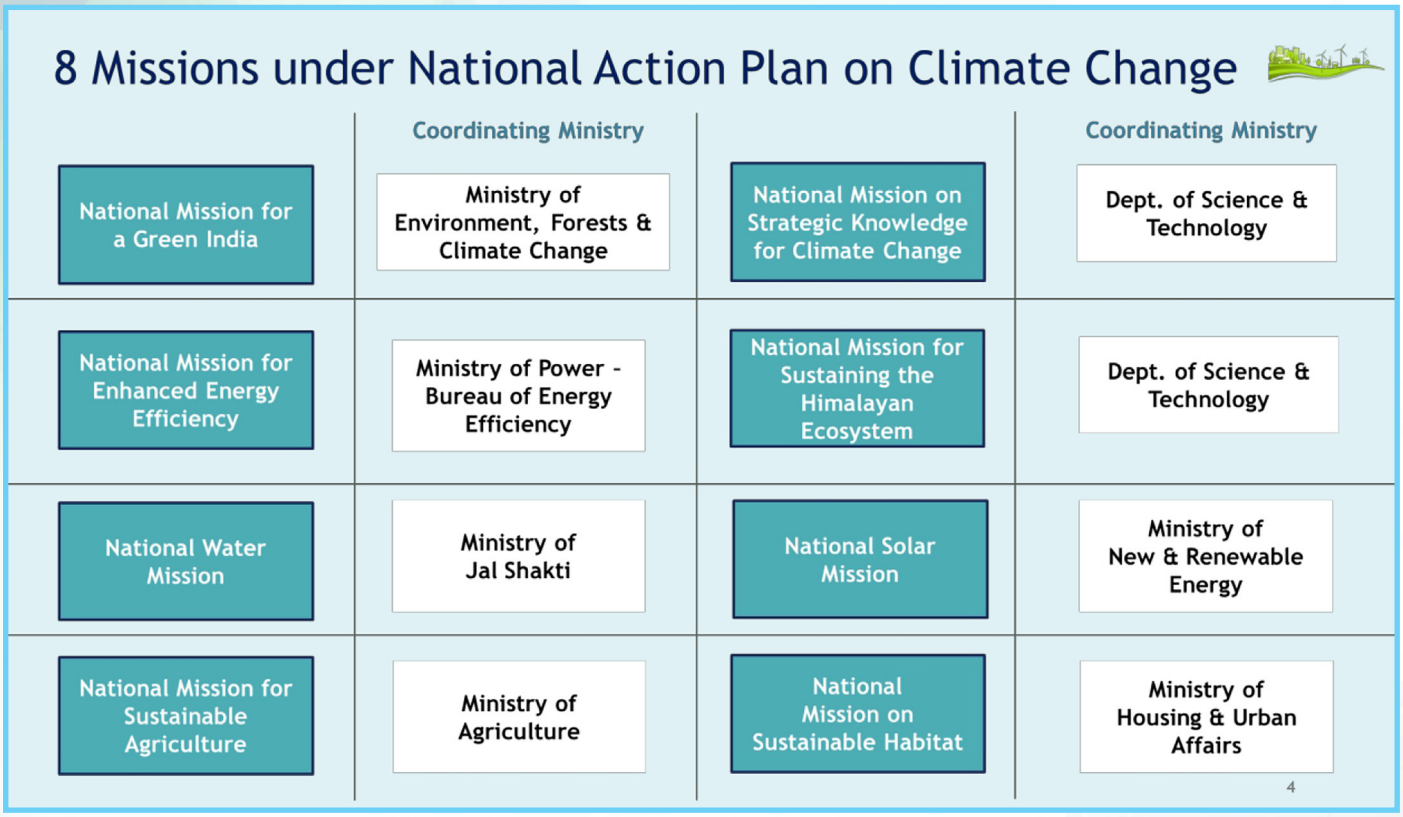


Figure 1: Details of the 8 Missions under the NAPCC and their Coordinating Ministries

Under the National Mission on Strategic Knowledge for Climate Change (NMSKCC), one of the eight national missions under the NAPCC, DST acknowledges that India, with its inherent diversity and geographical spread, cannot adopt and develop climate adaptation strategies based on the global averages of climate change.3 This means India has to indigenously build climate modelling studies and technological systems to mitigate adverse effects based on local and regional research.

i. *Climate modelling*

Climate modelling is crucial for India's development of mitigation strategies. While the Intergovernmental Panel on Climate Change (IPCC) reports that the simulations generated by Global Climate Models (GCMs) predict how anthropogenic warming affects different aspects of the Earth's system, it is unable to accurately simulate India's monsoon climate due to its inability to comprehend monsoon dynamics.4

The DST has identified long-term goals for climate resilience that involve building up technological capacities and infrastructure to simulate warming effects, learning from paleoclimatic studies, and enhancing mitigation strategies on all levels: national, state, and district. The short-term roadmap put in place by DST includes setting up bodies of academic institutions and researchers incorporating newer technologies to assess district-level vulnerabilities.

ii. *Extreme events*

The Climate Risk Index 2020 indicates that India was ranked the fifth most affected country in the world in 2018, with the highest death toll and economic losses among the ten most affected

countries.[5] Extreme events arise from a limited

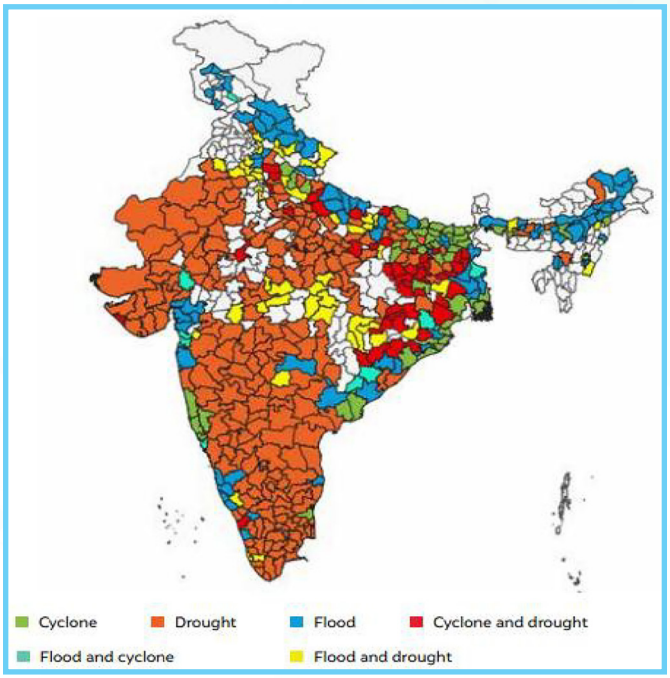


Figure 2: CEEW analyzed that >75% of Indian districts are extreme climate event hotspots

understanding of the physical and ecological properties of the Indian Ocean region, leading to an increase in events such as droughts, forest fires, and marine heatwaves. According to India's Climate Research Agenda: 2030 and Beyond[6], the Indian Ocean's basic-wide warming has experienced an average rise of 0.15^{O}C every decade since 1951. India's regional diversity experiences extreme events in distinct ways. Some of the events observed are coastal erosions and flooding, destruction of mangroves, impediments to food security, availability of clean drinking water, and disease control in the scenario of extreme sea level rise. Moreover, according to India's Climate Research Agenda, extreme events between 2006 and 2011 contributed to agricultural losses of approximately USD 3.75 billion.[6]

iii. *Urban climate*

India has the world's second-largest urban population. An increase in temperatures is impacting the urban environment, and cities are becoming 'urban heat islands' (UHI). The UHI effect, combined with the increasing sea levels, is resulting in warmer regions attracting cyclonic events. Metropolitan cities are at increased risk due to their lack of vegetation and green cover, putting the large population at risk of the impacts of extreme heat stress. Heat waves are becoming more frequent, exacerbating water and electricity challenges, poverty, and sanitation in urban India.

iv. Aerosols

According to the IPCC, aerosols are the second highest radiators behind greenhouse gas emissions.7 In India, aerosols interact with different environments, such as radiation, precipitation, and climate, distinctly compared to the global norm. Natural dust and aerosols interact differently in diverse climates, while biomass burning also contributes to the dynamic. However, a lack of research on this subject has led to a superficial understanding of the impact of aerosols on monsoons and tropical cyclones, as stated by India's Climate Research Agenda. Technological capacities are to be strengthened by using satellites and instrumentation, which shall contribute to a deeper understanding of the adverse effects of aerosols.

v. Himalayan ecosystem

The Himalayan ecosystem interacts with the aforementioned themes, and their impact must be mitigated to conserve the ecosystem. Extreme events caused by oceanic disturbances result in extreme flooding and rain in the Himalayan region. In contrast, disturbances in the cryosphere have shrunk glacial areas in the region at an annual rate of approximately 0.36% during 1960-2010.8 Nearly 51 million people practice agriculture in the region. They are at various risks of climate change, and the DST, through the NMSHE initiative, has the objective of increasing knowledge networks and improving regional sustainability to create mitigation strategies specific to the Himalayan region.

❑ Effects of climate change on human health in India

India has a population of 1.4 billion across diverse regions and environments, facing various challenges, especially regarding health. With the growing ill effects of climate change, vulnerable groups find it more challenging to adapt without proper support to mitigate the effects of climate change. Several factors should be considered, given that deaths are rising due to extreme weather events over the last five decades (India's Climate Research Agenda). This section briefly summarizes the pertinent interplay of climate change and human health, especially within the Indian context.

❑ Heat stress and pollution

There has been an average global temperature increase of 1.5-2□, contributing to higher mortality risks across India. According to official figures, more than 23900 people have died from heat stroke between 1990 and 2020 in India9, with 2300 deaths in 2015 alone.10 India is also at high risk of air pollution, mainly due to the increase in the burning of fossil fuels. Research shows increased ozone levels due to pollution and high temperatures increase cardiorespiratory mortality and morbidity risk. Heat stress also causes an increase in day-to-day challenges such as nausea, headaches, and malaise.11

❑ Vector-borne diseases

Sporadic climate conditions are linked to the rise in vector-borne diseases, primarily malaria and dengue. Excessive rainfall and humidity ensure sufficient breeding grounds for mosquitoes, and India has a long history of mortality risks associated with these diseases. Research shows that a 2–3°C increase in global temperatures would increase the risk of malaria by 3-5%.12 The temperature rise also poses a risk of higher transmission of dengue and other endemic diseases like chikungunya, filariasis, Japanese encephalitis, and visceral leishmaniasis. There is cause for concern that due to the impact of climate change, certain new areas like north-eastern states and Himachal Pradesh may witness new transmission windows, while re-emergence of chikungunya is a possibility for southern India.13

❑ Food security and nutrition

Increases in temperatures and erratic rainfall patterns impact agricultural yields. In India, there has been a growing concern among farmers about their crops being at higher risk of climate change. The impact on crops means an increase in food insecurity for a significant population. Malnutrition has been an ongoing struggle for the Indian population and is linked to reduced nutrition and food variety. Extreme weather also impacts maternal health, causing suboptimal breastfeeding and, hence, exposing the infant to more significant risks of malnutrition and low immunity.14

❑ Underlying barriers to research on climate change and human health in India

Barriers to climate change and health research in India present significant factors that impede progress in understanding and mitigating the impacts of climate change on public health. Among these factors, three key themes stand out: the low priority assigned to environmental health research, the lack of trained personnel, and inconsistent funding.

Despite the increasing recognition of climate change as a pressing global issue, environmental health research often receives lower priority in India compared to other areas, such as infectious diseases or maternal and child health.15 This may be due to a lack of awareness among policymakers and the public about the interconnectedness of climate change and health and competing priorities for limited research resources. As a result, insufficient

investment in studying the complex interactions between environmental factors, climate change, and human health hinders efforts to develop effective interventions and policies. The 1984 Union Carbide methyl isocyanate gas leak tragedy in Bhopal, considered one of the most severe global industrial disasters, was an inflection point in India's history of environmental health research and legislation. The Government of India took cognizance of the public health effects of methyl isocyanate. It established the National Institute for Research in Environmental Health in Bhopal under the ambit of the Indian Council of Medical Research.16

Another significant barrier is the shortage of trained personnel with expertise in environmental science and public health.15 Climate change and its impacts on health are interdisciplinary issues requiring diverse skills, including expertise in climatology, epidemiology, environmental science, and public health. However, there is a shortage of professionals in India who possess this interdisciplinary knowledge and can conduct high-quality research in this field. This shortage limits the capacity for conducting research and hampers the ability to translate research findings into actionable policies and interventions.

Inconsistent funding poses a significant challenge to India's climate change and health research. Research projects in this field often require long-term funding commitments to collect data, conduct analyses, and assess the effectiveness of interventions over time. However, funding for such projects tends to be sporadic and subject to shifting priorities, making it difficult for researchers to plan and execute comprehensive studies. Moreover, reliance on short-term funding cycles can discourage researchers from pursuing ambitious or innovative projects that may take years to yield results, further stifling progress in this critical area.

❑ Evolution of research priorities for climate change and health

Over the past decade, research priorities for climate change and human health have evolved significantly. The field has expanded to include a broader understanding of the complex interrelationships between environmental change, human health, and socioeconomic transitions.

Initially, research focused on the direct impacts of climate change on human health, such as extreme weather events, changes in temperature, and the spread of infectious diseases. This approach recognized climate change's immediate and tangible effects on human well-being.

Researchers have recently broadened their scope to include the interplay between socioeconomic transitions and environmental change. This transdisciplinary approach acknowledges the complex interactions between human activities, ecosystems, and health.

Research now emphasizes the direct health impacts of climate change and the indirect effects mediated through social, economic, and environmental pathways. Studies have shifted towards recognizing the broader impact of climate change on human health, including indirect effects mediated through social, economic, and environmental pathways. This evolution in research priorities reflects a more comprehensive understanding of the complex interrelationships between climate change and human health, highlighting the need to consider the immediate health impacts and the underlying social, economic, and environmental factors that can influence health outcomes.17 18

This broader perspective has also led to increased attention on vulnerable populations, such as low-income communities and indigenous groups, who are disproportionately affected by both climate change and health disparities.

The research priorities for climate change and human health have also evolved to include a broader understanding of the complex interrelationships between environmental change, human health, and socioeconomic transitions. This evolution has led to a transdisciplinary approach that spans multiple scales and disciplines and recognizes the need for evidence-based policies and programs to address the health risks associated with climate change.

This paper has identified four major forward-thinking priorities for India to promote a holistic view of the intersectionality between climate change and human health and build a future-proof, climate-resilient healthcare ecosystem.

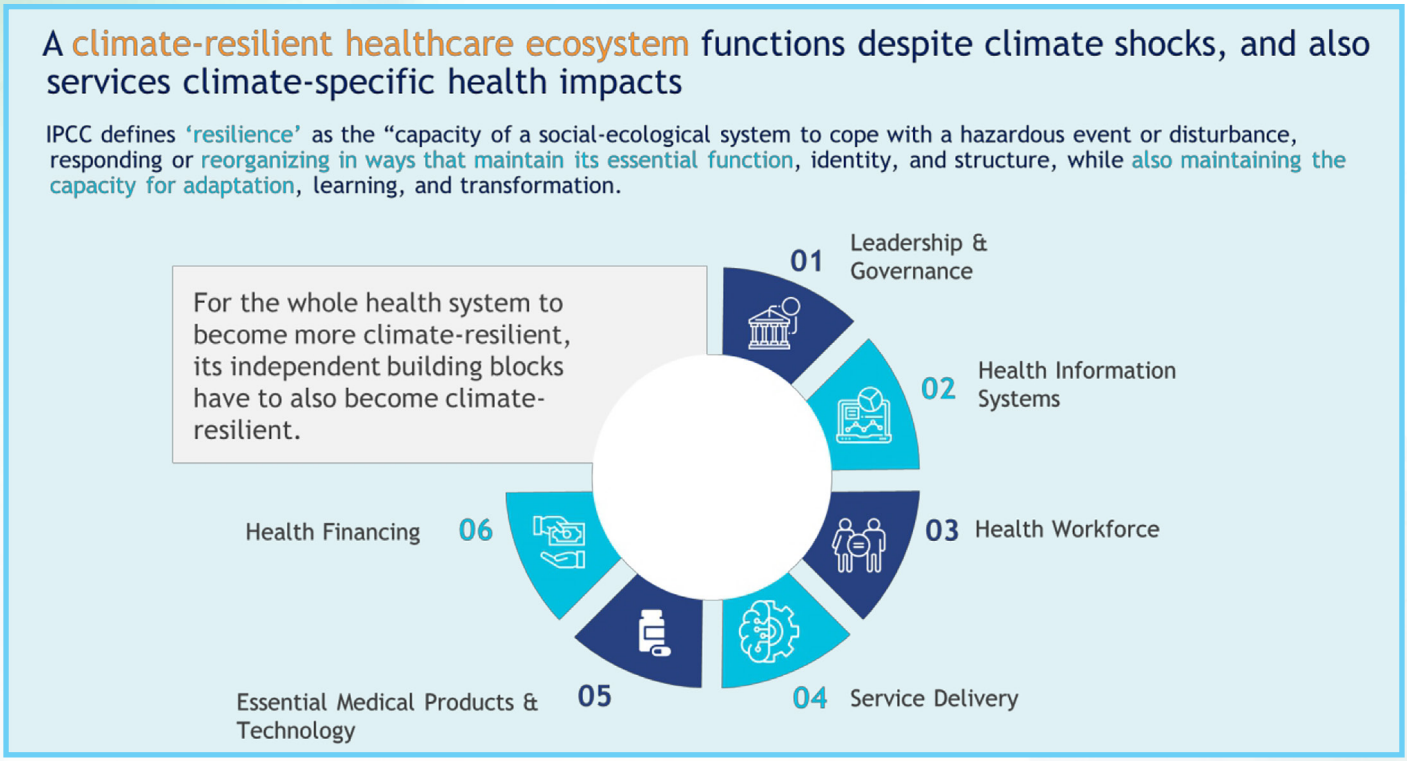


Figure 3: Building blocks of a climate-resilient healthcare ecosystem

i. Developing a Comprehensive Archive of Climate Change and Health Outcomes

Developing a comprehensive archive of climate change and associated health outcomes across the range of climatic and socioeconomic differences in India is crucial for understanding the diverse impacts of environmental changes on public health. Such an initiative can capture the varying health vulnerabilities and risks faced by different regions and populations in India due to climate change. By compiling a detailed archive that considers the broad spectrum of climatic conditions and socioeconomic factors present in the country, policymakers and healthcare professionals can tailor interventions and policies to address specific health challenges effectively. This comprehensive approach will enable a more nuanced understanding of how climate change influences public health outcomes in India, paving the way for targeted strategies to mitigate risks and enhance resilience.

The United States Environmental Protection Agency (USEPA) maintains a similar database19, with dedicated sections on health impacts on various sectors such as health, agriculture and food supply, air quality, ecosystems, and energy, among others.

Research efforts focusing on developing this archive are essential for informing evidence-based decision-making and resource allocation to address climate-related health challenges in

India. This archive will not only facilitate the identification of vulnerable populations but also guide the implementation of preventive measures and adaptive strategies to safeguard public health. Furthermore, by considering the complex interplay between climatic variations, socioeconomic disparities, and health outcomes, this comprehensive archive can serve as a valuable tool for promoting equity in healthcare access and improving overall resilience to the health impacts of climate change in India.

ii. Improving Environmental Monitoring and Surveillance Systems

Improving environmental monitoring and surveillance systems to gain a deeper understanding of the current climate-health associations in India is crucial for enhancing public health preparedness and response strategies in the face of climate change impacts. By strengthening these systems, policymakers and healthcare professionals can gain valuable insights into the intricate relationships between environmental factors and health outcomes, allowing for more targeted interventions and mitigation measures. Enhanced monitoring and surveillance capabilities enable the timely detection of emerging health risks associated with climate change, such as the spread of infectious diseases or the effects of extreme weather events, facilitating proactive measures to protect public health.

Furthermore, by investing in advanced environmental monitoring technologies and surveillance systems, India can effectively track and analyze the current climate-health associations across different regions and populations. This comprehensive approach provides valuable data on the immediate impacts of climate change on public health and helps identify vulnerable communities and develop tailored interventions to address their specific needs. Improved surveillance systems can also contribute to early warning systems for climate-related health risks, enabling prompt responses and adaptive strategies to mitigate the adverse effects of environmental changes on human health in India.

iii. Encouraging Interdisciplinary Investigations

Encouraging research on interdisciplinary and multidisciplinary investigations using environmental epidemiologic methods to elucidate health risks posed by climate change is essential for developing a comprehensive understanding of the complex interactions between environmental factors and public health outcomes. By promoting collaboration across disciplines, such as environmental science, epidemiology, and public health, researchers can uncover the intricate pathways through which climate change impacts human health. This approach allows for a more holistic assessment of the health risks associated with climate change, considering direct impacts and indirect effects mediated through social, economic, and environmental pathways.

iv. Expanding Partnerships for Coordinated Strategies

Expanding partnerships among researchers, governments, and communities in India is crucial to developing a coordinated strategy that effectively addresses public health challenges and risks associated with climate change. Despite limited engagement and research on the varied health impacts of climate change in India, collaboration between stakeholders can bridge this gap and foster a more comprehensive understanding of the nexus between climate change and public health. By forming strategic partnerships, researchers can leverage expertise from various fields to conduct interdisciplinary studies that elucidate the specific health risks posed by climate change in different regions of India.

Moreover, involving governments and

communities in these partnerships is essential for translating research findings into actionable policies and interventions that mitigate the adverse effects of climate change on public health. India can effectively develop tailored strategies to address climate-related health challenges by fostering collaboration between policymakers, researchers, and local communities. This coordinated approach not only enhances the resilience of communities to climate change impacts but also promotes sustainable public health practices that prioritize the well-being of all individuals, especially those most vulnerable to the health risks associated with environmental changes.

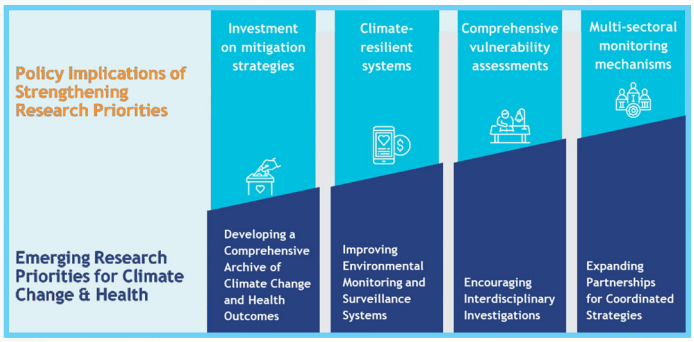


Figure 4: Inter-dependence of research priorities and policy actions

❑ Policy Implications of Strengthening Research Priorities

As part of the National Action Plan for Climate Change (NAPCC) formulated by the Government of India in 2008, the National Mission on Strategic Knowledge for Climate Change (NMSKCC) highlights systematic knowledge gaps in crucial underlying scientific areas of climate change. Further, it underscores that critical scientific gaps persist alongside inadequate data on climate change impacts across agriculture, ecosystems, and health sectors. Fragmented knowledge networks, limited connectivity, and a lack of institutional mechanisms hinder effective decision-making. There's also a need for a global technology watch system linking technology choices with climate responses. Furthermore, a system for scenario-based impact assessment and risk-minimized technology selection is absent, impeding developmental goals.3

As the global climate crisis escalates, its profound implications on human health are increasingly evident. In the Indian context, strengthening and streamlining the existing research and policy efforts dealing with climate change and public health has become imperative. The policy implications of bolstering the identified research priorities highlight the potential pathways to build a comprehensive knowledge base tailored to India's geographical and social diversity.

i. Increasing funding for research on the mitigation of health impacts of climate change

While there is enough documented evidence on the interplay between climate change and health, the research landscape for climate-risk mitigation strategies for health systems is relatively scant.20 Increasing funding for research on strategies to mitigate the effects of climate change on the Indian health system can enable researchers to collect longitudinal data related to climate variability and health outcomes in specific locations and use decision-analysis frameworks to weigh the costs and benefits of interventions. Further, the National Center for Disease Control can spearhead cutting-edge research on climate-sensitive outcomes that have been less studied and that incorporate economic research to understand the health-related costs of climate change. It is an opportune juncture to formalize India's G20 commitments on climate action through a policy-level consensus between the Government and leading global funding organizations and research-based agencies.

ii. Pan-India Vulnerability Assessment of Health Systems to Climate Change

A pan-India vulnerability assessment of health systems to climate change is crucial for informing the National Programme for Climate Change and Human Health (NPCCHH), being administered by the National Centre for Disease Control

(NCDC). Such an assessment would enable a deeper understanding of the impacts of climate change on health systems across India. The vulnerability assessment in the Indian Himalayan Region commissioned by the Dept. of Science & Technology, for example, highlights ecosystems' fragility and the millions' dependence on these regions for water, food, and energy. A study by Berry et al. provides valuable insights into the dynamic risks climate change poses on health systems. It emphasizes the importance of evidence-based information in supporting public health officials in addressing these challenges.21

iii. Investing in operational research on building climate-resilience

Climate change has notably impacted various aspects such as the environment, ecology, economy, agricultural production, and global food security, including human nutrition.22 Therefore, operational research on building climate resilience is crucial for addressing the impacts of climate change on health and nutrition systems in India. The World Health Organization has been pushing for creating resilient health systems that can effectively respond to the challenges posed by climate change.23 The Union Ministry of Health & Family Welfare operates the National Programme for Climate Change & Human Health (NPCCHH) under the NHM umbrella. Under this Programme, an Energy Assessment of healthcare facilities has already been initiated, covering 18 States/UTs representing all five climate zones of India, covering nine building typologies and 1600 healthcare facilities. Additionally, a Health Facility Energy Ranking is being developed to calculate the Energy Performance Indicator of health facilities.

Systems thinking can provide a holistic view of the interconnectedness of various factors contributing to public health outcomes and their interplay with India's food and nutrition ecosystem.

These factors are particularly relevant to India's Public Distribution System (PDS), which is crucial in ensuring populations' access to food and nutritional support amidst changing environmental conditions. Field trials in wheat, maize, rice, and soybeans have now established that rising environmental carbon-monoxide levels, largely due to fossil fuels burning, have significantly reduced the levels of the essential nutrients iron and zinc and cutting protein levels.24 Diversifying the household nutrition basket through the PDS and scaling up climate-resilient crop varieties can help the PDS become more climate-resilient and future-proof.25

iv. Establishing an inter-ministerial monitoring mechanism for guiding the implementation of NAPCC

To enable streamlining and institutionalization of efforts for effective implementation of the National Action Plan for Climate Change, in line with the Mission LiFE (Lifestyle for Environment) envisioned by the Prime Minister's Office (PMO), it is proposed that as a first step, a dedicated Climate Change Governance Cell may be established within the PMO or the NITI Aayog. This Cell would be suitably positioned to streamline the efforts of the 8 Ministries involved in implementing the National Missions under the National Action Plan on Climate Change. This approach is also echoed by the Mission Document of the National Mission on Strategic Knowledge for Climate Change (NMSKCC), which recommends the establishment of Oversight Committees and inter-ministerial approval mechanisms. This approach can help guide the implementation of the NAPCC and ensure that the various missions are aligned for cohesive action.

Discussion

Geography has emerged as an interdisciplinary player connecting the realms of health and public policy with data that is crucial to informing

effective decisions. Therefore, India's geographic diversity can be turned into an advantage for building systemic climate resilience across diverse sectors, much like the demographic dividend of the country's 1.4 billion-plus population. Localized action on targeted challenges, backed by digital technologies, has been documented to develop stakeholder mobilization and garner sustainable community support.26 Further, domains such as household nutritional diversity also have the potential to benefit from a systems approach to building resilience.

Addressing the emerging research priorities for climate change and health in India is crucial to mitigate and adapt to the health impacts of climate change. The need for increased funding for research on the mitigation of health impacts of climate change is paramount. This funding will support research on strategies to reduce the health risks associated with climate change and promote interdisciplinary research toward creating a centralized knowledge repository.

Conducting multi-sectoral vulnerability assessments to climate change across geographies, is essential for understanding the impacts of climate change on government service delivery systems in diverse regions of India. This assessment will help identify the most vulnerable pockets and populations, enabling the development of targeted interventions. By investing in operational research on building climate-resilient health systems, India can develop strategies to enhance its adaptability to changing climatic conditions.

Establishing an inter-ministerial monitoring mechanism for guiding the implementation of the National Action Plan on Climate Change (NAPCC) in India is crucial for ensuring effective and coordinated action across various sectors. This mechanism will help track progress, identify challenges, and ensure the plan's successful implementation, balancing climate objectives with domestic priorities of growth, development, and poverty reduction.

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