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Linking Climate Change and Society: Environmental Transitions and Human Responses in India

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Abstract: India faces escalating climate challenges characterized by rising temperatures, erratic monsoons, and increasing frequency of extreme weather events. As the world's most populous nation and third largest greenhouse gas emitter, India's climate trajectory holds global significance. The country's unique position as a developing economy with substantial climate vulnerabilities creates complex trade-offs between economic growth aspirations and environmental sustainability. With approximately 58% of the population dependent on agriculture and allied sectors for livelihoods, climate-induced disruptions cascade through multiple socioeconomic dimensions. This review integrated recent peer-reviewed articles to examine the complex relationship between environmental transitions and societal responses in India. The analysis reveals that urbanization has contributed 60% additional warming in Indian cities, with agricultural systems experiencing yield reductions of 3-22% for major crops like rice. Coastal cities face substantial inundation risks, with Mumbai experiencing 4.44 cm sea level rise between 1987 and 2021 and projections indicating 76.2 cm rise by 2100 under medium emission scenarios. Vulnerable populations including small holder farmers and coastal communities bear disproportionate impacts despite minimal contribution to emissions. The intersection of rapid urbanization, demographic pressures, and climate variability creates compounding risks that threaten food security, water availability, and public health across the subcontinent. While India has made progress in renewable energy deployment and policy development, significant challenges remain in climate finance, institutional capacity, and equitable adaptation. The review identifies critical research gaps and recommends integrated approaches combining mitigation, adaptation, and social justice principles to build climate-resilient pathways for India's sustainable development.

1. Introduction

Climate change presents multifaceted challenges for India, intertwining with rapid urbanization, agricultural dependence, and socioeconomic inequalities (Rana and Saini, 2025c). India is home to approximately 18% of the global population while housing more than half of the world's large cities in low elevation coastal zones. In 2019, India ranked seventh among countries most affected by extreme weather events, with 2,267 lives lost and economic damages of 66,182 million USD in purchasing power parities (Hussain *et al.*, 2024). The frequency and intensity of extreme weather events have increased markedly, affecting vulnerable communities across the subcontinent. Recent evidence demonstrates that climate impacts are intensifying across multiple dimensions. The World Meteorological Organization's State of Climate in Asia 2024 report revealed that Asia's warming trend nearly doubled from 1991 to 2024, with temperature rises representing one of the warmest periods on record. India experienced over 450 premature deaths due to intense heat waves in 2024 alone, with heat wave days increasing by three per year over the past 30 years (Ravindra *et al*., 2025). These trends underscore the urgency of understanding climate-society interactions to inform effective response strategies. A bibliometric analysis helps assess scientific productivity, identify leading authors and countries, and explore collaboration networks across institutions. Over the last four decades, more than 10,200 Scopus-indexed documents have been published on environment, climate change, and society, reflecting growing global interest in these interconnected themes. India contributed 494 publications during this period, demonstrating significant engagement with climate and environmental research. Despite this contribution, India ranks 8th globally, trailing behind the United States, United Kingdom, China, Australia, Canada, Germany, and France in terms of publication output. This ranking highlights both India's active participation in the field and the dominance of developed nations in shaping the global research agenda on environmental issues (Lrhoul *et al*., 2023; Hammouti *et al*., 2025; Rana and Saini, 2025c).

This review examines how environmental transitions driven by climate change interact with human responses in India. The analysis uses recent peer-reviewed research, focusing on climate trends, sectoral impacts, vulnerability patterns, adaptation strategies, and policy frameworks. By analyzing current evidence, this review aims to identify knowledge gaps and provide actionable insights for policymakers, researchers, and practitioners working toward climate resilient development in India.

2. Climate Change Trends and Urban Warming

2.1 Urbanization and temperature increase

Urbanization has emerged as a critical driver of localized warming across Indian cities. A groundbreaking study by Sethi and Vinoj analyzed night time land surface temperatures to quantify the urban contribution to warming. The spatial distribution of this urban warming effect is illustrated in **Figure 1**, which shows how urbanization compounds global climate change to create 60% enhanced warming in Indian cities over recent decades, with eastern Tier-II cities experiencing the most pronounced effects. This finding demonstrates that cities face compounding effects from both global climate change and local urban heat island effects. The spatial heterogeneity of urban warming patterns necessitates differentiated approaches to combat urban heat effectively. Tier-II cities in eastern India show particularly high vulnerability due to rapid, often unplanned urbanization combined with limited infrastructure for heat mitigation. The study emphasizes that despite accounting for only approximately 1% of land area, cities house more than half of the world's inhabitants, with projections indicating the urban population share will reach 68% by 2050 (Sethi and Vinoj, 2024). This demographic concentration amplifies the urgency of addressing urban climate adaptation.

2.2 Temperature and extreme weather events

Temperature increases across India have manifested in multiple forms of extreme weather. Charak and co-worker conducted a comprehensive review of climate change exacerbated natural hazards in India, documenting substantial increases in heat waves, droughts, floods, and cyclones. The Indo-

Gangetic Plain, which serves as the center of wheat growing regions globally, faces particular vulnerability due to variations in temperature, precipitation, and reduced water availability for irrigation (Charak *et al*., 2024). Studies analyzing direct and indirect effects of climate change on wheat production in Punjab, Haryana, Uttar Pradesh, and Bihar found reductions in wheat production ranging from 1% to 8% depending on the location analyzed. The changing monsoon patterns present critical concerns for agricultural systems. In 2024, India's monsoon was the heaviest since 2020, yet rather than providing relief, excess rainfall damaged summer crops, contributing to food inflation and economic strain. Between 2016 and 2020, India's average food inflation stood at 2.9%, while in the 2020s it has more than doubled to 6.3%, driven predominantly by erratic weather and extreme climatic events (Policy Circle, 2025). The Reserve Bank of India identified climate change as a major factor behind endemic food price inflation, describing how extreme events increasingly disrupt supply chains. **Figure 1** presents an integrated framework synthesizing the major climate change impacts across India's most vulnerable sectors. The framework demonstrates how climate drivers manifest through urban warming, agricultural disruptions, and coastal inundation, ultimately affecting populations inequitably based on socioeconomic positioning and geographic location.

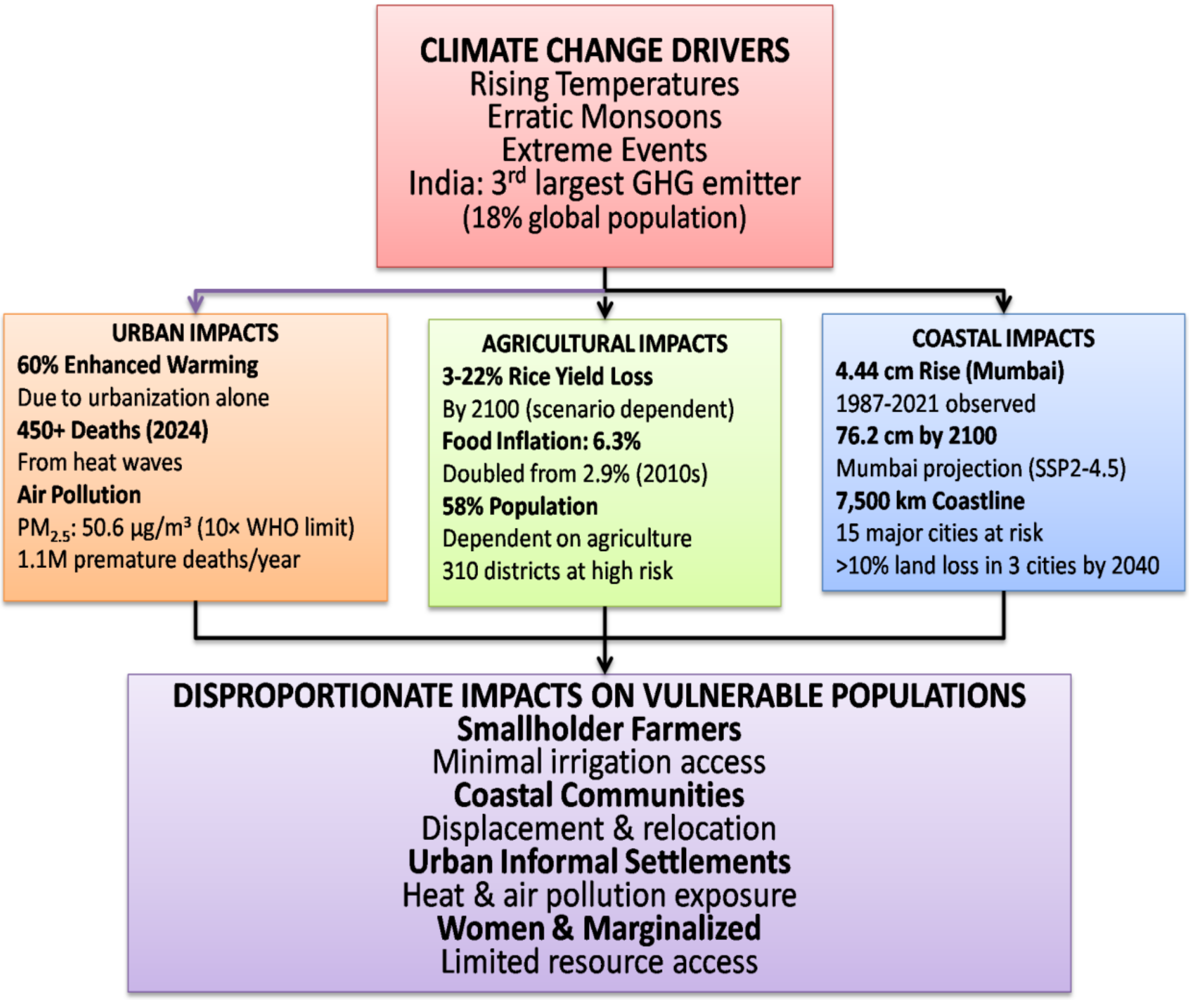

Figure 1. Climate change impacts and sectoral vulnerabilities in India

As illustrated in **Figure 1**, the sectoral impacts converge to create compounding vulnerabilities for specific population groups. The 60% urban warming enhancement (Sethi and Vinoj, 2024) simultaneously affects the same communities experiencing air pollution levels ten times above WHO guidelines, while agricultural yield reductions threaten the livelihoods of the 58% of India's population dependent on farming (GARP, 2025). This multi-sectoral vulnerability framework underscores the need for integrated policy responses rather than siloed interventions.

3. Agricultural Impacts and Food Security

3.1 Crop yield reductions

Agriculture constitutes the primary source of livelihood for approximately 58% of India's population, with agriculture and allied sectors contributing about 18% of gross value added (GARP, 2025). Climate change threatens this critical sector through multiple pathways. Gallé and Katzenberger analyzed the competing effects of temperature and rainfall anomalies on Indian agriculture using data from 1966-2014. Their research revealed opposing effects, increased seasonal rainfall and wet days during the monsoon season (June-September) positively affected rice yields, while strong negative impacts of October-November temperatures occurred shortly before harvest. Projecting forward using eight state-of-the-art climate models under two emission scenarios (2021-2100), they found that rice yield losses by the end of the 21st century range between 3-22% depending on the underlying emission scenario. Under the worst-case global warming scenario (SSP5-8.5), rice yield decreases on average by 22% relative to 1994-2014 in the long-term (2081-2100). For the sustainable Shared Socioeconomic Pathways1-2.6 (SSP1-2.6) scenario, predicted losses remain at 3.4% in the long-term, demonstrating the critical importance of emission reduction pathways (Gallé and Katzenberger, 2025).

Choudhary and Gupta examined climate change impacts on major crop production using panel data from 1970-2020. Their analysis confirmed that climatic changes significantly affect production of major crops grown in India (Choudhary and Gupta, 2024). As visualized in the mid-century and end-century projections in **Figure 2**, these yield reductions will intensify substantially without adaptation measures, rain-fed rice yields will decline 20% by 2050, wheat yields by 19%, and maize by 18% (GARP, 2025). A temperature increase of 1°C results in a 3% reduction in wheat yield, even before considering potential increases in physical inputs and short-term adaptation strategies farmers might employ (Baraj *et al*., 2024).

3.2 Regional and crop-specific vulnerabilities

Vulnerability varies substantially across regions and crops. Of India's 787 districts, 109 have very high climate risk and 201 have high climate change risk, with major causes including low irrigation access, high numbers of droughts, cyclones or floods, increases in minimum temperature, small farm sizes, and high-value assets located in hazard zones (GARP, 2025). Arid zones in Rajasthan, flood-prone regions in Assam and Bihar, and coastal areas susceptible to cyclones face heightened risks from extreme weather events. Analysis by the Reserve Bank of India highlighted how spatial variation in rainfall across districts affects Kharif crop production (Policy Circle, 2025). Insufficient rainfall during June and July adversely affects cereals and pulses output, while oilseeds are particularly vulnerable to excessive rainfall during August-September harvesting months. Maize demonstrates greater sensitivity to rainfall variation than paddy, likely due to its reliance on natural water sources in rain fed regions. These crop-specific and timing dependent vulnerabilities complicate adaptation planning and require targeted interventions.

Research by Baraj and co-worker conducted a bibliometric review of climate change resilience, adaptation, and sustainability of agriculture in India. Their analysis revealed that high rainfall variability adversely influences agricultural specialization and household occupational choices.

Better access to credit, irrigation facilities, education, roads, and communication is associated with greater emphasis on agriculture-related employment. A 1°C increase in temperature results in 3% wheat yield reduction, though this does not account for short-term adaptations farmers implement. The study found that adaptation to extreme heat remains challenging for crops, particularly in districts like Janjigir-Champa in Chhattisgarh (Baraj *et al*., 2024).

3.3 Air pollution as a compounding climate stressor

Ambient air pollution compounds urban climate vulnerabilities by imposing severe health and environmental burdens. India's average $PM_{2.5}$ concentration reached 50.6μg/m^3 in 2024, exceeding WHO safe limits by tenfold, with 13 of the world's 20 most polluted cities located in India. Ambient particulate matter exposure has been linked to an estimated 1.1 million premature deaths annually in India, with air pollution becoming the fourth leading cause of mortality nationwide. During pollution episodes, respiratory disease cases increase by 10-15%, with patients presenting symptoms including persistent cough, throat irritation, watery eyes, and breathing difficulties. Children with developing respiratory systems and elderly populations with compromised immunity face particularly elevated risks from prolonged exposure to pollutants including $PM_{2.5}$, nitrogen dioxide, sulfur dioxide, and ozone (Saini *et al*., 2019; Saini and Kumar, 2021, 2022, 2024).

Beyond human health impacts, air pollution significantly affects urban vegetation and agricultural productivity. Pollutants including ozone and black carbon reduce crop yields through direct toxicity and alterations to solar radiation, with studies showing that air pollution contributed to 36% wheat yield reductions in India, of which approximately 33% was attributable to air pollutants alone (Burney and Ramanathan, 2014). Air pollutants disrupt plant physiology by acting as mechanical barriers to light penetration, blocking stomatal openings, increasing respiration rates, and causing visible injury including leaf yellowing and burns. These effects reduce photosynthetic activity, biomass accumulation, and chlorophyll content in both crops and urban vegetation (Saini *et al*., 2021; Saini, 2022). The deterioration of urban green spaces due to pollution creates a vicious cycle, as vegetation plays crucial roles in filtering particulate matter, absorbing gaseous pollutants, and moderating urban microclimates.

3.4 Adaptation in agricultural systems

Farmers across India have demonstrated adaptive capacity through various strategies. Researchers examined long-term climate change impacts using 60 years of data across Indian districts. They found that farmers adapted to temperature changes for rice and maize but not for wheat. The increased precipitation enhanced rice yields while adversely affecting wheat and maize yields. Importantly, farmers customized strategies across regions and crops, with heat-prone districts faring better to higher temperatures compared to colder region districts. The distributional analysis revealed heterogeneous impacts with farmers in less productive areas (lower tail of distribution) taking more adaptation measures due to experiencing higher impacts (Kumar and Khanna, 2023). This finding underscores that vulnerability and adaptive capacity are not uniformly distributed, requiring differentiated support mechanisms. Transformational adaptations including substantial changes in land use, resource and labor allocations, occupational patterns, and cropping systems are increasingly adopted alongside incremental systemic adaptations (Datta and Behera, 2022).

Specific adaptation measures include crop diversification away from rice toward other crops to relieve pressure on water supplies while improving soil quality and enhancing nutritional security.

Crops are being bred for greater tolerance to heat, drought, flood, and salinity through advanced biotechnology and participatory breeding programs. Farmers are strategically changing sowing times for cereals and millets, using chickpeas and mustard plants with shorter growing periods, and implementing efficient irrigation systems like drip and sprinkler methods delivering water directly to plant roots (GARP, 2025). Zero-till sowing, mulching, crop residue retention, and improved water and nutrient management through precision agriculture represent additional adaptation strategies being adopted across diverse agro-ecological regions, supported by government extension services and farmer cooperatives.

4. Coastal Vulnerabilities and Sea Level Rise

4.1 Sea level rise trends

India's extensive coastline of approximately 7,500 kilometers faces significant threats from sea level rise. Between 1901 and 2018, global average sea levels rose by 15-25 cm, with projections indicating further increases of 15 mm per year by 2100 (Das and Swain, 2024). The Intergovernmental Panel on Climate Change projects global mean sea level rise of 1.3-1.6 meters by 2100 under high-emission scenarios, posing major hazards to coastal cities worldwide including those in India. A comprehensive report by the Centre for Study of Science, Technology and Policy (CSTEP, 2024) analyzed sea level rise scenarios and inundation maps for 15 Indian coastal cities and towns. The study documented maximum sea level rise over three decades (1987-2021) at Mumbai (4.44 cm), followed by Haldia (2.72 cm), Visakhapatnam (2.38 cm), Paradip (0.72 cm), and Chennai (0.68 cm). Increasing trends were observed for Mumbai, Kochi, and Mormugao on the west coast and Haldia, Paradip, Visakhapatnam, and Chennai on the east coast.

Future projections under the SSP2-4.5 medium-emission scenario indicate that by 2100, sea levels would rise by 76.2 cm in Mumbai, 75.5 cm in Panaji, 75.3 cm in Udupi, and 75.2 cm in Mangaluru (CSTEP, 2024). These projections carry profound implications for coastal infrastructure, communities, and ecosystems. Machine learning models analyzing flood risks under four Shared Socioeconomic Pathways revealed that Mumbai and Kolkata face the highest flood risks, particularly under high emission scenarios (Chakrabortty *et al*., 2025).

4.2 Inundation risks and impacts

Submergence projections for 2040 indicate that more than 10% of land in Mumbai, Yanam, and Thoothukudi will be submerged, 5-10% in Panaji and Chennai, and 1-5% in Kochi, Mangaluru, Visakhapatnam, Haldia, Udupi, Paradip, and Puri (CSTEP, 2024). These inundation patterns threaten critical infrastructure, residential areas, and economic activities concentrated in coastal zones. Low-lying coastal communities face substantial risks of land flooding, necessitating adaptation and potential relocation strategies. Case studies from specific cities illustrate the severity of impacts. Sahu and Mehta (2024) examined coastal inundation in Surat city, a major coastal district of Gujarat with a population of 6,081,556. Surat has experienced multiple catastrophic floods including the August 2006 event affecting approximately 3,817,235 people. Projections indicate a 100 cm sea level rise would affect 4.47% of land, rendering it uninhabitable. The city's six harbors and its significant contribution (approximately $40 billion USD or 2.162% of national GDP) face substantial climate risks (Sahu and Mehta, 2024).

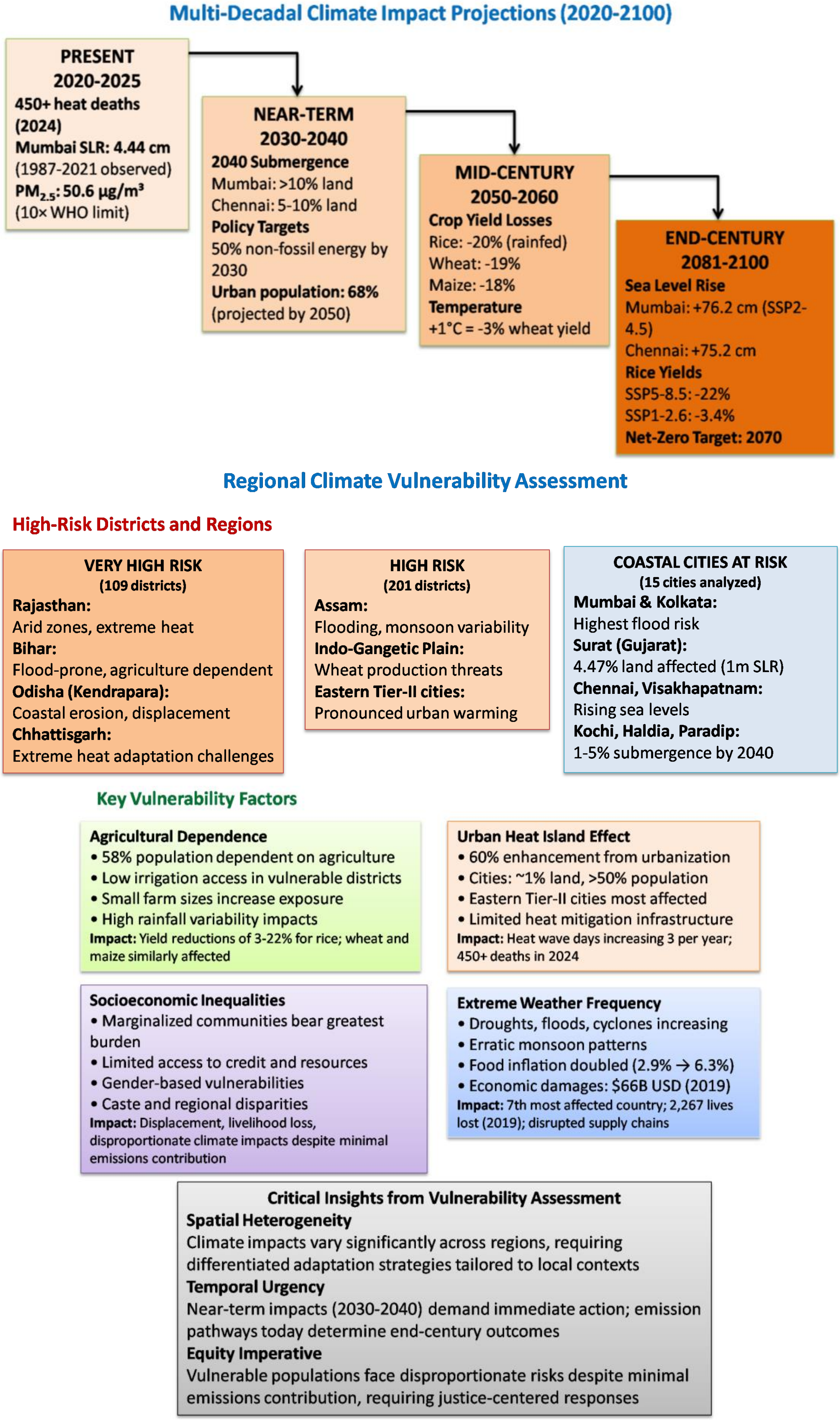

Figure 2. Projected climate impacts timeline and regional vulnerability assessment

Das and Swain conducted an interdisciplinary analysis exploring the interplay between climate change, sea level rise, and coastal communities in India. Their research documented displacement of communities and impacts on food security, infrastructure, tourism, and ecological systems. The Satabhaya village in Kendrapara district of Odisha exemplifies these challenges, where massive erosion caused by rising sea levels led to a state-initiated rehabilitation and resettlement program in 2011 for 571 affected families (Das and Swain, 2024). Many residents suffered significant losses of farmland and homes, illustrating the human dimensions of coastal climate impacts. Understanding the temporal and spatial dimensions of climate vulnerability is essential for prioritizing adaptation investments and interventions. **Figure 2** integrates projected climate impacts across multiple time horizons with a comprehensive regional vulnerability assessment, revealing how climate risks will intensify over coming decades while manifesting heterogeneously across India's diverse geographic and socioeconomic landscape. **Figure 2** demonstrates the critical importance of both temporal urgency and spatial differentiation in climate response planning. The timeline reveals that near term impacts (2030-2040) are already largely determined by historical emissions, with coastal submergence and continued agricultural stress inevitable even under optimistic scenarios. However, the stark difference between end century outcomes under different emission pathways, 22% rice yield loss under SSP5-8.5 versus 3.4% under SSP1-2.6; underscores how current mitigation actions will fundamentally shape long-term impacts (Gallé and Katzenberger, 2025).

The regional vulnerability assessment highlights that climate impacts concentrate in specific geographic zones; 310 districts face high or very high risk, representing substantial portions of India's agricultural heartland and coastal economic centers. The identification of eastern Tier-II cities as experiencing pronounced urban warming (Sethi and Vinoj, 2024), combined with flood-prone regions in Bihar and Assam and arid zones in Rajasthan, reveals the necessity of geographically targeted adaptation strategies. Furthermore, the vulnerability factors panel illustrates how climate stressors interact with pre-existing inequalities: agricultural dependence, limited infrastructure, and socioeconomic marginalization; to create compounding risks that cannot be addressed through climate interventions alone but require integrated development approaches.

5. Policy Frameworks and Climate Action

5.1 National climate commitments

India has developed comprehensive policy frameworks to address climate change, though implementation challenges persist. Hussain and co-worker reviewed India's efforts toward achieving Sustainable Development Goals 13 (Climate Action) and 11 (Sustainable Cities and Communities). Their analysis highlighted that despite being the most populous nation with 1.4 billion people (18% of global population), India faces significant challenges balancing development needs with climate action (Hussain *et al*., 2024). The review of climate policies revealed progress alongside persistent gaps. India demonstrated remarkable success by achieving its 2030 target of 50% cumulative installed capacity from non-fossil fuel based energy sources five years ahead of schedule in 2025 (Press Information Bureau, 2025). The country has also committed to achieving net-zero emissions by 2070. However, India continues relying on coal for a significant portion of energy production, creating ongoing tensions in climate strategy. Research examining India's inflation, fiscal space, and growth in relation to climate change found that a unit increase in climate change indicators is associated with 0.463% increase in inflation (SenGupta and Atal, 2025), demonstrating macroeconomic implications of climate impacts.

5.2 Sectoral policies and initiatives

Various sectoral policies address specific climate challenges. The Mangrove Initiative for Shoreline Habitats and Tangible Incomes (MISHTI) aims to establish 540 square kilometers of mangrove forests across 11 states and 2 union territories over five years beginning fiscal year 2023-2024 (Chakrabortty *et al*., 2025).

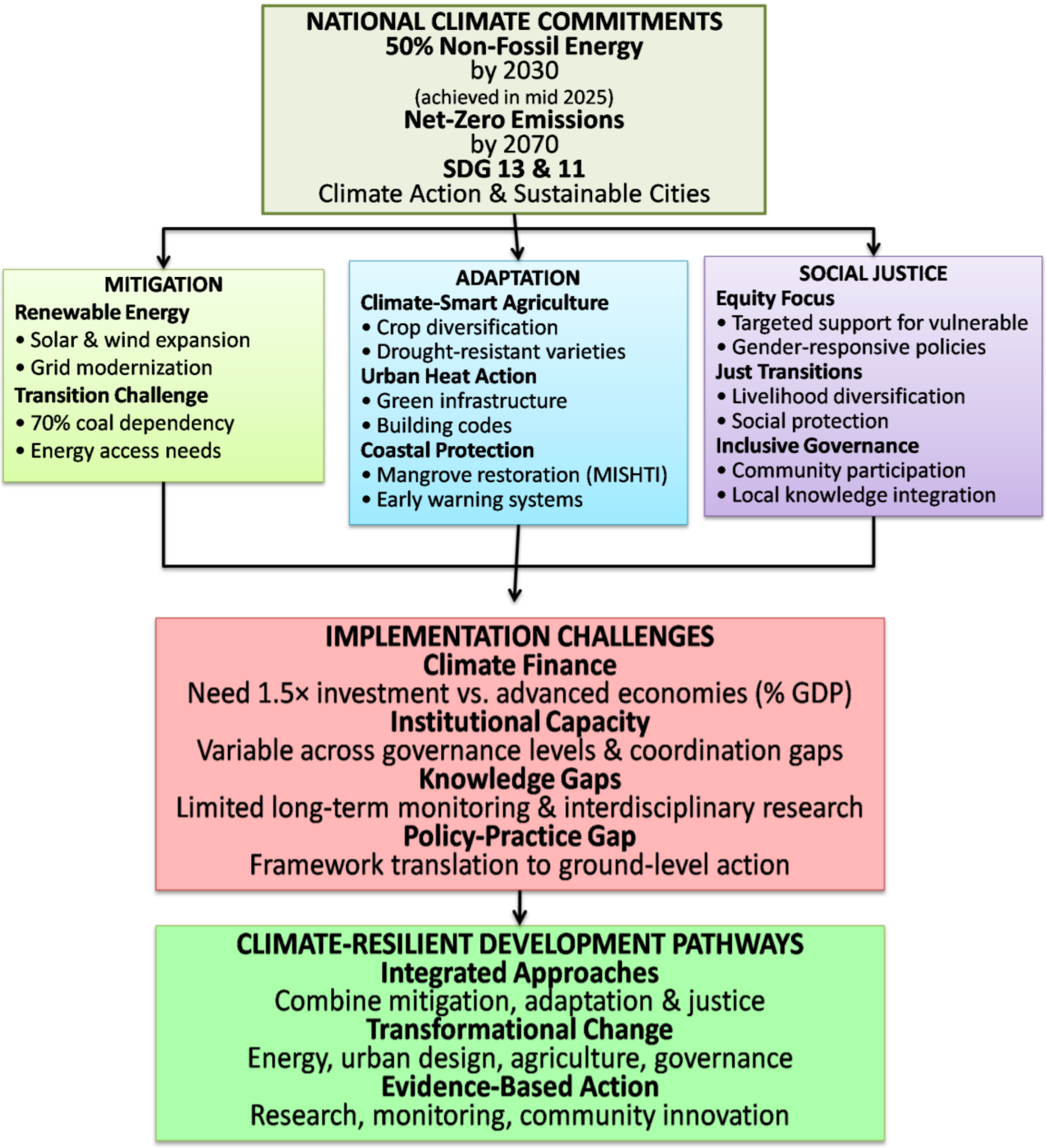

Figure 3. Integrated policy response and adaptation framework

The Coastal Regulation Zone Notification 2019 seeks to preserve maritime areas and coastal stretches while ensuring livelihood security for fishing communities and other coastal populations. For agriculture, the National Mission for Sustainable Agriculture provides frameworks for climate-smart practices. Ravindra and co-worker discussed the Lifestyle for Environment (LiFE) initiative as a global approach to fight climate change through community engagement and lifestyle modification (Ravindra *et al*., 2023). However, translating policy frameworks into effective ground-level implementation remains challenging. Institutional capacity varies considerably across governance levels, and coordination between central and state governments often faces obstacles. The complexity of India's climate challenge necessitates a coordinated policy response spanning mitigation, adaptation, and social justice dimensions. **Figure 3** synthesizes India's climate policy architecture, illustrating how national commitments translate into sectoral actions while highlighting critical implementation barriers that must be addressed for effective climate governance. **Figure 3** reveals that while India has established comprehensive policy frameworks spanning mitigation and adaptation, significant implementation gaps persist. The framework demonstrates that climate finance constraints, variable institutional capacity, and coordination challenges between policy formulation and ground-level implementation represent critical bottlenecks. Notably, the interdependence of the three pillars: mitigation, adaptation, and social justice; suggests that progress in one domain without corresponding advances in others risks undermining overall climate resilience. The challenge of maintaining 70% coal dependency while pursuing 50% non-fossil energy targets by 2030 exemplifies these tensions, requiring careful navigation of energy transitions that balance development needs with climate commitments.

6. Challenges and Future Directions

6.1 Knowledge gaps and research needs

Despite growing research attention, significant knowledge gaps persist. Researchers identified that most vulnerability studies emphasize climate-induced external stressors over internal ones, often neglecting socio-cultural-politico-economic and physical dynamics of agriculture that generate risks and vulnerabilities. Research shows significant spatial, temporal, and thematic differences in agricultural vulnerability across India, yet comprehensive assessments integrating multiple dimensions remain limited. Long-term ecological monitoring across diverse ecosystems could track climate impacts and inform adaptive management (Baraj *et al*. 2024). Social science research on vulnerability, adaptation, and behavior change deserves greater investment. Interdisciplinary approaches connecting natural sciences, social sciences, and humanities can generate holistic understanding of climate-society interactions. Documentation and rigorous evaluation of community-based adaptation initiatives would support evidence-based scaling of successful approaches (Rana and Saini, 2025b).

6.2 Adaptation and resilience building

Building climate resilience requires integrated approaches across multiple scales. Urban areas need differentiated strategies recognizing that the 60% urbanization contribution to warming varies substantially across cities (Sethi and Vinoj, 2024). Eastern Tier-II cities require particular attention given their pronounced warming trends. Green infrastructure, improved building codes, and heat action plans represent critical urban adaptation measures. For agriculture, Climate-Smart Agriculture incorporating conservation tillage, crop rotation, and integrated nutrient management must be supported through comprehensive farmer training programs. Substantial investment is needed in developing drought and flood resistant crop varieties and establishing well managed seed banks (Policy Circle, 2025). Modernizing irrigation infrastructure using water efficient technologies and encouraging rainwater harvesting can enhance water security. Promoting crop diversification reduces risks associated with climate-induced yield volatility but requires sustained funding for agricultural research and innovation.

Coastal adaptation strategies must combine ecosystem-based and infrastructure approaches. Mangrove restoration provides natural coastal protection while supporting biodiversity and fisheries.

Integrated coastal zone management combining development with environmental stewardship offers frameworks for balancing economic activities with climate resilience (Chakrabortty *et al*., 2025). Early warning systems for coastal flooding and cyclones require strengthening to protect vulnerable populations.

6.3 Equity and justice considerations

Climate impacts fall unevenly across societies, striking hardest at those least responsible for emissions (Rana and Saini, 2025a). Digital environmentalism through social media platforms has become an important tool for climate awareness, yet access remains unequally distributed across social classes and rural-urban divides (Saini and Rana, 2025). Research consistently documents that marginalized communities including small and marginal farmers, coastal fishing communities, and urban informal settlement residents bear the greatest burdens (Hussain *et al*., 2024). Climate policies should clearly focus on fairness and equality. They must include special support for poor and vulnerable groups through social protection programs and fair decision-making systems. Women need particular attention because they often face greater difficulties during climate disasters and have less access to money, land, and power in planning or policy discussions. People from lower castes, different regions, and various age groups experience climate change in unequal ways. For example, farmers, elderly people, or those in remote areas may suffer more from droughts or floods. To ensure justice, governments should plan ahead and create fair solutions for communities whose jobs and lives depend on climate sensitive work, such as farming or fishing, by giving training, financial help, and long-term security.

6.4 Climate finance and international cooperation

India requires substantial climate finance to meet adaptation and mitigation needs. As shown in the implementation challenges section of **Figure 3**, climate finance gaps represent a critical barrier, with India requiring 1.5 times greater investment as a share of GDP compared to advanced economies as a share of GDP for low-carbon infrastructure development. International climate finance commitments have not materialized adequately, with developed countries failing to deliver promised support. Mobilizing domestic resources through carbon taxation, subsidy reform, and green bonds while securing international finance on favorable terms represents a critical challenge. Regional cooperation in South Asia can address shared climate challenges including trans-boundary water resources, air pollution, disaster management, and ecosystem conservation. Technology collaboration accelerates innovation and deployment of climate solutions. South-South cooperation enables peer learning and adaptation of successful models. India's experience with large-scale programs offers lessons for other developing countries while learning from global best practices.

Conclusions

This review combines recent peer-reviewed research examining the complex relationship between climate change and society in India. Key findings demonstrate that climate impacts are intensifying across multiple dimensions, from urban warming to agricultural yield reductions to coastal inundation risks. Urbanization has contributed 60% additional warming in Indian cities, with significant spatial heterogeneity requiring differentiated adaptation approaches. Agricultural systems face yield reductions of 3-22% for major crops under various emission scenarios, threatening food security and farmer livelihoods. Coastal cities face substantial sea level rise, with Mumbai experiencing 4.44 cm rise between 1987 and 2021 and projections of 76.2 cm by 2100. Vulnerability is profoundly shaped by socioeconomic inequalities, with marginalized communities bearing disproportionate impacts despite minimal contribution to emissions. Farmers demonstrate adaptive capacity through crop diversification, modified planting schedules, and improved water management, though adaptation potential varies substantially across regions and social groups. Policy frameworks provide structure for climate action, yet implementation challenges persist related to finance, institutional capacity, and coordination.

The three-pillar framework presented in **Figure 3** demonstrates that effective resilience building requires simultaneous progress in mitigation, adaptation, and social justice principles. Urban planning requires heat mitigation strategies tailored to local warming patterns. Agricultural systems need climate smart practices supported by research, extension services, and farmer training. Coastal areas require ecosystem based adaptation combined with infrastructure improvements and early warning systems. All interventions must explicitly address equity dimensions to ensure vulnerable populations are protected and empowered. The transition to climate-resilient development in India requires transformational changes in energy systems, urban design, agricultural practices, and governance structures. This transformation must be managed justly, with adequate climate finance, technological innovation, and inclusive decision-making processes. While challenges are substantial, India's demographic dividend, technological capacity, and policy innovation offer pathways toward sustainable, equitable climate futures. Continued research integrating natural and social sciences, rigorous evaluation of adaptation initiatives, and learning from community innovations will be essential for navigating the climate-society nexus in coming decades. **Figures 1-3** collectively reveal three critical insights for climate-resilient development in India. First, climate impacts manifest through interconnected sectoral vulnerabilities (**Figure 1**) that cannot be addressed in isolation. Second, the policy response framework (**Figure 3**) demonstrates that mitigation, adaptation, and social justice must be pursued simultaneously despite implementation challenges. Third, the temporal-spatial analysis (**Figure 2**) shows that while near-term impacts are largely determined, emission pathways today will fundamentally shape end-century outcomes, particularly for agricultural productivity and coastal habitability. Together, these frameworks underscore that India's climate challenge is both urgent and long-term, requiring immediate action while planning for multi-generational impacts.

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