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The Economic Impact Of Climate Change In India - Analysis Of Risks, Costs And Policy Constraints

Dr. SURAPPA NAIK

Associate Professor of Economics, LBS Government First Grade College,
R.T. Nagar, Bangalore, Karnataka - 560032

Abstract

The Climate change poses a serious threat to India's economic development through multiple channels: declining labor productivity, damage to infrastructure, loss in agricultural output, increased health burdens, and mounting adaptation costs. This paper assesses the projected economic losses to India under different emissions and warming scenarios, estimates the costs of adaptation and mitigation, and examines how these costs interact with development goals. We also analyze policy options that can help minimize these losses while supporting sustainable growth. Our findings suggest that under a high emissions scenario, India could face GDP losses of 20-25 per cent by 2070 and much higher by 2100. The cost of adapting to climate change by 2030 projected in the many trillions of rupees, imposing a substantial burden but also offering opportunities for innovation, resilience, and inclusive development. Climate change is already affecting India through rising temperatures, changing monsoon patterns, more frequent and severe extreme events, and slow-onset changes that undermine productivity and infrastructure. Using recent literature and institutional estimates, this paper synthesizes evidence on the channels through which climate change reduces output in agriculture, labor productivity, health, and infrastructure, and quantifies likely macroeconomic costs under plausible scenarios. The evidence suggests substantial short and long-term costs: sectoral losses (especially in agriculture and informal labor) and fiscal strains from disaster response and adaptation investments could reduce growth and push millions back into poverty if unaddressed. The article closes with prioritized policy responses—strengthening climate-resilient agriculture, expanding social protection, investing in nature-based solutions and cooling infrastructure, and mobilizing green finance.

Key words: Climate change, Economic development, Sustainable growth, GDP

Introduction

India is one of the most climate-vulnerable countries in the world. Its large population, dependence on agriculture and natural resources, widespread poverty, and exposure to extreme weather events (heat waves, flooding, droughts, and cyclones) make its economy particularly sensitive to changes in temperature, precipitation patterns, and sea level. While growth over recent decades has lifted hundreds of millions out of poverty, climate change risks threaten to reverse some of these gains. Observed increases in extreme weather events (heatwaves, floods, cyclones) and projected temperature rises create direct output losses and indirect effects through human health, labor productivity, supply chains, and public finances. India is among the countries most exposed to climate risk because a large share of its population and economy depends on climate-sensitive activities (agriculture, fisheries, and informal labor) and because of dense populations in flood- and heat-prone areas. The scale and multi-sectoral nature of these impacts call for a comprehensive economic assessment and practical policy responses. This article seeks to quantify economic losses under different climate scenarios; assess the costs of adaptation and mitigation; and discuss policy strategies that balance economic development and environmental sustainability.

Review of Literature

1. The Asian Development Bank (ADB) Asia-Pacific Climate Report (2024) projects that under a high emissions scenario; India may suffer GDP losses of 24.7 percent by 2070 due mainly to rising sea levels and decreasing labor productivity.
2. Another ADB report (Assessing the Costs of Climate Change and Adaptation in South Asia) estimates that without mitigation/adaptation, India could lose 8.7 percent of GDP by 2100.
3. On adaptation costs: India is estimated to need around ₹56.7 lakh crore (i.e. US\$700-800 billion depending on exchange rates and inflation) by 2030 to adapt to climate change.
4. Current spending on adaptation is already substantial: in 2021-22, India spent about Rs 13.35 lakh crore (5.5 percent of GDP) on adaptation, and anticipates spending ₹57 lakh crore over the next seven years. The Indian Express & The Hindu
5. Sectoral impacts: agriculture, health, water resources, coastal infrastructure, and labor productivity commonly cited as being among the hardest hit.

Research Methodology

To assess the impact of climate change on economic development in India, the article uses:

1. **Scenario Analysis:** Modeling under different Representative Concentration Pathways (RCPs) or Shared Socioeconomic Pathways (SSPs), matching high emissions (business as usual) vs. mitigation paths (2 °C or lower warming).
2. **Sectoral Impact Assessment**, focusing on:
 - Agriculture (yield declines, crop failures);
 - Labor productivity (heat stress, outdoor work limitations);

- Infrastructure (damage from flooding, coastal inundation, storms);
 - Health costs (heat related illness, vector borne diseases);
 - Energy demand (cooling, heating, etc.).
3. **Economic Costing:** Estimating direct losses (e.g. damaged assets, lower yields) and indirect losses (e.g., productivity drops, migration, lost labor hours).
 4. **Adaptation and mitigation cost estimation:** Adaptation and mitigation cost estimation from reports by Government bodies (e.g., RBI, Economic Survey), multilateral agencies (ADB), and peer-reviewed studies.
 5. **Policy simulation:** Policy simulation to assess how different combinations of investment, regulation, and innovation affect outcomes.
 6. **Methods and Data:** This article is a synthesis and policy-oriented assessment that combines: (a) recent peer-reviewed empirical estimates of sectoral affects (agriculture, health, labor), (b) institutional scenario reports (IPCC, World Bank, WEF, CEEW, CPI) for macro projections, and (c) case evidence of recent extreme-event losses in India. Where possible, ranges from multiple sources reported to reflect uncertainty.

Conceptual Framework - Channels of Economic Impact

Empirical and modelling studies identify five principal channels by which climate change affects the Indian economy.

1. **Agricultural yields and food security:** Temperature rise, altered rainfall timing/intensity, and elevated heat/drought events lower yields for staple crops, raising food prices and reducing rural incomes. Several studies project declines in major crops (rice, maize) under modest warming scenarios
2. **Labor productivity and health:** Heat stress causes direct productivity losses in outdoor and informal work, increases heat-related mortality/morbidity, and raises cooling and health-care demand. Global and regional studies find notable labor-hour and output losses at higher temperatures.
3. **Extreme-event damages to infrastructure and assets:** Floods, cyclones, and storms damage transport, energy, housing and industrial assets, requiring fiscal outlays for reconstruction and lowering productive capacity.
4. **Disruptions to supply chains and trade:** Localized shocks propagate through national and international supply chains, amplifying output losses beyond directly affected regions.
5. **Macroeconomic and fiscal channels:** Recurrent disasters raise public spending needs (relief, reconstruction, adaptation), depress tax bases via lower growth, and may increase borrowing costs-reducing fiscal space for development. Recent Indian analyses estimate substantial near-term fiscal exposure from climate-related disasters.

Recent Quantitative Findings & Projections:

1. GDP Loss Projections under High Emissions

A 2024 ADB report estimates that India may face a 24.7 percent loss of GDP by 2070 under a high emissions scenario, driven particularly by labor productivity declines and sea level rise. By 2100, developmental Asia and Pacific could lose up to 41 percent of GDP under such high emission trajectories. India is among the worst-affected in these projections.

2. Annual GDP Loss under Different Warming Scenarios

If global warming is limited to 2 °C over preindustrial levels, one-study projects that India could lose about 2.6 percent of GDP per annum. Under more severe warming (e.g. 4 °C or more), this could rise to -13.4 percent annual GDP loss.

3. Recent Losses Already Experienced

India has estimated in 2022 to suffer an 8 percent GDP loss due to climate impacts and a cumulative capital wealth decline of 7.9 percent. The Times of India. The districts that have warmed fastest are showing substantially lower growth: in the report, those districts grew 56 percent less GDP than slower-warming districts.

4. Adaptation Cost & Financial Needs

RBI estimates that the cumulative adaptation cost for India up to 2030 will be ₹ 85.6 lakh crore (in 2011-12 prices). To bridge infrastructure gaps caused by climate events, India may need to spend at least 2.5 percent of GDP annually in green financing.

5. Sectoral Contributions to Losses

Labor productivity is one of the largest contributors to projected losses: heat stress in outdoor work, etc. For example, labor losses, heat stress make up to 11.6 percent of GDP loss in ADB's estimates by 2070 under high emission scenarios for India. Submerging (especially riverine) and sea level rise contributed in terms of direct damage (infrastructure, capital stock) and indirect losses.

Emerging Trends of Climate Risk Patterns

- 1. Shifting Rainfall & Monsoon Variability:** More erratic monsoon rains, with periods of excessive rain and drought. This not only affects agriculture but also exacerbates floods, landslides, and disrupts urban drainage.
- 2. Heatwaves Increasing:** Temperature extremes are increasing, especially in north western, central, in addition, south central India. Heat exacerbates labor loss, health problems, and energy demand (cooling).
- 3. Urbanization and Infrastructure Stress:** Cities are hotspots of risk due to urban heat islands, poor drainage, flood risk, and pressures on water supply system. The World Bank estimates Indian cities need \$2.4 trillion in investment by 2050 for climate resilient infrastructure.

Magnitude Estimates from Major Assessments

IPCC AR6 and related syntheses document that climate change is already causing economic damages and increasing the frequency and severity of extremes-impacts concentrated among vulnerable populations. Adaptation needs are non-trivial but generally yield positive benefit-cost ratios when focuses and targeted.

Country-focused assessments suggest substantial long-run costs: scenario studies estimate that by 2100, climate damages could reduce national income by several percent under moderate-to-high warming pathways, with even larger sectoral impacts in agriculture and labor-intensive activities.

Evidence and Results

Agriculture and Food Systems

Multiple studies find that staple yields are sensitive to temperature and moisture changes. Scenario analyses indicate potential declines in rice yields (10-30 percent) and maize (25-70 percent) with warming between 1°C and 4°C absent adaptation, with large regional heterogeneity. Projected agricultural losses translate to larger income shocks for rural households and higher food inflation, which amplifies poverty risks.

Labor Productivity and Health Costs

Heat exposure already reduces labor capacity in outdoor and informal sectors central to India's economy. Macro-analyses suggest measurable GDP impacts from lost labor hours and rising health burdens; by mid-century, heat-related productivity losses will be a major drag without major adaptation investments (cooling, schedule changes, mechanization).

Infrastructure and Disaster Losses

Historic and recent disasters demonstrate high economic volatility: flood and cyclone damages impose recurrent reconstruction costs and interrupt services (transport, power). Institutional estimates project large near-term fiscal exposures-e.g., disaster-related costs to infrastructure and banking sector exposure in the tens of billions of USD over short windows - highlighting the need for resilient infrastructure planning.

Aggregate Macroeconomic Effects & Poverty Implications

Across assessed scenarios, the impact on GDP ranges by scenario and model, but several credible analyses show that without adaptation and mitigation, climate change could shave several percent points off growth by the end of the century and push tens of millions back into poverty. The magnitude varies with assumptions on warming, adaptation uptake, and global economic interactions.

Key Empirical Findings & Quantitative Data

Sl. No.	Topic	Data / Finding
1.	GDP Loss Projections (India & Asia-Pacific)	India could suffer a 24.7 percent loss in GDP by 2070 under high emissions. Across Asia Pacific, the projected loss is 16.9 percent. Main drivers are labor productivity loss and sea level rise. India may lose 8.7 percent of GDP by 2100 if global warming proceeds without mitigation.
2.	Annual GDP Loss under Different Warming Scenarios	If warming is limited to 2 °C, India could lose 2.6 percent of GDP annually by 2100 . If warming rises to 4 °C 3 °C, annual GDP losses could rise to 13.4 percent.
3.	Recent (2022) Economic Impacts	India's economy suffered an 8 percent GDP loss in 2022 . Due to climate change (compared against a hypothetical baseline without climate impacts). In addition, a cumulative capital wealth loss of 7.9 percent has reported.
4.	Labor Productivity / Hours Lost	India loses 259 billion labor hours annually due to humid heat, valued at USD 624 billion (PPP).
5.	Sectoral Productivity Loss (Workplaces, Indoor/Outdoor, Heavy Work)	Study with 442 workers across 18 workplaces: 82 percent had WBGT (wet bulb globe temperature) above recommended levels in hot season; 57 percent reported productivity loss; heavy work & outdoor/semi-outdoor settings had significantly higher losses.
6.	Health Impacts / Mortality Risk	On 'sweltering' heatwave days versus 'comfortable' days: all-cause mortality risk rises by 8.1 percent in Varanasi, 5.9 percent in Delhi, and 8.0 percent in Chennai. Females had higher risk than males in some cities.
7.	Adaptation Spending	In 2021-22, India's adaptation-relevant expenditures were 5.6 percent of GDP .

Interpretation of the Data

- The losses in GDP under high emission scenarios are large enough to reduce growth rates, and could reverse gains made in poverty reduction and infrastructure development. For example, if India loses 24.7 percent of GDP by 2070, that cuts into what growth would have been over those decades, with compounding effects.
- Labor productivity losses (via heat stress) are already substantial (hundreds of billions of hours and significant economic value). This suggests that many of the more severe effects are not just in the future—they are happening now.
- Sectoral studies show that outdoor/semi outdoor, heavy work sectors (construction, agriculture, brick-making, etc.) are especially vulnerable. The indoor sectors also suffer, but to a lesser degree.
- Mortality and health data indicate that severe heat days increase mortality by several percent points in major cities. These health impacts translate into economic costs (medical costs, lost workdays etc.), and might reduce human capital.
- Adaptation efforts are already large (5.6 percent of GDP), suggesting recognition of risk, but questions remain about whether they are sufficient given projected losses, especially under high warming paths.

Discussion on Uncertainties and Interaction effects

Key uncertainties include climate model projections for monsoon dynamics, socio-economic pathway choices (urbanization, technology), and adaptation uptake. Interaction effects (e.g., simultaneous heat and water stress) can produce non-linear losses. Moreover, distributional effects are critical: impacts disproportionately affect low-income, rural, and informal workers, worsening inequality. Despite uncertainties, benefit-cost analysis of many adaptation options (early warning, nature-based solutions, resilient irrigation, and targeted social protection) remains favorable.

Research Gaps, Risks, and Further Research

Uncertainty & Localization: Many projections are at national level; local/regional level projections are needed (districts, states) to tailor policy.

Non-linear & Compound Risks: Interactions between heat, water scarcity, extreme rainfall and sea level rise can amplify losses.

Infrastructure Lock: Building infrastructure that is not climate resilient may lock in future losses.

Financing Bottlenecks: Mobilizing finance (especially from private sector/international sources) remains a challenge, as does ensuring that funds used effectively.

Governance & Institutional Capacity: Subnational governments often lack capability, planning tools, and enforcement mechanisms.

Monitoring & Data Gaps: Need for better, high-resolution data on temperature, rainfall, flood risk, labor productivity, and health outcomes etc.

Policy Responses & Emerging Strategies

1. National & Sectoral Plans

National Action Plan on Climate Change (NAPCC) with its missions (Solar Mission, Water Mission, Sustainable Habitat etc.) remains a foundational policy framework.

Increasing focus on integrating climate risk into urban planning (e.g., drainage master plans, flood mitigation). Recently Delhi has finalized a storm-water drainage master plan for climate resilience.

2. Green Finance & Adaptation Financing

Government and RBI recognize huge financing needs. Reports suggest mobilizing 2.5 percent of GDP annually for climate-resilient infrastructure. Down To Earth

Incentives for carbon capture technologies considered to reduce emissions from the continued use of coal. Reuters

3. Technological & Nature-based Approaches

Use of AI and better forecasting to help farmers adapt to monsoon variability. Push towards renewables, decarbonizing electricity grid, improving energy efficiency. Research suggests India has potential to meet much of electricity demand from renewables by 2030 under favorable policies.

4. Urban Infrastructure & Resilience

Large allocations needed for urban resilience: flood mitigation, green infrastructure, water systems etc. World Bank's report saying \$2.4 trillion required by 2050 for Indian cities.

5. Labor & Health

Heat adaptation plans (e.g. work rest cycles, shade, cooling centers), better public health systems to handle vector borne diseases and heat stress etc. Social safety nets, crop insurance, livelihood diversification to reduce vulnerability of farmers and those dependent on climate sensitive sectors.

Findings of the Study & Policy Recommendations

Under a high emissions scenario, India could lose 24.7 percent of GDP by 2070 due to climate change effects. By 2100, GDP losses could be 8.7 percent annually under certain scenarios if climate change remains unchecked.

Scale Climate and Resilient Agriculture: Invest in heat-and drought-tolerant crop varieties, improved irrigation, weather-indexed crop insurance, and climate-smart extension services. This reduces yield volatility and protects rural incomes.

Protect Labor and Health: Implement heat-safety standards, shift work schedules where feasible, expand access to cooling in vulnerable communities (including sustainable cooling investments), and strengthen public health systems for climate-sensitive diseases.

Resilient Infrastructure and Urban Planning: Mainstream climate risk in transport, power, and water infrastructure investments; upgrade drainage and flood defenses in urbanizing areas. Cost-effective resilience saves reconstruction costs over time.

Nature-based Solutions and Ecosystem Restoration: Protect and restore mangroves, wetlands, and watershed ecosystems to reduce flood risk, sustain fisheries and agriculture, and sequester carbon-these often deliver co-benefits for livelihoods.

Mobilize Finance for Adaptation: Scale up green and climate finance (public and private), strengthen risk-transfer mechanisms (insurance markets), and use fiscal policy to protect vulnerable households and support long-term adaptation. Improving the investment pipeline and de-risking projects will attract private capital.

Data, Early Warning, and Institutional Capacity: Invest in granular climate and socio-economic data, expand early-warning systems (including AI-enabled localized forecasts), and strengthen institutional coordination across central and state governments. Recent initiatives demonstrating improved localized forecasts to farmers highlight the value of these investments.

Other Suggestions

Integrate climate risks into all aspects of economic planning - infrastructure, land use, urban planning and development of agriculture sector.

Invest in climate resilient infrastructure - flood defenses, resilient roads, drainage, water storage and coastal protection.

Improve agricultural adaptation - drought resistant crops, better water management, crop insurance and agro ecological approaches.

Ensure labor protections and heat adaptation - rest breaks, shade, cooling centers, work time scheduling especially for outdoor workers.

Boost renewable energy, reduce energy intensity - align with India's net zero commitments, push for clean electricity generation, energy efficiency in buildings and industry.

Mobilize finance - domestic (budgetary re-allocations, green taxes, incentives) and international; use innovative financing (e.g. blended finance, climate bonds).

Strengthen institutions and data infrastructure - decentralized planning, early warning systems, climate insurance and better modelling and local level climate projections.

Distributional Impacts & Social Dimensions

The poorest populations (rural farmers, informal sector, marginalized communities) of the country has excessively affected, having less buffer (financial, infrastructural, and social) against climate shocks. Inequality is likely to increase slower growth in districts that warm fastest means existing regional disparities may widen.

Poverty reversal risk: Some projections suggest climate change could slow pace of poverty reduction, or even increase poverty rates by several percent points in coming decades under high warming.

Sectoral Impacts of Climate Change

Agriculture: Changes in rainfall and greater frequency and severity of droughts and floods will reduce agricultural productivity. Southern India in particular could see large declines in yields later this century.

Labor productivity: Heat stress reduces outdoor labor capacity; this not only lowers output directly but also may shift labor away from some sectors.

Health: Increase in heat related illnesses, vector borne diseases, and respiratory diseases; costs of public health interventions rise.

Infrastructure & Coastal Zones: Sea level rise, coastal flooding, storm surges threaten coastal settlements, ports, and livelihoods. Damage to roads, power, water systems, and drainage from extreme weather becomes more frequent.

Key Limitations of the Study

This article is a synthesis rather than a new empirical estimation. Quantitative ranges reported derive from heterogeneous models and scenario assumptions (different warming pathways, adaptation assumptions). More localized empirical studies with micro-level data and integrated assessment models calibrated to Indian sub-regions would improve precision for policy design.

Conclusion

Climate change poses a multi-faceted economic challenge to India that is already materializing through lost agricultural output, reduced labor productivity, infrastructure damage, and fiscal pressures. The scale of potential losses is large but not predictable and strategic, well-sequenced investments in adaptation, resilient infrastructure, nature-based solutions, and mobilization of finance can substantially reduce damages and support inclusive growth. Given India's development priorities, integrating climate risk into planning and accelerating adaptation finance are urgent. Climate change is no longer a distant threat to India, it already imposes measurable economic costs, and the future risks are large. Without urgent action, India risks losing a sizeable fraction of its GDP by mid to late century, with particularly severe impacts for vulnerable populations and key economic sectors. However, the costs of action are far

smaller than those of in action, especially when considering co benefits for health, employment and sustainable development. Policy choices made now on emissions trajectories, adaptation investment, institutional strengthening will shape whether India can sustain robust growth that is both resilient and inclusive.

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