

A Comprehensive Review of Climate Change: Environmental Impacts, Economic Challenges, and Policy Responses

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ABSTRACT

Climate change has also shifted from an environmental externality to a systemic development risk, with implications for economic growth, agricultural productivity, labor supply, public health, food prices, infrastructure, energy security and distributional outcomes. The paper draws on peer-reviewed research and authoritative institutional sources, and each substantive empirical claim is linked to an in-text citation. India is facing high climate variability and warming. The India Meteorological Department (IMD) reported that 2024 was the warmest year in the national instrumental record at 0.65°C above the 1991–2020 average, while 2025 was the eighth-warmest year at 0.28°C above the average (IMD, 2025, 2026). The paper also looks at agricultural heat stress, labor productivity, health, urban vulnerability, climate finance, energy transition and inequality. The core argument is that India's best climate strategy is not a choice between development and mitigation, but an integrated climate-resilient development path that combines adaptation, low-carbon growth, social protection, technology, finance and institutional capacity.

Keywords: Climate change, Agriculture, Environment

INTRODUCTION

Climate change refers to shifts in climate patterns primarily driven by human activities, such as greenhouse gas emissions, land-use changes, and deforestation. Climate change impacts the environmental degradation and loss of ecosystem services, posing risks to humans, animals, and ecosystems, and contributing to inequalities in human well-being. The economics of climate change therefore combines inter temporal welfare, uncertainty, externalities, distribution, technological change, and collective action (Nordhaus 1991, 2017; Stern 2006; Tol 2018). Its synthesis highlights that climate change is already

impacting weather and climate extremes, ecosystems, human health, and economic systems, and that risks increase with warming (IPCC, 2021, 2022, and 2023). The economic literature has increasingly shifted from aggregate model projections to quasi-experimental and panel-data estimates. Dell *et al.* (2012) found that temperature shocks affect growth of the economy, while Burke *et al.* (2015) found the relation between the temperature-productivity was nonlinear. Kahn *et al.* (2021) analyzed the macroeconomic impacts of temperature rises. In India, agriculture provides millions of livelihood but the significant share of employment is still climate-sensitive. Climate change has effect on physical damages and macroeconomic transmission channels. India's exposure is multi-dimensional: heat, monsoon variability, floods, droughts, coastal hazards, and urban heat interweave with development pressures. India had recorded 2024 as warmest year, and 2025 was still considerably warmer than the 1991–2020 baseline (IMD, 2025, 2026). There is evidence associating temperature shocks with agriculture productivity and long-run economic performance (Dell *et al.*, 2012; Burke *et al.*, 2015; Kahn *et al.*, 2021). Further in India wheat evidence shows that extreme heat can reduce crop performance, and irrigation provides partial adaptation (Lobell *et al.*, 2012; Zaveri & Lobell, 2019). Much of the international climate economics literature is global or country-aggregated. Climate shocks can have spillover effects across several markets. For instance, heat can lower crop production, reduce the labor supply, and raise food prices. Adaptation is often considered a residual, not an endogenous economic choice. A better India-focused research agenda should therefore integrate physical exposure, economic sensitivity, and adaptive capacity. This systematic review addresses these knowledge gaps by providing an integrated synthesis of current evidence regarding the impacts of climate change. The paper addressing the challenges posed by climate change requires an integrated approach combining climate-resilient technologies and strengthening the adaptive capacity of farmers can help reduce climate-related agricultural losses while contributing long-term economic development.

OBJECTIVES

- To study out the environmental and economic consequences of climate change and evidence for approximately 2000–2025.
- To study the impact of climate change on Agriculture, Food Security and Rural Livelihoods
- To view out the climate report of India.

METHODOLOGY AND EVIDENCE STRATEGY

This study adopted a systematic literature review approach to synthesize existing evidence and used secondary-data synthesis rather than new estimate. Literature review based on peer-reviewed journal articles and reports from various organizations like IPCC, UNFCCC,

IMD, Government of India, World Bank, IEA etc. Literature review used physical climate evidence, empirical economic evidence and policy evidence. A source-to-claim crosswalk is provided later in the paper to reduce citation ambiguity. Numerical indicators are explicitly labelled by reference year.

LITERATURE REVIEW

Nordhaus (1991) discussed about the influential perspectives on the welfare economics of climate policy. **Dell *et al.* (2012)** showed the evidence of the temperature shocks which reduce the economic performance in poorer economies. **Burke *et al.* (2015)** discussed about the nonlinear global relationship between temperature and production. **Kahn *et al.* (2021)** highlighted the temperature increases have long-term consequences. Agriculture is exposed to heat, rainfall variability, drought, floods, pests and water stress. **Lobell *et al.* (2011)** estimate historical climate-related crop effects globally. **Challinor *et al.* (2014)** synthesize evidence on crop responses and adaptation. **Rosenzweig *et al.* (2014)** demonstrate the importance of crop-model uncertainty and adaptation in projecting future risks. **Lobell *et al.* (2012)** document extreme-heat effects on wheat senescence in India. **Zaveri and Lobell (2019)** show that irrigation can reduce the sensitivity of wheat yields to heat, but adaptation may generate water and energy trade-offs. These studies imply that adaptation should be evaluated on net welfare rather than yield effects alone. Heat reduces labour capacity through physiological stress and can affect working hours and productivity, especially in physically demanding outdoor occupations. The IPCC identifies heat exposure, food insecurity and disease as major climate-related health pathways (**IPCC, 2022**). **Somanathan *et al.* (2021)** provide India-specific evidence that extreme heat affects labour productivity and economic activity. Climate damages are unequally distributed. Poor households often have higher exposure and fewer assets for adaptation. **Hallegatte *et al.* (2016)** connect climate shocks with poverty dynamics, while **Diffenbaugh and Burke (2019)** identify an international inequality dimension. In India, distributional effects should be studied through household assets, employment type, gender, caste-neutral socioeconomic indicators, location and access to public services rather than national averages alone.

Literature Review Matrix

Author/year	Setting	Design / contribution	Core Finding	India Relevance
Nordhaus (2017)	Global	Welfare economics	Social cost of carbon	Policy appraisal
Stern (2006)	Global	Integrated assessment	Delayed action has large welfare costs	Intertemporal policy
Dell <i>et al.</i> (2012)	Global	Panel econometrics	Temperature shocks affect growth	Macro climate sensitivity

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Burke <i>et al.</i> (2015)	Global	Panel econometrics	Nonlinear temperature-productivity effect	Heat-growth mechanism
Carleton & Hsiang (2016)	Global	Synthesis	Multiple economic channels	Integrated assessment
Kahn <i>et al.</i> (2021)	Global	Cross-country panel	Persistent macro effects	Growth resilience
Lobell <i>et al.</i> (2012)	India	Crop-climate analysis	Extreme heat affects wheat	Direct India evidence
Zaveri & Lobell (2019)	India	Crop + irrigation analysis	Irrigation buffers heat effects	Adaptation trade-off
Somanathan <i>et al.</i> (2021)	India	Economic/labour evidence	Heat affects productivity	Employment
Diffenbaugh & Burke (2019)	Global	Distributional analysis	Warming increases inequality	Equity
IPCC (2023)	Global	Assessment	Risks increase with warming	Policy urgency

INDIA-SPECIFIC EVIDENCE: CLIMATE OBSERVATIONS

The India Meteorological Department’s 2025 climate statement reports an all-India annual mean land-surface air temperature anomaly of +0.28°C relative to the 1991–2020 long-term average, making 2025 the eighth warmest year since nationwide records began in 1901. The same statement identifies 2024 as the warmest year, with an anomaly of +0.65°C (IMD, 2026).

Indicator	Value	Interpretation	Source
2024 annual temperature anomaly	+0.65°C	Warmest year in national record	IMD (2025, 2026)
2025 annual temperature anomaly	+0.28°C	8th warmest year	IMD (2026)
2025 winter anomaly	+1.17°C	Above 1991–2020 average	IMD (2026)
2025 annual rainfall	1,274 mm; 110% of 1971–2020 LPA	Above long-period average	IMD (2026)

Figure 1. India climate observation pathway.

CLIMATE HAZARDS

Heat → drought/flood → crop stress → labour/health stress → economic losses

INDIA’S OFFICIAL EMISSIONS AND CLIMATE REPORTING

India’s Fourth Biennial Update Report (BUR4), submitted to the UNFCCC on 30 December 2024, is a primary official source for India’s greenhouse-gas inventory and mitigation information. The report should be preferred over secondary summaries when citing national inventory values (Government of India, 2024). The UNFCCC repository also records India’s Adaptation Communication and long-term low-emission development strategy, demonstrating that India’s climate policy architecture increasingly covers both mitigation and adaptation (UNFCCC, 2023, 2022).

Official source	Year	Use in research
India Fourth Biennial Update Report	2024	GHG inventory, mitigation actions
India Adaptation Communication	2023	Adaptation priorities and vulnerability
India LT-LEDS	2022	Long-term low-carbon development
India NDC / updated commitments	2022 onward	2030 mitigation targets
Economic Survey 2024–25	2025	Macroeconomic and adaptation context
Economic Survey 2025–26	2026	Recent policy and energy evidence
IMD climate statement	2026	Observed 2025 climate

INDIA: AGRICULTURE, FOOD SECURITY AND RURAL LIVELIHOODS

Indian agriculture is multidimensional affected by climate change. Increasing temperature affects the crop production, rainfall affects the planting and water availability and damage done by flood to standing crops, drought reduces agriculture productivity; and heat affects the irrigation. Adaptation is not costless. Irrigation helps to reduce crop sensitivity but it affects the groundwater by increasing extraction and energy consumption. Hence, an adaptation measure should be evaluated using net social benefits, including water sustainability and distributional effects (Zaveri & Lobell, 2019).

LABOUR PRODUCTIVITY AND HEALTH

The extreme heat has measurable implications for labour productivity in India. This is especially important because climate-sensitive employment is concentrated in agriculture, construction, manufacturing and informal services. The IPCC identifies heat stress as a major and growing risk to human health and labour capacity (IPCC, 2022). Policy responses should include heat-health action plans, occupational heat standards, work-rest cycles, shaded workspaces, hydration, early-warning systems and social protection. Adaptation can therefore be interpreted as an investment in human capital rather than merely as disaster expenditure.

URBAN CLIMATE RISK

Rapid urbanization increases exposure to heat and flooding through dense built environments, limited green space, drainage constraints and rising cooling demand. The IPCC identifies cities as critical sites for integrated climate action because urban systems concentrate people, infrastructure, energy consumption and economic activity (IPCC, 2022, 2023).

For Indian cities, climate-resilient development should integrate heat-action plans, cool roofs, urban forests, drainage, water security, public transport, energy-efficient buildings and distributed renewable energy.

Energy Transition and Development: India's climate policy faces a dual requirement: meeting rising electricity demand while reducing the carbon intensity of future growth. The energy transition therefore has implications for industrial competitiveness, energy security, employment, air pollution and external energy dependence (IEA, 2021; Government of India, 2026). The Economic Survey 2025–26 reports that non-fossil sources represented 51.93% of India's installed power capacity at the end of December 2025 (Government of India, 2026). Installed-capacity shares should not, however, be interpreted as equivalent to generation shares because renewable availability and dispatchability differ across technologies.

Climate Finance and the Economics of Adaptation: Climate finance is central because adaptation benefits are often local and public, while financing capacity differs across regions and households. The IPCC identifies finance, technology and institutional capacity as enabling conditions for climate action (IPCC, 2023). For India, climate finance should combine public budgets, development finance, private capital, green bonds, blended finance, insurance and concessional international resources. The key evaluation question is not only how much finance is mobilized but whether it reaches high-vulnerability communities and produces measurable reductions in expected losses.

CLIMATE CHANGE, INFLATION AND MACROECONOMIC STABILITY

Climate shocks can produce supply-side inflation through crop losses, food shortages, damaged logistics and energy disruptions.

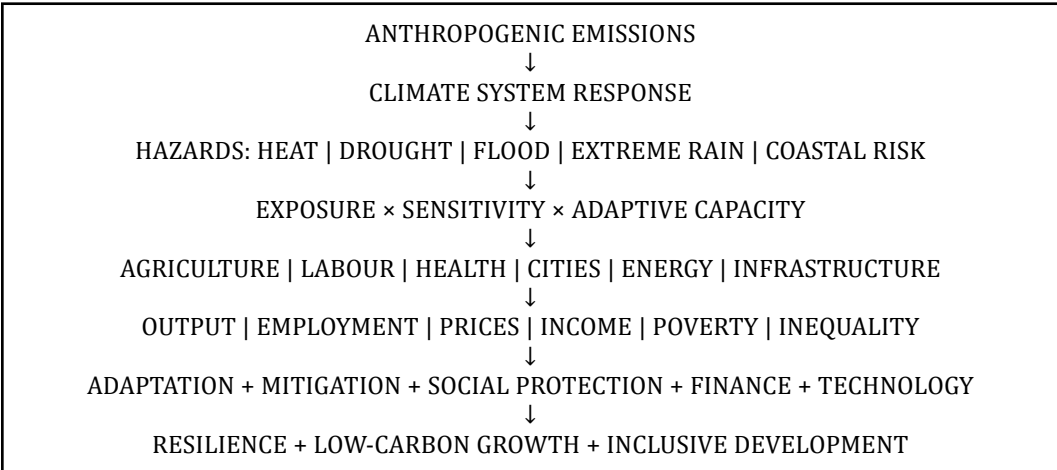


Figure 2: Conceptual Framework: Climate-Resilient Development

India 2000–2025 Evidence Dashboard

Domain	Key indicator	Period	Interpretation/source
Climate	Annual temperature anomaly	2024–2025	2024 warmest; 2025 eighth warmest (IMD)
Rainfall	Annual rainfall	2025	110% of 1971–2020 LPA (IMD)
Emissions	National inventory	Latest official inventory	Use BUR4 rather than unsourced estimates (GoI, 2024)
Energy	Non-fossil installed capacity	Dec. 2025	51.93% (Economic Survey 2025–26)
Adaptation	Domestic adaptation/ resilience spending	FY2016–FY2022	3.7% → 5.6% of GDP (Economic Survey 2025–26)
Agriculture	Heat-wheat relationship	India	Extreme heat reduces wheat performance (Lobell <i>et al.</i> , 2012)
Labour	Heat-productivity relationship	India	Extreme heat reduces productivity (Somanathan <i>et al.</i> , 2021)

POLICY RECOMMENDATIONS

- There should be anticipatory risk management through early warning and climate information.
- Climate-resilient agricultural systems should be developed based on crop diversification, water-efficient irrigation, heat-tolerant varieties and climate information services etc.
- Integrate climate risk into public infrastructure appraisal, municipal finance and land-use planning.
- Electricity flexibility system should be accelerated through transmission, storage and demand management alongside renewable expansion.
- To create the transparent climate-budget tagging and outcome indicators for adaptation expenditure.
- Climate finance should be strengthening by the states, municipalities, MSMEs and vulnerable households.
- Transition measures should be designed for workers and regions dependent on carbon-intensive industries.
- Climate-economic datasets should be established to support causal research and policy evaluation.

As we know climate impacts the poverty, infrastructure and labour markets and we cannot measure the welfare effects of climate change only through aggregate GDP. In India, the policy challenge is particularly complex further Urbanization also increases vulnerability by inefficient infrastructure. The irrigation can protect crops from heat but can increase the risk of groundwater extraction. Renewable energy can reduce emissions and energy-import exposure but requires grid flexibility and storage.

CONCLUSION

Climate change, most emerging issues of present world domain as India is facing its impacts through droughts, floods cyclones etc. which have become threats to sustainable development. Increasing global temperature from various sources is the cause of climate change and impacts. Climate change impacts the environmental degradation and loss of ecosystem services, posing risks to humans, animals, and ecosystems, and contributing to inequalities in human well-being. Climate change creates a structural risk to India's development trajectory. The evidence and economic research demonstrates that climate shocks can affect production, agriculture, labour etc. India studies found that heat can damage crops and labour productivity. As per the IMD observations 2024 was India's warmest year in the record and 2025 remained among the warmest years. The IPCC identifies cities as critical sites for integrated climate action because urban systems concentrate people, infrastructure, energy consumption and economic activity. As per the

review the climate shocks can produce supply-side inflation through crop losses, food shortages, damaged logistics and energy disruptions. The next generation of research should combine high-resolution climate data with district-level economic outcomes and causal identification.

REFERENCES

- Auffhammer, M. (2018). Quantifying economic damages from climate change. *Journal of Economic Perspectives*, 32(4), 33–52.
- Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. *Nature*, 527, 235–239. <https://doi.org/10.1038/nature15725>
- Carleton, T. A., & Hsiang, S. M. (2016). Social and economic impacts of climate. *Science*, 353(6304), aad9837. <https://doi.org/10.1126/science.aad9837>
- Challinor, A. J., Watson, J., Lobell, D. B., Howden, S. M., Smith, D. R., & Chhetri, N. (2014). A meta-analysis of crop yield under climate change and adaptation. *Nature Climate Change*, 4, 287–291.
- Dell, M., Jones, B. F., & Olken, B. A. (2012). Temperature shocks and economic growth: Evidence from the last half century. *American Economic Journal: Macroeconomics*, 4(3), 66–95.
- Diffenbaugh, N. S., & Burke, M. (2019). Global warming has increased global economic inequality. *Proceedings of the National Academy of Sciences*, 116(20), 9808–9813.
- Hallegatte, S., Bangalore, M., Bonzanigo, L., Fay, M., Kane, T., Narloch, U., Rozenberg, J., Treguer, D., & Vogt-Schilb, A. (2016). Shock waves: *Managing the impacts of climate change on poverty*. World Bank.
- Hsiang, S., Kopp, R., Jina, A., Rising, J., Delgado, M., Mohan, S., Rasmussen, D., Muir-Wood, R., Wilson, P., Oppenheimer, M., Larsen, K., & Houser, T. (2017). Estimating economic damage from climate change in the United States. *Science*, 356(6345), 1362–1369.
- India Meteorological Department. (2025). Annual climate summary 2024. Ministry of Earth Sciences, Government of India.
- India Meteorological Department. (2026). Statement on the climate of India during 2025. Ministry of Earth Sciences, Government of India.
- Intergovernmental Panel on Climate Change. (2021). *Climate change 2021: The physical science basis*. Cambridge University Press.
- Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Impacts, adaptation and vulnerability*. Cambridge University Press.
- Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Mitigation of climate change*. Cambridge University Press.
- Intergovernmental Panel on Climate Change. (2023). *Climate change 2023: Synthesis report*. IPCC.
- International Energy Agency. (2021). India energy outlook 2021. IEA.
- Kahn, M. E., Mohaddes, K., Ng, R. N. C., Pesaran, M. H., Raissi, M., & Yang, J.-C. (2021). Long-term macroeconomic effects of climate change: A cross-country analysis. *Energy Economics*, 104, 105624.
- Lobell, D. B., Schlenker, W., & Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. *Science*, 333(6042), 616–620.

- Lobell, D. B., Sibley, A., & Ortiz-Monasterio, J. I. (2012). Extreme heat effects on wheat senescence in India. *Nature Climate Change*, 2, 186–189.
- Mendelsohn, R., Dinar, A., & Williams, L. (2006). The distributional impact of climate change on rich and poor countries. *Environment and Development Economics*, 11(2), 159–178.
- Nordhaus, W. D. (1991). To slow or not to slow: The economics of the greenhouse effect. *The Economic Journal*, 101(407), 920–937.
- Nordhaus, W. D. (2017). Revisiting the social cost of carbon. *Proceedings of the National Academy of Sciences*, 114(7), 1518–1523.
- Pindyck, R. S. (2013). Climate change policy: What do the models tell us? *Journal of Economic Literature*, 51(3), 860–872.
- Rosenzweig, C., Elliott, J., Deryng, D., Ruane, A. C., Müller, C., Arneth, A., Boote, K. J., Folberth, C., Glotter, M., Khabarov, N., Neumann, K., Piontek, F., Pugh, T. A. M., Schmid, E., Stehfest, E., Yang, H., & Jones, J. W. (2014). Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. *Proceedings of the National Academy of Sciences*, 111(9), 3268–3273.
- Somanathan, E., Kotia, A., & Raghavan, A. (2021). Impact of temperature on productivity and labour in India. In *climate and economic productivity literature*.
- Stern, N. (2006). *The economics of climate change: The Stern review*. Cambridge University Press.
- Tol, R. S. J. (2018). The economic impacts of climate change. *Review of Environmental Economics and Policy*, 12(1), 4–25.
- Zaveri, E., & Lobell, D. B. (2019). The role of irrigation in changing wheat yields and heat sensitivity in India. *Nature Communications*, 10, 4144. <https://doi.org/10.1038/s41467-019-12183-9>
- Government of India. (2024). India's fourth biennial update report to the United Nations Framework Convention on Climate Change. Ministry of Environment, Forest and Climate Change.
- Government of India. (2025). *Economic Survey 2024–25*. Ministry of Finance.
- Government of India. (2026). *Economic Survey 2025–26*. Ministry of Finance.
- United Nations Framework Convention on Climate Change. (2022). *India's long-term low-carbon development strategy*.
- United Nations Framework Convention on Climate Change. (2023). *India: Adaptation communication*.
- United Nations Framework Convention on Climate Change. (2024). India: Biennial update report (BUR4).
- United Nations Environment Programme. (2024). *Emissions gap report 2024*.
- World Bank. (2022). Climate investment opportunities in India's cooling sector.
- World Bank. (2024). World development indicators: Greenhouse gas emissions database (EDGAR/JRC).
- World Meteorological Organization. (2025). State of the climate in Asia 2024.