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Climate Change and Sustainable Development: Challenges, Strategies and Policy Perspectives with Evidence from India

M. Santhoshkumar

Assistant Professor, Department of Economics, Thiruvalluvar University, Vellore, Tamil Nadu, India

Email: santhoshmurugan430@gmail.com

Abstract

Climate change has become a systemic development challenge because it affects economic productivity, livelihoods, health, food and water security, infrastructure, ecosystems and the distribution of development gains. This paper examines the relationship between climate change and sustainable development, with particular emphasis on India. It integrates a structured review of theoretical and empirical literature with secondary-data analysis using official Indian and international sources. The study develops a conceptual framework linking economic activity, greenhouse-gas emissions, climate risks and sustainable-development outcomes, and formulates testable hypotheses concerning renewable energy, emissions intensity, forest cover and SDG-13 performance. The India evidence indicates substantial progress alongside continuing structural challenges. India reduced the emissions intensity of GDP by 36% between 2005 and 2020; the share of non-fossil sources in installed electricity-generation capacity reached 46.52% by October 2024; forest and tree cover reached 25.17% of geographical area in the 2023 assessment; and the national SDG-13 score increased from 54 in 2020-21 to 67 in 2023-24. Renewable-energy capacity excluding large hydro expanded rapidly, with solar providing a major share of recent additions. These trends are consistent with movement towards a lower-emission development pathway, but they do not by themselves establish causality or eliminate climate vulnerability. The paper argues that India's sustainable-development strategy should combine mitigation with adaptation, climate-resilient agriculture, ecosystem restoration, green finance, technological innovation, just-transition measures and stronger subnational implementation.

Keywords: Climate change; sustainable development; India; renewable energy; emissions intensity; climate adaptation; mitigation; green finance; SDGs; climate resilience

1. Introduction

Climate change is increasingly understood as a development problem as well as an environmental problem. Changes in temperature and precipitation, extreme weather events, sea-level rise and ecosystem disruption can affect productive resources. The effects are transmitted through agriculture, energy, labour markets, health, infrastructure, trade, public finance and household welfare. The development consequences are particularly significant where livelihoods depend on climate-sensitive natural resources and where households have limited capacity to absorb shocks.

The sustainable-development perspective emerged from the recognition that economic growth cannot be evaluated only by current output. The Brundtland Commission defined sustainable development in terms of meeting present needs without compromising the ability of future generations to meet their own needs. The 2030 Agenda subsequently translated this broad idea into 17 Sustainable Development Goals (SDGs), with climate action explicitly represented by SDG 13 but interconnected with poverty, hunger, health, energy, cities, responsible consumption, oceans and terrestrial ecosystems.

India presents a particularly important case. The country must sustain economic growth, expand employment and improve living standards while reducing the environmental intensity of growth and adapting to climate risks. This creates a dual policy challenge: development needs increase energy, infrastructure and resource demand, while climate objectives require decarbonization, resource efficiency and resilience.

This article contributes by combining four elements: (i) the theoretical relationship between climate change and sustainable development; (ii) a structured review of international and India-focused literature; (iii) an integrated descriptive analysis of recent official indicators; and (iv) a policy framework covering mitigation, adaptation, finance, technology and social inclusion.

2. Objectives

- To examine the conceptual and theoretical relationship between climate change and sustainable development.
- To review major empirical findings on climate-growth, energy-emissions and climate-development relationships.

- To analyse selected India-specific secondary indicators of climate action and sustainable development.
- To formulate hypotheses connecting renewable energy, emissions intensity, ecosystem protection and sustainable-development performance.
- To identify policy priorities for climate-resilient and inclusive development in India.

3. Scope and Significance

The paper focuses on India while drawing on international evidence. It covers mitigation, adaptation, renewable energy, forests, agriculture, climate finance, technology and SDG implementation. The analysis is a secondary-data study. It does not claim to estimate causal effects from the descriptive indicator series; rather, it triangulates official indicators with established empirical literature and policy documents.

4. Review of Literature

4.1 Theoretical foundations

The economic literature on climate change begins from the recognition that greenhouse-gas emissions create an externality: private emission decisions do not fully capture social damages imposed across time and space. Pigouvian reasoning supports corrective instruments, while modern climate economics emphasises uncertainty, intergenerational distribution and the option value of early action. Stern (2007) framed climate change as a major market failure and argued that the costs of inaction can be large relative to the costs of mitigation.

The Environmental Kuznets Curve literature asks whether environmental degradation initially rises with income and subsequently declines after a turning point. Results are mixed across pollutants, countries and periods. India-focused studies likewise find that the growth-emissions relationship depends on energy structure, trade, technology and model specification.

4.2 Climate change and economic growth

Recent India-focused evidence reinforces the macroeconomic relevance of climate shocks. Verma and Giri (2026) report persistent dampening effects of temperature shocks on growth in an India time-series framework and argue that climate variability should be integrated into macroeconomic stabilisation and development planning. Earlier studies have examined growth, energy use and emissions using cointegration, causality and VAR methods, with heterogeneous results.

4.3 Renewable energy and sustainable development

The renewable-energy literature increasingly treats clean energy as a bridge between climate mitigation and development. India studies report that economic development, environmental conditions and policy incentives influence renewable-energy consumption. Dynamic ARDL evidence for 2000-2020 finds that economic efficiency and environmental sustainability can be associated with increased renewable-energy consumption. Other work highlights transition costs, grid integration, storage and regional differences.

4.4 Low-carbon pathways

Macroeconomic modelling for India indicates that high growth can be compatible with low-carbon pathways when investment shifts toward low-carbon technologies and energy efficiency. However, the transition can create adjustment costs for fossil-fuel-intensive sectors and regions. This supports a just-transition perspective in which workers, consumers and regions affected by structural change receive support.

4.5 Ecosystems, forests and resilience

Forests and tree cover contribute to carbon sequestration, biodiversity, water regulation and livelihood security. India's State of Forest Report provides a recurring national evidence base. The 2023 assessment reports 21.76% forest cover and 3.41% tree cover, together 25.17% of geographical area. The development significance is not limited to carbon storage; ecosystems also provide adaptation services.

4.6 SDGs and climate action

Climate action is cross-cutting across the SDGs. NITI Aayog's SDG India Index 2023-24 reports that India's composite SDG score improved from 66 in 2020-21 to 71 in 2023-24, while Goal 13 increased from 54 to 67. This is useful as a policy-performance indicator, although an index score is not a direct measure of climate damages avoided.

4.7 Research gap

Three gaps motivate this paper. First, many studies focus narrowly on emissions-growth or renewable-energy-growth relationships, whereas sustainable development requires simultaneous consideration of mitigation, adaptation, ecosystems and social outcomes. Second, econometric studies often use older periods and therefore do not fully reflect recent changes in

renewable capacity, NDC implementation and SDG localisation. Third, policy discussions sometimes report achievements without connecting them to a coherent conceptual framework. The present study addresses these gaps through integrated framing and transparent descriptive analysis.

5. Conceptual and Theoretical Framework

The framework combines environmental economics, sustainable-development theory and climate-resilience thinking. Economic activity generates energy and material demand; the composition of energy supply and technology determines part of associated emissions. Emissions contribute to climate change, while climate shocks affect productive assets, labour, health and ecosystems. Policy interventions can act at several points.

Stage	Mechanism	Development implication
Economic activity	Production, transport, construction and consumption require energy/resources	Income and employment, but environmental pressure
Energy/technology	Fossil vs. low-carbon technologies influence emission intensity	Energy security, costs and competitiveness
Emissions	GHG accumulation changes climate risks	Long-term environmental externality
Climate impacts	Heat, floods, droughts, storms and sea-level rise	Losses in agriculture, health, infrastructure and productivity
Adaptation	Infrastructure, insurance, early warning, resilient agriculture	Reduces vulnerability
Mitigation	Renewables, efficiency, forests and low-carbon industry	Reduces future climate damages
Inclusion	Distribution of costs and benefits	Determines social sustainability and just transition

6. Hypotheses

The hypotheses are framed as empirical propositions that can be tested in future econometric work using annual or state-level panel data. In this paper, they are assessed only through descriptive triangulation.

H1: Greater deployment of renewable energy is associated with improved environmental sustainability and lower emissions intensity.

H2: Reductions in the emissions intensity of GDP are positively associated with progress toward climate-compatible sustainable development.

H3: Expansion and conservation of forest and tree cover strengthen the environmental-resilience component of sustainable development.

H4: Stronger climate-action performance is associated with broader progress in sustainable-development indicators.

H5: Climate-compatible development requires both mitigation and adaptation; mitigation alone is insufficient for protecting development outcomes.

7. Research Methodology

7.1 Research design

The study adopts a descriptive, analytical and documentary research design. Secondary data are drawn from official Indian government sources and internationally recognised institutions. The analysis combines trend comparison, percentage change, CAGR calculations and policy-document analysis.

7.2 Data sources

Indicator	Source	Reference period
Renewable-energy installed capacity	MNRE	FY 2013-14 to FY 2024-25
SDG-13 score	NITI Aayog SDG India Index	2020-21 and 2023-24

Forest cover	Forest Survey of India ISFR	2013, 2021, 2023
GHG emissions and emissions intensity	MoEFCC / BUR-4	2005-2020
CO2e per capita	World Bank WDI	2024 latest
Climate commitments	UNFCCC / Government of India	2015-2026

7.3 Analytical techniques

Percentage change, CAGR, trend comparison, index-score comparison and qualitative policy analysis are used. CAGR is calculated as [(Vt/V0)^(1/n) − 1] × 100. Indicators are not merged into a new composite index because their definitions, units and reference periods differ.

7.4 Limitations

The paper does not estimate causal coefficients. Official indicators use different methodologies and reference years. Installed capacity is not equivalent to generation; an SDG score is not a direct measure of emissions; and forest-cover change does not imply equivalent changes in ecological quality or carbon density.

8. India-Specific Secondary Data Analysis

8.1 Renewable-energy expansion

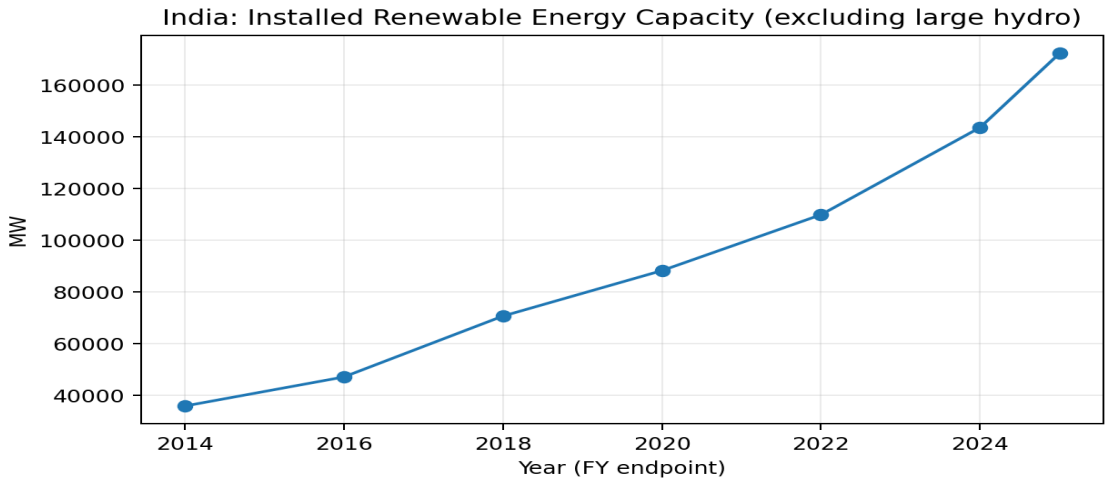
MNRE's year-wise statistics show substantial expansion in renewable-energy capacity excluding large hydro. Cumulative capacity was 35,849.59 MW at the end of March 2014. Based on the published annual additions, it reached 243,489.70 MW by March 2025. Solar has been a major driver of recent additions.

FY endpoint	RE capacity excluding large hydro (MW)	Interpretation
2013-14	35,849.59	Baseline
2015-16	47,091.39	Expansion
2017-18	70,651.44	Expansion
2019-20	88,255.31	Near 100 GW
2021-22	109,885.39	Acceleration

2023-24	143,644.50	Strong additions
2024-25	172,368.15	Major expansion

Descriptively, capacity excluding large hydro increased by approximately 381% between March 2014 and March 2025, corresponding to a CAGR of approximately 15.3%. This is a capacity trend, not a causal estimate of emissions reduction.

Figure 1: India's installed renewable-energy capacity excluding large hydro, selected fiscal-year endpoints



Source: Ministry of New and Renewable Energy

8.2 Emissions intensity and non-fossil capacity

India's official climate reporting provides evidence of declining emissions intensity alongside increasing non-fossil capacity. MoEFCC reports a 36% reduction in GDP emissions intensity between 2005 and 2020. India's Fourth Biennial Update Report also reports that, by October 2024, non-fossil sources represented 46.52% of installed electricity-generation capacity.

Indicator	Reference	Latest reported value	Interpretation
GDP emissions intensity	2005 baseline	36% reduction by 2020	Substantial decline

Non-fossil installed capacity	2015 NDC target 40% by 2030	46.52% by Oct. 2024	Above original target threshold
Updated NDC emissions intensity	2005 baseline	45% reduction target by 2030	Forward commitment
Long-term net-zero objective	Policy horizon	2070	Long-term transition goal

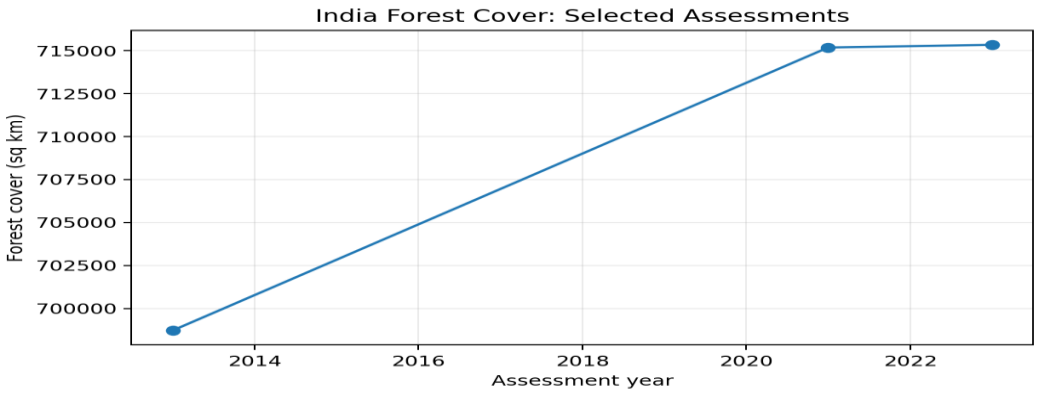
Interpretation should remain cautious: installed capacity, electricity generation, total energy consumption and emissions are different indicators. Capacity growth reduces emissions only when supported by generation, grid integration, storage, demand management and displacement of higher-emission sources.

8.3 Forest and tree cover

ISFR 2023 reports forest cover of 715,343 sq km (21.76% of geographical area) and tree cover of 112,014 sq km (3.41%), giving combined forest and tree cover of 25.17%. Compared with 2021, total forest and tree cover increased by 1,445 sq km.

Assessment	Forest cover (sq km)	Forest cover (%)
2013	698,712	~21.25
2021	715,187	~21.75
2023	715,343	21.76

Figure 2: India forest-cover trend across selected assessments



Source: Forest Survey of India, ISFR 2023.

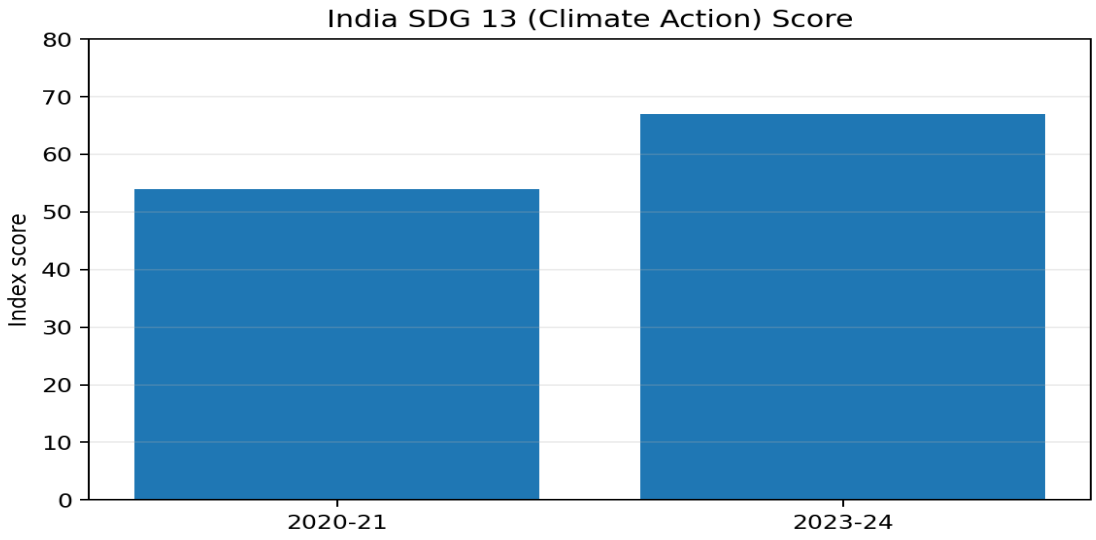
Forest and tree cover contribute to mitigation and adaptation, but area indicators should not be treated as complete measures of forest quality, biodiversity or carbon density.

8.4 SDG-13 Performance

NITI Aayog's SDG India Index 2023-24 reports that India's national composite SDG score improved from 66 in 2020-21 to 71 in 2023-24. Goal 13 increased from 54 to 67 and entered the Front Runner category.

Measure	2020-21	2023-24	Change
India composite SDG Index	66	71	+5 points
SDG 13: Climate Action	54	67	+13 points
SDG 13 relative change	54	67	+24.1%

Figure 3: India's SDG-13 score, 2020 – 21 and 2023 – 24



Source: NITI Aayog, SDG India Index 2023-24.

8.5 Selected environmental indicators

Indicator	India value/reference	Interpretive relevance
CO2e emissions excluding LULUCF per capita	2.2 t CO2e/person, 2024	Below the reported world value of 4.7
Forest area	24.5% of land, 2023	Importance of land-based climate policy

Access to electricity	99.9%, 2024	Near-universal reported access
Freshwater withdrawals	45% of internal resources, 2022	Water-management pressure
Renewable electricity excluding hydro	9.2%, 2021	Generation indicator; differs from capacity share

These indicators illustrate why sustainable development requires a portfolio approach. Energy access can improve while water stress remains significant; renewable capacity can expand while fossil generation remains important; and forest area can increase while ecosystem quality varies spatially.

9. Climate Change, Agriculture and Rural Development

Agriculture is central to India's sustainable-development challenge because it supports livelihoods while remaining exposed to heat, rainfall variability, droughts, floods, pests and water stress. Climate-smart agriculture should combine productivity enhancement with resilience and resource efficiency. Crop diversification, micro-irrigation, soil-health management, agroforestry, weather advisories, resilient seed varieties and insurance can reduce exposure to climate shocks.

Adaptation policies should recognise farm households' financial constraints and imperfect information. Public investment in rural infrastructure, storage, irrigation and extension can complement market instruments. Digital weather information and local climate advisories can improve farm decisions.

10. Climate Change and Health

Climate change affects health directly through heat stress and extreme events and indirectly through air pollution, water quality, food security and vector-borne disease patterns. Heat exposure can reduce labour productivity, especially for outdoor workers. Sustainable development therefore requires climate risk to be integrated into health surveillance, urban planning, occupational safety and emergency preparedness.

11. Sustainable Cities and Infrastructure

Urbanisation increases the importance of resilient infrastructure. Urban climate policy should prioritise public transport, efficient buildings, drainage, water conservation, waste

management, urban vegetation and heat-action plans. Infrastructure appraisal can incorporate climate-risk screening so roads, bridges, electricity networks, hospitals and water systems remain functional under plausible future conditions.

12. Green Finance and Investment

Climate-compatible development requires sustained investment. Public finance can crowd in private capital through risk-sharing, guarantees, concessional finance and stable policy frameworks. Green bonds, blended finance, transition finance and climate-risk disclosure can improve capital allocation. Green finance should be linked to measurable environmental and social outcomes to reduce greenwashing risks.

Recent India-focused research increasingly examines green finance as a determinant of renewable-energy transition, connecting finance with emissions, growth, population and trade. This supports treating finance as an enabling institution rather than a separate financial-sector issue.

13. Just Transition and Social Inclusion

A transition away from carbon-intensive activities can create employment opportunities in renewable energy, energy efficiency, electric mobility, construction, ecosystem restoration and circular-economy activities. It can also impose costs on workers, firms and regions dependent on fossil fuels. A just-transition framework should combine reskilling, social protection, regional diversification and worker participation.

Climate policies can have different effects across income groups. Energy-price reforms, for example, may affect low-income households more strongly unless accompanied by targeted transfers or affordable clean-energy alternatives. Climate policy should therefore be evaluated using both environmental and distributional criteria.

14. Discussion of Hypotheses

Hypothesis	Secondary evidence	Assessment
H1	Large renewable-capacity expansion; solar major recent driver	Consistent descriptively; causal effect not estimated

H2	36% reduction in GDP emissions intensity, 2005-2020	Consistent descriptively; attribution requires econometrics
H3	25.17% combined forest/tree cover in 2023; increase since 2021	Consistent with resilience proposition
H4	SDG-13 score rose 54 to 67	Consistent descriptively; index is not causal
H5	Climate risks remain despite mitigation progress	Supported conceptually and by policy evidence

This is a hypothesis-screening exercise rather than a statistical test. A full causal test would require consistent annual or state-level panel data, control variables, appropriate stationarity/cointegration treatment, and an identification strategy.

15. Policy Implications

- Integrate climate risk into national, state and local development planning and public-investment appraisal.
- Accelerate renewable-energy deployment while prioritising grid flexibility, storage, transmission and reliability.
- Track both renewable capacity and renewable generation, alongside emissions intensity and absolute emissions.
- Scale climate-resilient agriculture through irrigation efficiency, diversification, weather services, soil management and risk-transfer instruments.
- Protect and restore forests, mangroves, wetlands and other ecosystems while monitoring ecological quality as well as area.
- Expand climate finance and reduce the cost of capital for adaptation and mitigation projects.
- Support just transition through reskilling, social protection and regional diversification in carbon-intensive areas.
- Strengthen local climate governance and community participation.
- Improve climate-data systems so environmental, economic, health and social indicators can be analysed jointly.
- Strengthen university-government-industry collaboration for climate innovation.

16. Conclusion

Climate change and sustainable development are inseparable policy challenges. Climate change can weaken development through damage to productive assets, agriculture, health, infrastructure and ecosystems, while unsustainable development can increase the drivers of climate change. The appropriate response is therefore a transition toward development that is productive, inclusive, resource-efficient and resilient.

India's recent secondary evidence demonstrates significant movement in this direction. Renewable-energy capacity has expanded rapidly; emissions intensity of GDP has declined substantially since 2005; non-fossil capacity has increased; forest and tree cover has expanded; and the SDG-13 score has improved. These developments are important, but they should be interpreted as components of a continuing transition rather than evidence that climate risks have been solved.

The next phase should emphasise quality and resilience in addition to scale: renewable generation rather than capacity alone; reliable and affordable clean energy; climate-resilient agriculture; ecosystem integrity; adaptive urban infrastructure; accessible climate finance; and a just transition. A useful research extension is a state-level panel analysis combining SDG scores, renewable-energy capacity, emissions intensity, economic output, forest cover, climate shocks and social indicators.

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