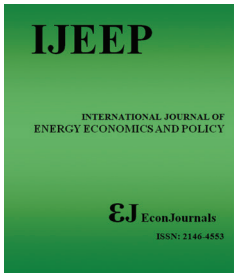

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Economic Growth and Environmental Quality Indicators

T. Sasikala[1], Zakiya Abdul Samad[2], N. Robindro Singh[3], J. Sathya[1]*, J. Gayathri[4]

[1]Sri Sarada College for Women (Autonomous), Salem, Tamil Nadu, India, [2]Department of Finance and Economics, Edinburgh Business School, Heriot-Watt University, Knowledge Park, Dubai, UAE, [3]Department of Accounting and Finance, College of Business and Economics, University of Kabridahar, India, [4]Department of Commerce and Financial Studies, Bharathidasan University, Tiruchirappalli, India. *Email: sathyaeco81@gmail.com

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ABSTRACT

The economic growth of a nation is deeply intertwined with the availability and quality of its environmental resources. However, industrialisation, urbanisation, and agricultural expansion often pursued in the name of development have led to the overexploitation of natural assets, resulting in environmental degradation, climate change, and biodiversity loss. This paper examines the trade-off between economic growth, measured by Gross Domestic Product (GDP), and environmental quality indicators such as CO□ emissions, maximum, minimum, and mean temperatures, total greenhouse gas emissions, water stress levels, annual rainfall, and freshwater withdrawals by agriculture and industry. Drawing on data from 1990 to 2020, the study employs statistical analysis to investigate these relationships in the Indian context. The findings reveal a significant and positive correlation between GDP growth and environmental degradation, particularly in terms of rising emissions and temperature levels, increased water stress, and unsustainable freshwater use. These results underscore the need for policies that align economic development with environmental sustainability to safeguard long-term growth and resilience.

Keywords: Economic Growth, Gross Domestic Product, CO_2 Emissions, Temperature, Water Stress, Environmental Sustainability
JEL Classifications: Q56, O44, Q53, Q25, and Q54

1. INTRODUCTION

The relationship between economic growth and environmental quality is inherently complex and multifaceted. On one hand, the environment provides essential natural resources such as land, water, air, and energy that fuel economic development. On the other hand, it absorbs the waste and emissions resulting from economic activities, including industrial production, transportation, and agricultural expansion. While a healthy environment serves as a foundation for sustainable economic growth, rapid economic expansion often exerts considerable pressure on ecological systems. This paradox underscores a fundamental tension: although economic growth is indispensable for improving national well-being and reducing poverty, it frequently comes at the cost of environmental degradation in the form of resource depletion, pollution, and climate change.

In the Indian context, this trade-off has become increasingly apparent over the past three decades. Since the early 1990s, India has experienced a remarkable trajectory of GDP growth, driven by structural reforms, industrialisation, and global integration. However, this growth has been accompanied by rising carbon dioxide (CO_2) and greenhouse gas (GHG) emissions, increasing average and extreme temperatures, declining air and water quality, water stress, and escalating demands on freshwater resources particularly in agriculture and industry. These environmental challenges not only threaten ecological sustainability but also risk undermining the long-term foundations of economic prosperity and public health.

Recognising the dual imperative of sustaining economic momentum while preserving environmental quality, this study aims to empirically analyse the long-run trade-off between

economic growth and environmental indicators in India. Using annual data from 1990 to 2020, the paper examines the relationship between GDP and key environmental variables, including CO_2 emissions, mean, maximum and minimum temperature, total GHG emissions, level of water stress, annual rainfall, and annual freshwater withdrawals by agriculture and industry. The findings seek to contribute to policy debates on achieving a balance between developmental and environmental goals, thereby supporting a more inclusive and sustainable model of growth.

This study is grounded in the premise that economic growth and environmental quality are interconnected through a dynamic relationship. Economic activities, particularly industrialisation, urbanisation, and agricultural expansion drive GDP growth but simultaneously contribute to environmental degradation through increased CO_2 emissions, rising temperatures, water stress, and resource depletion. This relationship aligns with the Environmental Kuznets Curve (EKC) hypothesis, which suggests that environmental degradation initially increases with economic growth, but after reaching a certain income level, further growth leads to environmental improvement due to better technologies and stricter regulations (Dinda, 2004). In the short term, the direct contribution of green finance to economic growth remains modest, mainly due to less integration of green finance within economic systems as well as institutional barriers (Dahhou et al., 2025). By examining long-term data on GDP and multiple environmental indicators, this study aims to identify patterns of interaction and assess the sustainability of India's growth trajectory.

1.1. Research Objectives

- To analyse the long-term trend of economic growth in India, measured through Gross Domestic Product (GDP)
- To assess the temporal changes in environmental quality using indicators such as CO_2 emissions, temperature (mean, maximum, and minimum), greenhouse gas emissions, water stress, rainfall, and freshwater withdrawals in agriculture and industry
- To evaluate the long-run relationship and trade-offs between economic growth and environmental quality in India.

2. LITERATURE REVIEW

The interplay between economic growth and environmental quality has been a central focus of research, with various studies investigating how economic development impacts environmental indicators such as CO_2 emissions, temperature rise, and water stress. While economic growth often leads to increased resource consumption and environmental degradation, it also has the potential to drive technological innovations and efficiencies that promote sustainability. This review synthesizes key studies exploring the relationship between economic growth and environmental degradation, with a particular focus on CO_2 emissions, temperature effects, and water usage.

2.1. Economic Growth and CO_2 Emissions

The relationship between economic growth and CO_2 emissions has been widely studied, particularly in the context of developing countries. Misra (2015) found a significant long-run positive relationship between economic growth (measured in terms of GDP), energy consumption, and CO_2 emissions in India. The study suggests that the growth in CO_2 emissions is largely driven by India's dependence on conventional energy sources such as coal and oil, highlighting the need for a transition to cleaner energy sources to mitigate environmental impacts (Misra, 2015).

Expanding on this, Soytas et al. (2007) explored the relationship between energy consumption, economic growth, and CO_2 emissions in Turkey. Their findings suggest a bidirectional causality between energy consumption and economic growth, though the link between economic growth and CO_2 emissions is more complex and context dependent. These results suggest that while economic growth initially leads to increased emissions, future technological advancements could decouple economic growth from environmental harm (Soytas et al., 2007).

Onofrei et al. (2022) conducted a study of 27 EU member states and found a long-run relationship between economic growth and CO_2 emissions. Their research supported the Environmental Kuznets Curve (EKC) hypothesis, which postulates that as economies grow, they initially increase environmental degradation, but later, this relationship reverses as economies develop cleaner technologies and adopt more sustainable practices (Onofrei et al., 2022). These findings suggest that policies aimed at fostering sustainable economic growth are essential for long-term environmental preservation.

2.2. Temperature Rise and Economic Growth

The impact of rising temperatures on economic performance is an emerging area of research. Srijana (2023) refers to the findings of Benjamin F. Jones, which suggest that a one-degree increase in temperature could result in a 2% reduction in global economic growth. The study emphasizes the significant negative effects that climate change could have on productivity, especially in sectors like agriculture, which are highly sensitive to temperature variations.

Supporting this, Dell et al. (2011) found that temperature increases adversely affect economic output in low-income countries, particularly through their effects on agricultural productivity. This highlights the vulnerability of poorer nations to climate change and the need for adaptive strategies that can mitigate its economic impact.

2.3. Forest Area and Economic Growth

In India forest economy is identified as a multi-billion dollar industry. It is capable of fulfilling the entire country's green needs in future. Forests were found as an excellent source of fossil-fuel substitutes, without compromising food security, without leading to forest degradation, and while increasing forest cover (Chhatre and Kattamuri, 2022).

Bhargava and Alam (2025) found that the sectors viz. agriculture, forestry, fishing and industry had a significant negative impact on forest cover in India. Services and net foreign direct investment (FDI) were found to have a detrimental negative impact in the short run. But in the long run, agriculture, forestry and fishing have

found a substantial negative impact, and services and net FDI had a significant positive impact on the forest cover.

2.4. Water Stress and Economic Growth

Water stress is another environmental factor that significantly impacts economic growth, particularly in agriculture-dominated economies. Badhwar (2022) highlighted that rising water stress in India could reduce the country's GDP by up to 6%, largely because agriculture accounts for approximately 80% of the country's total water withdrawals. This underscores the critical importance of water resource management to ensure that India's agricultural sector can continue to support economic growth while addressing environmental challenges.

In a broader context, Ritchie and Roser (2018) observed a negative correlation between the agriculture sector's share of total water withdrawals and GDP per capita. Their research suggests that as the share of water used by agriculture increases, per capita GDP tends to decrease, highlighting the inefficiencies in water use within the agricultural sector and the associated economic consequences.

Doungmanee (2016) conducted a study on 154 countries and found that water usage in the agricultural sector increases as per capita GNI rises, suggesting that as economies grow, their agricultural sectors demand more water. This trend points to the need for sustainable agricultural practices that reduce water consumption, ensuring that growth is not hampered by resource depletion.

2.5. Annual Rainfall and Economic Growth

Economic growth and rainfall variability have observed to have a complex and significant relationship in agrarian economies like India. Gilmont et al. (2018) in their study have found that the relationship between rainfall and long term income in complex. In India the growing states have appeared to observe significant correlation between rainfall and economic growth, while the less developed states were found to find no correlation.

2.6. Total Greenhouse Gas Emissions and Economic Growth

The reviewed studies collectively indicate that the relationship between economic growth and environmental quality is complex and multifaceted. While economic growth can lead to environmental degradation through increased CO_2 emissions, temperature rise, and water stress, it is also clear that strategic investments in technology, energy efficiency, and sustainable agricultural practices can help decouple economic growth from environmental harm. These findings underscore the need for policies that foster both economic development and environmental sustainability, ensuring long-term growth without compromising ecological health.

3. METHODOLOGY

3.1. Research Design

This study employs a quantitative longitudinal research design to systematically explore the dynamic relationship between economic growth and key environmental sustainability indicators in India over a 31-year period (1990-2020). By analysing temporal trends in Gross Domestic Product (GDP) alongside environmental variables namely carbon dioxide emissions, temperature fluctuations, levels of water stress, forest area, greenhouse gas emissions, and rainfall patterns the study aims to uncover both the direct and indirect effects of economic activity on environmental outcomes. The longitudinal design is particularly well-suited for this analysis, as it enables the identification of causal patterns and long-term trajectories that cross-sectional studies might overlook. As Menard (2008) emphasizes, longitudinal research provides a robust framework for evaluating how relationships between variables evolve over time, which is essential for understanding the sustainability implications of continuous economic expansion in developing economies like India.

3.2. Data Sources

Secondary data was compiled from a combination of national and international databases, including:

- World Bank Development Indicators (WDI) – for GDP, CO_2 emissions, and freshwater withdrawals
- World Resources Institute (WRI) CAIT – for greenhouse gas emissions
- Indian Meteorological Department (IMD) – for temperature and rainfall data
- FAO and Ministry of Environment, Forest and Climate Change (MoEFCC), India – for forest area statistics
- Ministry of Jal Shakti and MoHUA (Government of India) – for water resource-related data.

All data were collected on an annual basis and are expressed in standardized formats to enable meaningful statistical comparisons.

3.3. Variables and Indicators

The study includes the following variables:

- Economic Indicator: GDP (constant US$).

3.3.1. Environmental indicators

- Carbon dioxide emissions (metric tons per capita)
- Mean, maximum, and minimum annual temperature (in degrees Celsius)
- Forest area (as a percentage of total land area)
- Water stress (measured as total freshwater withdrawals as a percentage of available resources)
- Annual rainfall (in millimeters)
- Total greenhouse gas emissions (in million metric tons of CO_2-equivalent).

Each of these variables has been chosen for its policy relevance and ability to reflect environmental sustainability dimensions as outlined in the United Nations Sustainable Development Goals (UN SDGs), particularly SDG 13 (Climate Action), SDG 6 (Clean Water and Sanitation), and SDG 15 (Life on Land).

3.4. Statistical Tools and Techniques

Descriptive statistics were used to present average annual growth rates and trends. Pearson correlation coefficients (r) were employed to assess the strength and direction of relationships between GDP and each environmental indicator. Statistical significance was tested at the 1% level ($P < 0.01$), using a two-tailed test.

The Pearson correlation method is suitable for normally distributed continuous variables and provides a straightforward measure of linear association between pairs of variables (Field, 2013). Data was analyzed using IBM SPSS Statistics Version 26.

3.5. Limitations

While the study provides a macro-level understanding of GDP-environment relationships, it does not incorporate regional disparities, sectoral emissions, or nonlinearities in the climate-economy nexus. Further, some indicators such as biodiversity loss, air quality, and ecosystem services are not included due to data limitations.

4. RESULTS AND DISCUSSION

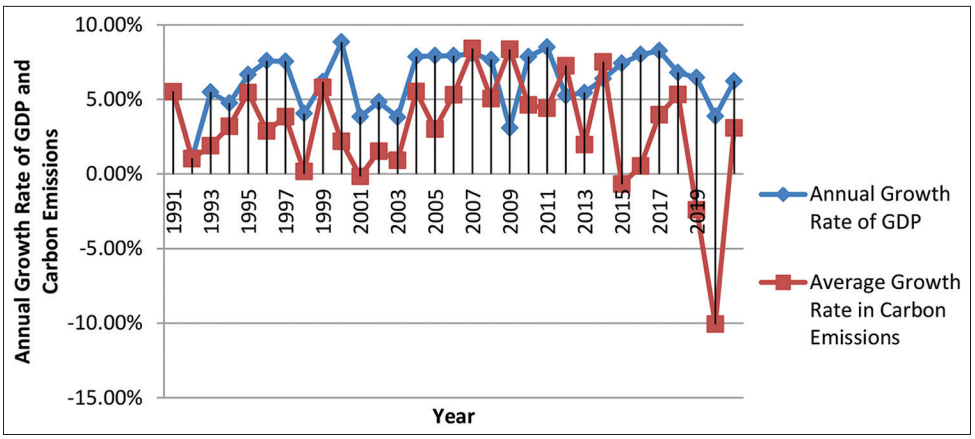
This section presents the results of the analysis of the relationship between economic growth and environmental quality in India. Various environmental factors such as temperature, water stress, freshwater withdrawals, forest area, CO2 emissions, greenhouse gas emissions, and rainfall have been analyzed in relation to Gross Domestic Product (GDP). The results are discussed with reference to tables and figures that illustrate the trends and correlations.

4.1. Trend in GDP and Carbon Emissions

To explore the environmental cost of economic development, this section analyzes the annual growth trends in GDP and carbon dioxide emissions. By evaluating changes over three decades, it provides insights into how closely economic growth is aligned with rising carbon emissions and discusses the implications of this trajectory for climate change and policy action.

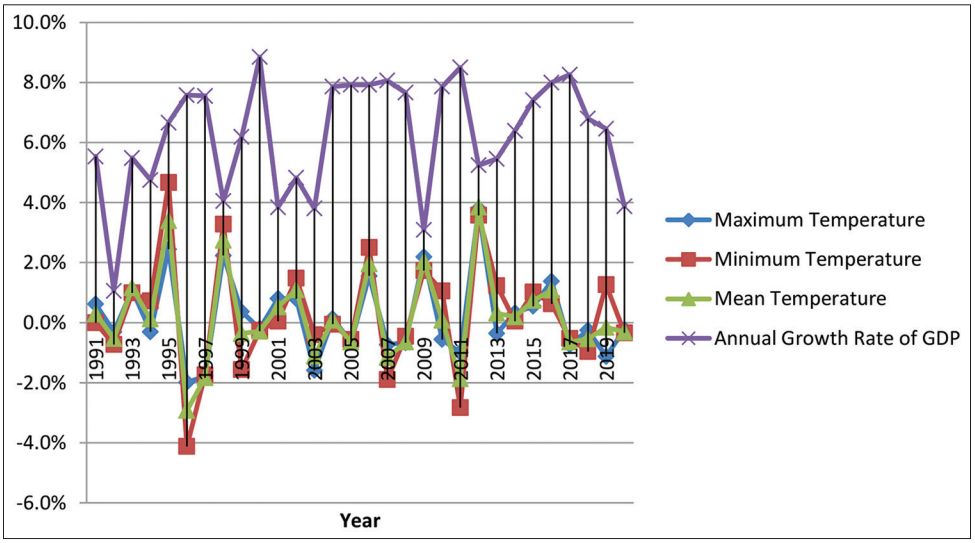
Figure 1 illustrates the trend in the annual growth rates of GDP and carbon emissions in India from 1990 to 2020. The average annual growth rates (AAGR) of GDP and carbon emissions are 6.23% and 3.08%, respectively. Both GDP and carbon emissions saw a significant fall in 2020, primarily due to the economic slowdown caused by the COVID-19 pandemic and associated lockdown measures. The significant positive correlation between GDP and carbon emissions (Pearson correlation = 0.968, P = 0.0001) confirms that higher economic growth is strongly associated with increased carbon emissions.

Figure 1: Annual growth rate in GDP and carbon emissions (1990-2020)



Source: https://data.worldbank.org

Figure 2: Annual growth rate of maximum, minimum, mean temperature and GDP (1991-2020)



Source: https://data.worldbank.org

4.2. Trend in Temperature and Economic Growth

Temperature is a crucial environmental variable sensitive to both natural and anthropogenic influences. This section investigates the annual growth patterns of maximum, minimum, and mean temperatures in relation to GDP growth, to determine whether economic expansion has coincided with climate warming in India over the past 31 years.

Over the period of 31 years from 1991 to 2020, Figure 2 shows the average annual growth rate of maximum, minimum, and mean temperature in India is 0.2%, 0.3%, and 0.2%, respectively. These upward trends coincide with significant economic expansion, where the average annual GDP growth rate stood at 6.23%. This suggests a strong linkage between economic growth and rising temperatures.

As India's GDP increased, driven by industrialisation, urbanisation, and expansion in agriculture, there has been a concurrent rise in carbon emissions, which in turn contributed to the increase in ambient temperatures. This pattern aligns with the Environmental Kuznets Curve (EKC) hypothesis, which postulates an initial environmental degradation with economic growth before a potential reversal.

The Pearson correlation results reinforce this relationship: GDP has a statistically significant and strong positive correlation with maximum temperature ($r = 0.910$, $P < 0.0001$) and mean temperature ($r = 0.918$, $P < 0.0001$). This confirms that higher levels of economic activity are associated with rising temperatures across all measured parameters.

Supporting this, Dell et al. (2011), investigated long-term temperature fluctuations and their economic impacts in both developed and developing countries. They found that increased temperatures negatively influence economic outcomes by lowering productivity in industrial and agricultural sectors. Similarly, Newell et al. (2021) identified statistically significant effects of rising temperature on GDP and agricultural production, especially in low-income nations like India.

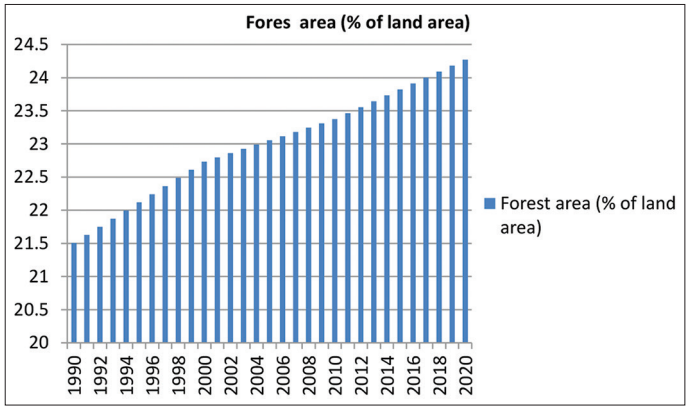
In essence, the data not only demonstrates a historical co-movement between GDP and temperature levels but also emphasizes the climate vulnerability of economic systems in emerging economies. These findings underline the necessity of integrating sustainable practices into development planning to mitigate long-term climate risks.

4.3. Forest Area and Economic Growth

Forests are vital for environmental regulation, carbon sequestration, and biodiversity. This section evaluates the trend in forest area as a percentage of land and its correlation with GDP, offering insights into whether economic growth has been accompanied by afforestation efforts or if it has come at the expense of forest resources.

There has been a continuous growth in the forest area in terms of percentage of total land area from 1991 to 2020. The Average Annual Growth Rate of forest area over the period is 0.4% (Figure 3). A significant high degree correlation is found between

Figure 3: Trend in forest area (1991-2020)



Source: https://data.worldbank.org

the percentage of forest area to land area and GDP (Pearson Correlation = 0.946, $P > 0.0001$). The forests played a vital role in promoting the economic development of a nation. Crespo Cuaresma et al., 2017 showed that in the earlier stages of economic development the effect of economic growth in terms of per capita income is strongest on the growth of forest area.

A long-term time series analysis between GDP and maximum temperature from 1991 to 2020 reveals a positive trend in both variables, suggesting a long-run association. This implies that as India's economic output has expanded, there has been a concurrent increase in the maximum annual temperature.

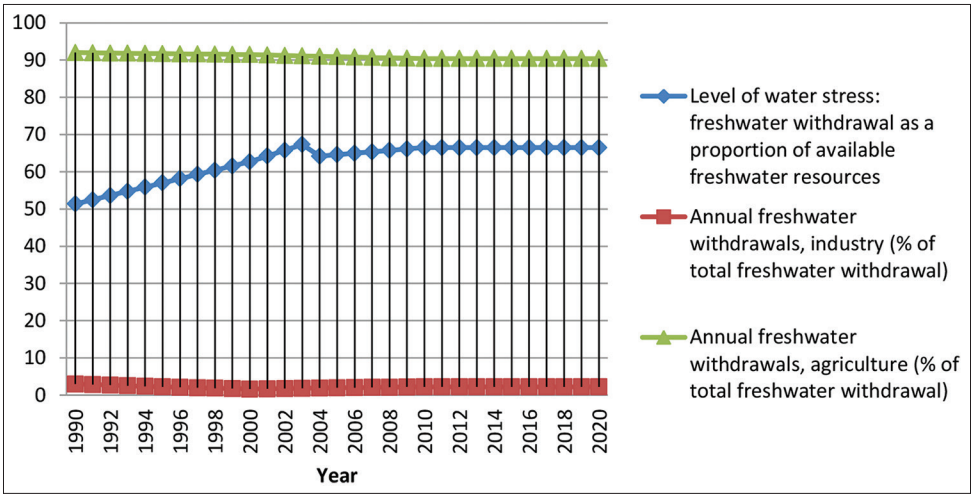
This relationship could be attributed to the carbon-intensive nature of economic growth, particularly in a rapidly developing country like India. Industrial emissions, increased transportation, energy production, and agricultural practices have all contributed to the greenhouse effect, reinforcing the warming trend. The observed long-term relationship implies that sustainable economic planning must account for temperature dynamics. Without mitigation, rising maximum temperatures could impair labour productivity, agricultural yields, and urban infrastructure resilience—ultimately undermining the very growth that contributed to environmental degradation.

4.4. Water Stress and Freshwater Withdrawals

Given the centrality of water resources to both agriculture and industry, this section examines trends in freshwater withdrawals and the level of water stress relative to GDP growth. It discusses sectoral water usage patterns, their implications for sustainability, and how economic development influences water resource management in India.

Over the study period, Figure 4 indicates that the level of water stress measured as the proportion of freshwater withdrawals relative to available freshwater resources showed a decline around 2004, likely due to improved water management practices or climate variability. A consistent pattern emerges wherein the agricultural sector accounts for a disproportionately large share of total freshwater withdrawals, averaging approximately 89% across the years, compared to only 7-8% by the industrial sector (Ministry of Jal Shakti, 2020).

Figure 4: Level of water stress and annual freshwater withdrawals of industry and agriculture



Source: https://data.worldbank.org

Statistical analysis reveals a strong positive correlation between GDP and the level of water stress ($r = 0.790$, $P < 0.0001$), suggesting that as economic activities intensify, water demand correspondingly rises, leading to greater pressure on available water resources. In contrast, a significant negative correlation exists between GDP and annual freshwater withdrawals by the agricultural sector ($r = -0.796$, $P < 0.0001$), which may reflect efficiency improvements or structural shifts away from water-intensive agriculture. The correlation between GDP and freshwater withdrawals by industry, though also negative, is relatively weak ($r = -0.390$, $P < 0.007$).

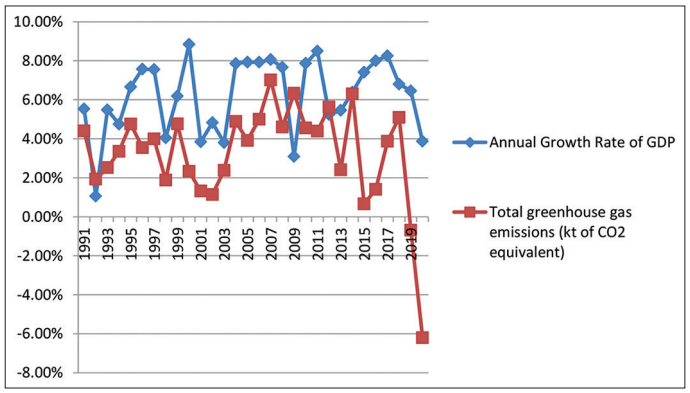
These findings align with previous research highlighting that in many developing countries, agriculture contributes minimally to GDP while consuming a substantial share of freshwater resources (Doungmanee, 2016). In India, for instance, agricultural water use more than doubled between 1975 and 2010, exacerbating water stress in several regions (Ritchie and Roser, 2018). The industrial sector, while central to economic growth, continues to use comparatively less water, suggesting scope for more sustainable water allocation in the context of economic planning.

4.5. Economic Growth and Total Greenhouse Gas Emissions

Total greenhouse gas emissions provide a more comprehensive picture of environmental impact beyond carbon dioxide. This section correlates GDP growth with greenhouse gas emissions to assess whether India's economic expansion has contributed proportionately or disproportionately to environmental degradation.

Over the 31-year period from 1990 to 2020, (Figure 5) India's Average Annual Growth Rate (AAGR) for Gross Domestic Product (GDP) was 6.23%, while the AAGR for total greenhouse gas (GHG) emissions stood at 3.2%. The trend suggests that economic growth has consistently outpaced emissions growth; however, the two indicators remain strongly correlated. A highly significant and positive correlation was observed between GDP and total GHG emissions ($r = 0.979$, $P < 0.0001$), indicating that economic expansion has been accompanied by an increase in environmental externalities.

Figure 5: Annual growth rate of GDP and total greenhouse gas emissions (1990-2020)



Source: https://data.worldbank.org

During the period 1990-2014, India's GDP rose by approximately 357%, while GHG emissions grew by 180%, reflecting both the energy-intensive nature of development and a partial decoupling between emissions and economic output. Nevertheless, the increase in GHG emissions remains substantial. According to the WRI CAIT (2017) database, India's per capita greenhouse gas emissions are more than double the global average, underscoring concerns about the sustainability of its growth model.

The strong association between GDP and GHG emissions aligns with the Environmental Kuznets Curve (EKC) hypothesis, which posits that environmental degradation tends to increase during the early stages of economic development but may decline once a certain level of income and technological maturity is reached. India's current trajectory characterized by rapid industrialization, urban expansion, and growing energy demand reflects this early phase, where growth remains closely tied to rising emissions. As Kaumudi (2019) underscores, India's economic advancement has historically been carbon-intensive, with GHG emissions

tracking closely alongside GDP, posing a significant challenge for sustainable development.

This pattern underscores the urgent need for structural transformation toward low-carbon growth. Without decisive investments in renewable energy, green technologies, and sustainable production systems supported by robust environmental governance and alignment with international climate commitments India risks locking in a development path that exacerbates ecological degradation and heightens climate-related vulnerabilities. Addressing this challenge is crucial not only for meeting global sustainability goals but also for safeguarding long-term economic resilience and social equity.

4.6. Economic Growth and Rainfall Variability

Another factor that plays a critical role in agricultural productivity and water availability is rainfall, particularly in monsoon-dependent economies like India. This section analyses the variability in annual rainfall growth and its relationship with GDP, discussing how erratic precipitation patterns may or may not affect macroeconomic performance.

An analysis of rainfall data from 1990 to 2020 reveals significant interannual variability, with a predominantly negative annual growth rate in most years. Despite occasional increases, the overall average annual growth rate of rainfall during this 31-year period was just 0.4% in Figure 6, indicating a stagnant or erratic trend without a clear upward or downward trajectory (MoEFCC, 2020).

Statistical analysis indicates a weak and statistically insignificant correlation between GDP growth and rainfall ($r = -0.090$, $P = 0.450$). This suggests that, at the national level, rainfall patterns have not exerted a consistent or substantial direct impact on economic growth during the observed period. However, this finding should be interpreted with caution. While aggregate economic indicators appear resilient, rainfall variability can have severe localized effects, especially in rural regions dependent on agriculture.

Given that agriculture continues to play a critical role in employment and food security in India, deviations in monsoon patterns can trigger localized economic distress and influence inflationary trends. Kotz et al. (2022) emphasize that changes in rainfall patterns, including increased variability and extreme precipitation events, can significantly reduce economic output, particularly in low- and middle-income countries. Their findings reinforce the importance of sub-national analysis, as national-level GDP may mask critical vulnerabilities at the regional level. Thus, despite weak national-level correlations, rainfall volatility remains a vital concern for regional economic stability and climate resilience planning.

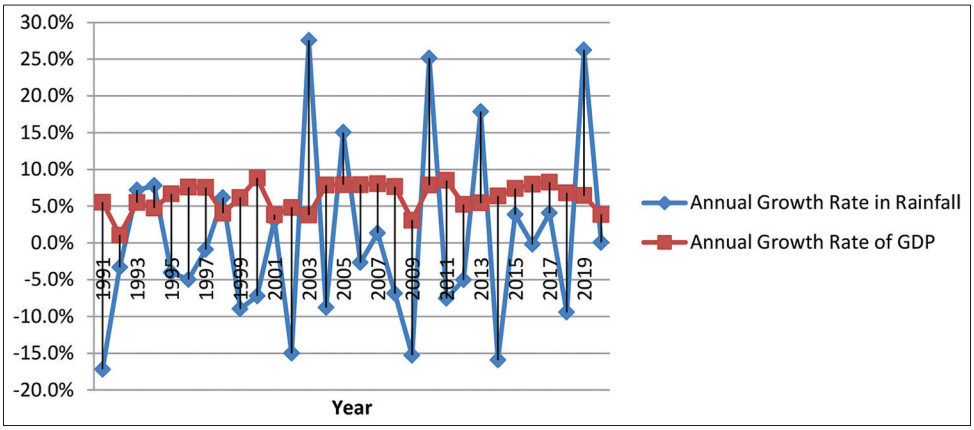
Moreover, as India transitions towards a more service- and industry-oriented economy, GDP may appear increasingly detached from environmental variables such as rainfall. Yet, with climate change expected to intensify both droughts and extreme rainfall events (Kotz et al., 2022), this perceived detachment could erode, underscoring the need for proactive climate adaptation strategies.

4.7. Relationship between Economic Growth and Environmental Quality

This section examines the relationship between economic growth, measured by Gross Domestic Product (GDP), and a range of environmental quality indicators including temperature variations, water stress, forest area, and emissions. Using Pearson correlation analysis, the strength and direction of these relationships are statistically assessed to understand how India's rapid economic development from 1990 to 2020 has impacted various dimensions of environmental sustainability. The Table 1 below summarizes the Pearson correlation between various environmental variables and GDP growth, along with their significance levels.

The correlation results in Table 1, show that economic growth in India is positively associated with most environmental factors, such as temperature, forest area, CO_2 emissions, and greenhouse gas emissions. The highest positive correlations are found between GDP and CO_2 emissions ($r = 0.968$) and between GDP and total greenhouse gas emissions ($r = 0.979$). These correlations are statistically significant at the 99% confidence level. Conversely, the relationship between GDP and annual freshwater withdrawals in agriculture is negative ($r = -0.796$), which suggests that higher economic growth may be associated with a reduction

Figure 6: Annual growth rate in GDP and rainfall (1990-2020)



Source: https://data.worldbank.org

Table 1: Relationship between economic growth and environmental quality indicators

Independent variables	Dependant variable Gross domestic product	
	Pearson correlation	Significant (2-tailed)
Maximum Temperature	0.910**	0.000
Mean Temperature	0.918**	0.000
Minimum Temperature	882*	0.005
Level of Water Stress: Freshwater Withdrawal as a Proportion of Available Freshwater Resources	0.790**	0.000
Annual Freshwater Withdrawals, Agriculture (% of total freshwater withdrawal)	−0.796**	0.000
Annual Freshwater Withdrawals, Industry (% of total freshwater withdrawal)	−0.390*	0.007
Forest Area (% of land area)	0.946**	0.000
CO_2 Emissions (metric tons per capita)	0.968**	0.000
Total Greenhouse Gas Emissions (kt of CO2 equivalent)	0.979**	0.000
Annual Rainfall in mm	−0.090	0.450

Source: World Bank Data

in freshwater usage by agriculture, as industrialization and urbanization increase.

5. IMPLICATIONS FOR POLICY AND SUSTAINABLE DEVELOPMENT

The findings from this study underscore the substantial environmental consequences of India's rapid economic growth. Over the past few decades, India has experienced remarkable GDP growth, yet this growth has significantly impacted its environmental quality, particularly in terms of rising temperatures, greenhouse gas emissions, water stress, and annual freshwater withdrawals. These environmental challenges pose risks not only to the environment but also to long-term economic stability and development.

The positive correlation between GDP and temperature rise, as well as the high increase in greenhouse gas emissions, signals a critical need for integrating climate change mitigation strategies into India's economic growth trajectory. India's greenhouse gas emissions have increased by 180% between 1990 and 2014, significantly outpacing GDP growth, which increased by 357% in the same period (WRI CAIT, 2017). This suggests that economic growth has been closely tied to environmental degradation, primarily through increased energy demand driven by industrialization, urbanization, and transportation. Without addressing these challenges, further economic development could be undermined by environmental degradation, exacerbating the risks of climate change, natural resource scarcity, and social inequality.

As noted by Newell et al. (2021), economic growth is often accompanied by increased greenhouse gas emissions, but this can be mitigated by shifting from fossil fuel-based energy sources to renewable energy solutions. The demand for renewable energy technologies, such as solar photovoltaic (PV), biomass, and hydropower, should be a central focus of policy. Such a transition not only aligns with global climate goals but also offers the potential to enhance energy security and reduce dependence on fossil fuels, contributing to a more sustainable and resilient economy. The shift to cleaner energy sources would reduce carbon emissions, which are strongly linked to the rise in temperature (Dell et al., 2011).

Another critical finding is the rising water stress in India, which is closely tied to the high demand for water from both the agriculture and industrial sectors. Agriculture, while consuming most freshwater resources, has shown a negative correlation with GDP growth, implying that while agriculture's contribution to economic growth remains low, its water consumption continues to be disproportionately high (Doungmanee, 2016). To ensure long-term economic stability, policies should focus on enhancing water-use efficiency in agriculture through techniques such as micro-irrigation, water-efficient crops, and rainwater harvesting. Moreover, transitioning to less water-intensive industries and investing in water recycling and wastewater treatment can help alleviate the pressure on freshwater resources.

The rising trend in forest cover observed in India is a promising sign for its transition to a low-carbon economy. Forests play a vital role in carbon sequestration, biodiversity preservation, and regulating local climate. Strengthening forest protection policies and promoting afforestation and reforestation programs will help offset the impact of emissions, while also contributing to the country's climate adaptation and sustainable development goals (Ritchie and Roser, 2018).

Despite these challenges, India's growing commitment to sustainability through various national initiatives, such as the National Action Plan on Climate Change and the promotion of sustainable development goals (SDGs), offers a pathway toward reconciling economic growth with environmental sustainability. However, the trade-off between growth and environmental protection requires careful policy design to ensure that economic objectives are met without compromising the environment's ability to support future generations.

Policymakers must also prioritize climate-resilient infrastructure to protect vulnerable sectors, especially agriculture, from extreme weather events. Investment in climate-smart agriculture, the development of early warning systems, and climate adaptation measures are essential to reduce the economic risks posed by climatic changes. As Damanai et al. (2020) highlight, the impact

of extreme rainfall events on agricultural productivity is more pronounced in developing countries, where economies are more dependent on weather patterns. The establishment of climate finance mechanisms can also support the most vulnerable sectors in adapting to climate change while ensuring that economic growth does not come at the expense of environmental and social well-being.

In conclusion, the findings of this study underscore the urgent need for India to adopt green growth strategies. By promoting the shift toward renewable energy, improving water efficiency, strengthening forestry management, and investing in climate-resilient agriculture, India can create a pathway for inclusive, sustainable economic growth that reduces the environmental toll of development. Failure to act on these fronts will not only threaten the environment but will also undermine the very economic progress that has fueled India's growth over the past few decades.

6. CONCLUSION

This study highlights the complex interplay between India's rapid economic growth and its environmental impacts, focusing on key indicators such as temperature rise, greenhouse gas emissions, water stress, and freshwater withdrawals. The analysis reveals that while economic growth has contributed to significant improvements in national GDP, it has also exacerbated environmental challenges, particularly in terms of carbon emissions and water usage. The findings suggest that economic development and environmental sustainability in India are currently at a crossroads, with the potential for a sustainable transition depending on effective policy interventions.

The positive correlation between GDP growth and greenhouse gas emissions emphasizes the need for a shift toward renewable energy sources, which can decouple growth from environmental degradation. Moreover, the rising water stress underlines the importance of enhancing water-use efficiency, particularly in the agriculture sector, to ensure sustainable growth in the long run. The rising forest cover provides a hopeful sign that India can transition toward a low-carbon economy if such trends are strengthened and supported by targeted policies.

The study also underscores the importance of climate-resilient infrastructure and sustainable agricultural practices to protect vulnerable sectors from the adverse impacts of climate change. As India continues its development journey, it must embrace policies that balance economic growth with environmental preservation, ensuring that future generations inherit a sustainable and thriving economy.

Ultimately, the findings of this study provide critical insights into the trade-offs between growth and environmental quality, offering a foundation for future research and policy development aimed at promoting inclusive, green growth in India.

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