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Impact of Climate Change on Indian Economy: A Review

Lakshmikantha H M[1], Preethi Rajesh[2]

[1]*Department of Life Science, School of Sciences, Garden City University, Bangalore, India.*
[2]*Department of Life Science, School of Sciences, Garden City University, Bangalore, India.*

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Abstract

Climate change has emerged as a critical global concern of the 21st century, with its escalating intensity causing widespread environmental and socio-economic disruptions. In India, its impact has profoundly transformed "environmental, socio-economic, and urban landscapes", posing significant challenges to economic stability. With an emphasis on important industries including infrastructure, energy, tourism, and agriculture, this analysis examines a range of viewpoints from the literature about how climate change is affecting the Indian economy. The findings reveal that while climate change initially reduces India's fiscal deficit, it ultimately diminishes GDP in both the short and long term. Substantial increases in temperature and rainfall may temporarily boost agricultural production, contributing to economic growth, but the overall economic consequences remain adverse. In order to mitigate long-term dangers to the Indian economy and address the multi-sectoral implications of climate change, this research emphasises the need of focused policies that foster sustainable development.

Keyword: Climate change, Indian economy, Global warming, greenhouse gases (GHGs)

INTRODUCTION

Over the span of this century and beyond, it is anticipated that the Earth's climate will continue to change. Global greenhouse gas emissions and the degree of uncertainty around the Earth's climate's sensitivity to these emissions will be the primary determinants of the extent of climate change over the next decades [1]. The annual average rise in world temperature might be kept to 2°C or below by drastically reducing greenhouse gas (GHG) emissions. By the completion of this century, the mean global temperature might increase by 5°C or more annually in comparison to preindustrial levels if substantial reductions in these greenhouse gas emissions are not implemented [2].

The present worldwide climate change is occurring at a faster rate than the normal temperature variations that have occurred throughout Earth's history [3]. "Sea level rise, arctic sea ice, land-based ice melt, upper-ocean heat content, depth of seasonal permafrost thaw", and the worldwide mean temperature all exhibit patterns of global warming [4]. The robustness of these patterns has been confirmed by several independent research organisations from across the world. According to Figure 1's anomalies, the average worldwide temperature rose by around 1°C throughout the 1880s.

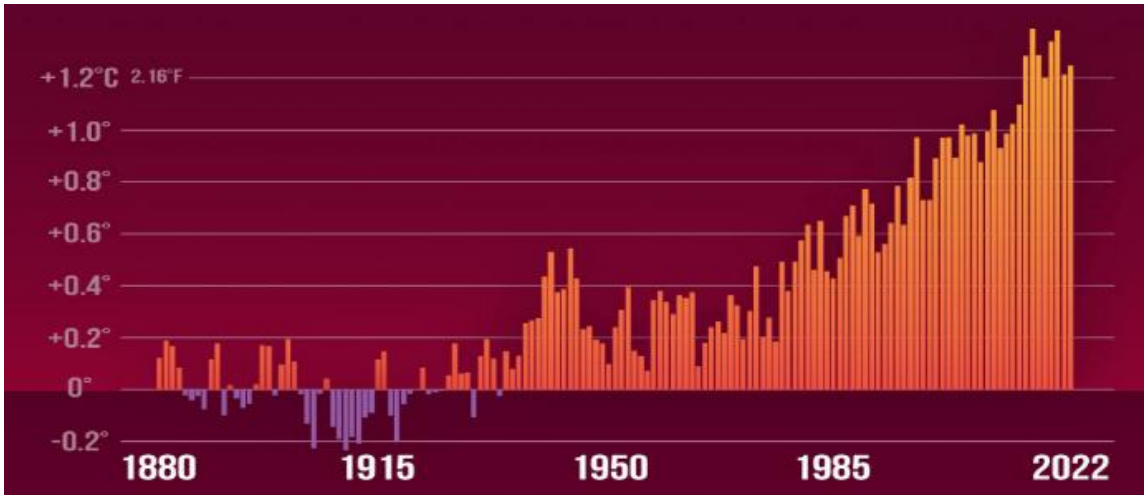


Figure 1 Global Average Temperature Anomalies.

Comparing the global annual average temperatures from 1880–2022 to those from 1881–1910. Higher temperatures above the early industrial standard are shown by red, while lower temperatures than the baseline are indicated by purple. The climate system is observed by remote sensing from satellites and ground stations, as well as direct physical and biogeochemical observations [5] [6]. Paleoclimate archives contain information about previous climates over a long period of time. To learn more about the Earth's historical climate and its causes, many forms of environmental evidence are utilized [7]. Documentation of former climate conditions may be found in "tree rings, the skeletons of tropical coral reefs, glaciers, ice caps, and laminated sediments from lakes and the ocean". We may expand our knowledge of climate back hundreds to millions of years by using such environmental recorders to estimate historical conditions [8]. The instrumental period didn't start collecting data on a worldwide basis until the middle of the nineteenth century, but because to paleoclimate reconstructions, we can now record values that are hundreds of thousands—if not millions—of years old. When taken as a whole, these variables provide a detailed picture of the land, sea, cryosphere, and atmospheric changes and oscillations over the long period [9].

Status of climate change in India

It is now well acknowledged that poor nations are more vulnerable than wealthy nations to the effects of climate change. The majority of residents' low incomes, significant risk to economic systems, and delicate natural conditions all contribute to this, making adaptation more difficult [10]. The influence of changing agriculture techniques, the expansion of erosion, the acceleration of desertification, the fast urbanization, and changes in river patterns are all contributing to the substantial changes in land use [11]. The hydrological cycle is directly correlated with these land use changes, and they are crucial in bringing about significant changes in related ecosystems [12]. A large amount of the world's "carbon dioxide (CO2) and greenhouse gas emissions" come from emerging countries like China and India, which are becoming more industrialised and populous. According to the Indian Meteorological Department, India saw 573 catastrophes including severe weather, climate, and water occurrences between 1970 and 2021, which claimed 138,377 lives [13]. India is now on the UN's "Global Drought Vulnerability Index" after experiencing the highest temperatures and longest dry periods in recent memory. West Bengal, Bihar, Jharkhand, and Uttar Pradesh—the four main rice-producing states—have all experienced droughts in quick succession [14]. With 1.4 billion inhabitants, India has just surpassed all other countries in population, accounting for 17.7% of the world's total population. This has resulted in a rising carbon footprint [15].

Temperature and rainfall anomaly

With an average temperature of 21.43°C in 2021, India's mean temperature was the third-highest since 1901, behind 2016 (21.8°C) and 2009 (21.59°C)[13]. The post-monsoon season average mean temperature time series for India from 1971 to 2021 was shown in Figure 2 [16]. The highest temperatures in the majority of the nation were higher than average, with the exception of several parts of central India, the southern peninsula, eastern and northeastern India, and northwest India. Only a few regions—"Assam and Meghalaya, Nagaland, Manipur, Mizoram, Tripura,

Himachal Pradesh, Saurashtra, and Kutch"—saw maximum temperature anomalies of more than 2°C. In a similar vein, the minimum temperatures were typically higher than average for the majority of the nation, with the exception of a few areas in Lakshadweep, central India, northwest India, and the southern peninsula. Some regions, such as "central Maharashtra, Bihar, North Interior Karnataka, southern Kerala and Mahe, northern Saurashtra and Kutch", and others, notably saw minimum temperature anomalies over 2◦C. In contrast, other regions, including "southern Madhya Pradesh, Chhattisgarh, Vidarbha, Andhra Pradesh, Telangana, Delhi, West Uttar Pradesh, Haryana, Chandigarh, East Rajasthan, and South Interior Karnataka", had minimum temperature anomalies below -1◦C [13]. Changes in the nation's precipitation patterns have been clearly seen. Rainfall anomalies above 100 mm were seen in the "Tamil Nadu, Puducherry, Karaikal, Kerala, Mahe, and Lakshadweep areas". In contrast, the western parts of Jammu & Kashmir and Ladakh, as well as various parts of "Arunachal Pradesh, Assam, Meghalaya, Uttarakhand, Punjab, and Himachal Pradesh", saw negative rainfall anomalies over 50 mm. Also, the negative rainfall anomaly was higher than 75 mm in "Himachal Pradesh, Punjab, Arunachal Pradesh, Jammu & Kashmir, and Uttarakhand (Figures 2 and 3)" [16].

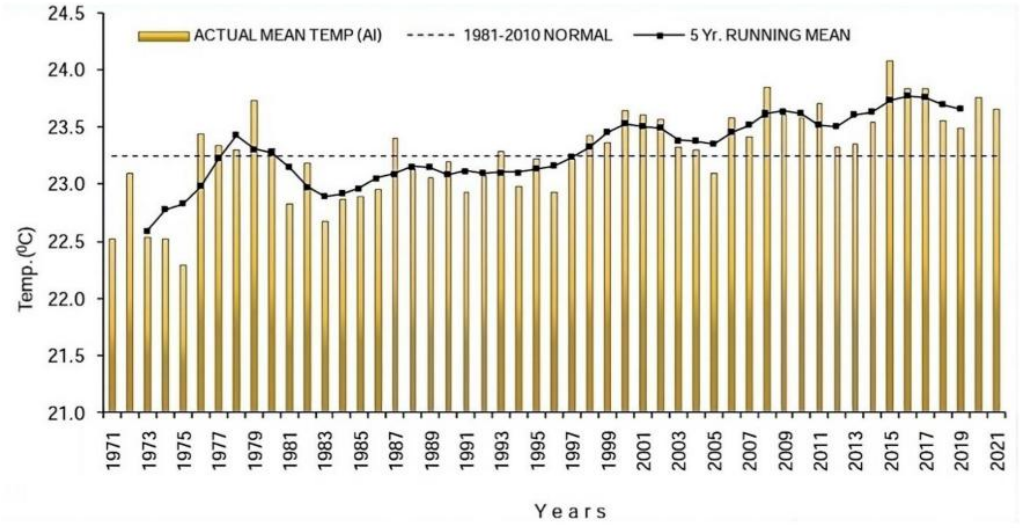


Figure 2 Time series of mean temperature averaged over India (vertical bars) and 5 year running mean (continuous line) for the post monsoon season (1971–2021) [16]

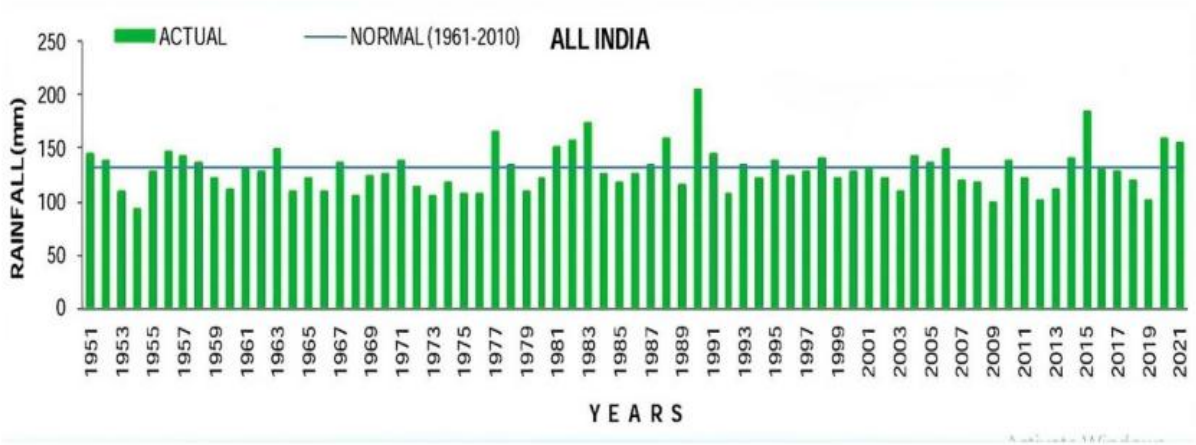


Figure 3 Seasonal rainfall over the country as a whole for the period 1951–2021 [16]

Climate change's effects on several Indian economic sectors

1. Agriculture

India's agricultural industry makes a substantial contribution to employment (42%), as well as GDP (14%). The fact that the business directly affects 1.38 billion people's lives is a measure of its criticality. Over two-thirds of the population still calls rural areas home as of the 2011 census, and many of those people rely on agriculture for both their daily sustenance and the linkages it offers to other areas of the economy. In 1981, agriculture accounted for 70% of all jobs; by 2016, that percentage had fallen to 42%. The sector's contribution has drastically changed in recent years, mostly as a result of recurrent droughts and exceptional rainfall. Between 1891 and 2012, there were 24 significant droughts in India, and the number has been rising each since. Warmer weather tends to encourage the growth of weeds and pests while decreasing agricultural production [10]. Although water is the most important agricultural resource, inadequate irrigation systems are present in more than 50% of all planted areas. Irrigated agricultural output in agro-ecological zones is negatively impacted by climate change as a result of increasing temperatures and changing water sources [15].

2. Energy

After the United States, China, and the European Union, India ranks fourth globally in terms of greenhouse gas emissions. By far the largest source, accounting for around two-thirds of total GHG emissions, is the energy sector. Giving people accessibility to power and lowering harmful emissions are two sides of the same coin. As long as coal is the primary energy source, emissions will undoubtedly rise. To maintain this delicate equilibrium, India must focus on two main areas: increasing efficiency in energy use and production, and supporting renewable energy sources with minimal carbon emissions, such as solar and wind power. At now, market forces are one of the two primary drivers of mitigation efforts. "Perform, Achieve, and Trade (PAT)" is one such program that seeks to increase energy efficiency for big energy-intensive companies by 1% to 2% annually. The second is the drive to fulfil India's non-disclosure agreements and energy goals. As of right now, the Indian government is aiming to construct 175 GW of renewable energy production by the year 2022. One hundred gigawatts (GW) will come from solar panels, sixty GW from wind turbines, ten GW from biopower, and five GW from small hydropower. The projected total by 2030 is 450 GW.

3. Tourism

In 2018, travel and tourism contributed 9.6 percent to India's gross domestic product (GDP), ranking the country ninth globally, according to "the World Travel and Tourism Council (WTTC)". About 4.2 crore jobs were generated in India's travel and tourism sector in 2019, which accounted for 8.1% of all jobs in the nation and contributed about USD 268 billion to the GDP. A contribution of "INR 15.24 lakh crore (USD 234.03 billion) to India's GDP in 2017 and INR 32.05 lakh crore (USD 492.21 billion) in 2028" is projected by the travel and tourism sector, given the pace of growth in this industry. In 2019, around 10.89 million foreign tourists visited India, a 3.2% rise from the previous year. "Foreign direct investment (FDI)" of USD 15.28 billion was obtained to support the expansion of the hospitality and tourism industry from April 2000 to March 2020. No foreign direct investment (FDI) is too little for this automated method. There is a possibility of a five-year tax break for hotels with 2, 3, or 4 stars that are located close to UNESCO World Heritage sites [16].

Finding ways to lessen "carbon dioxide (CO_2) emissions" and environmental effects is an issue that the tourism sector faces. Many types of tourism, especially coastal ones, are hit hard by seasonal declines in the spring and summer due to things like sea level rise, bleaching, and the demise of coral reefs. However, the winter tourist industry suffers from mountain loss due to snow melting. Since many tourist activities are influenced by weather and climate, unfavorable circumstances may have a significant impact on visitors' operations, activities, comforts, and flow. Traveler mobility is impacted by airline cancellations, delays, and rerouting, which exacerbates the effect. Tourism is responsible for 4.6% of global warming in terms of radiative forcing. Seventy-five percent of all emissions are produced by the transportation sector, which includes the air, automobiles, and railroads. 40% of the sector's overall carbon emissions and 54–75% of radiative forcing are attributable to air travel. Due to heating, air conditioning, and infrastructure maintenance, the lodging industry is responsible for 20% of emissions. Theme parks, museums, festivals, and retail establishments also account for around 3% of emissions.

4. Human Health

The general population's health is greatly threatened by climate change. Human health will face increased dangers as a result of climate change, according to the IPCC's Third Assessment Report. Climate change is expected to have far-

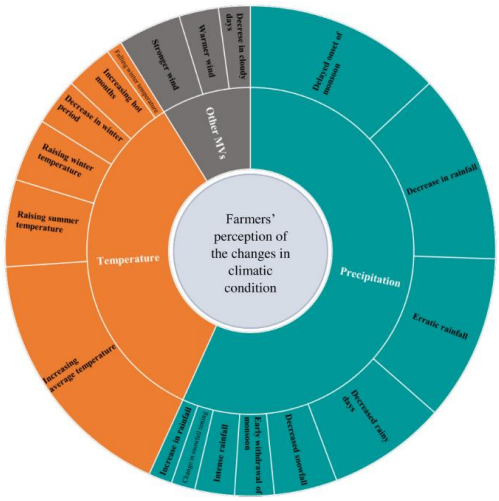
reaching repercussions on the health sector, including worsening air quality, more frequent and severe extreme weather events, an upsurge in climate-sensitive illnesses, and more food poverty. The spread of illness via food, water, insects, and vermin has a detrimental effect on people's health and well-being, and the present epidemic will make it worse.

5. Infrastructure

By 2041, 745 million more people are expected to live in Indian cities, placing further strain on the infrastructure and services of the country's largest cities. Furthermore, cities are becoming more susceptible to hazards associated with climate change. In addition to disrupting livelihoods and raising the risks of mortality, injury, and illness, climate change will also cause property, infrastructure, and settlement damage from “cyclones, coastal and inland floods, storm surges, and sea level rise”. By 2070, storm surges will be increasingly common in low-lying, heavily populated coastal regions of India, making coastal cities such as "Chennai, Dhaka, Kolkata, and Mumbai more vulnerable". While good disaster preparation has often save lives, enormous obstacles remain, such as restoring disrupted infrastructure and returning to normal after the disruptions and the stratospheric costs involved. The August 2018 Kerala floods destroyed almost 70,000 km of road structures, 140,000 hectares of crop land, and 280,000 dwellings; around INR 310 billion was expended on rehabilitation. Nearly half a million homes, 6,700 medical facilities, and 100,880 million acres of farmland were all impacted by the 2019 storm Fani. A total of INR 500 billion was lost due to significant damage to the electrical system, and it would likely take five to ten years for the coastal districts to recover and reconstruct.

LITERATURE REVIEW

(Datta et al., 2022) [10] that most Indian farmers have seen an increase in temperature, unpredictable rainfall, and decreasing rainfall, which matches meteorological data. Numerous systemic and gradual adaptation strategies have been used by Indian farmers. Land usage, labour and resource allocations, farming systems, and occupational patterns are among the transformative changes that farmers are implementing. Lack of knowledge and credit at the correct moment, gender, farm size, family income, and resource endowment often impact adaption measures. Large-scale investments in the Indian agricultural industry and farmer capacity are needed to prevent maladaptive consequences and promote long-term sustainability, according to the research. An integrated approach to examining farmers' perceptions and responses to changing climatic conditions and their outcomes is necessary for efficient strategy for "food security and farmers' wellbeing".



“Figure 4 Farmers’ perception of the changes in temperature, precipitation, and other meteorological variables (MVs)”.[9]

(Taraz, 2017) [11] If we want to know what the potential consequences of climate change are, we need to know how agents may adapt to their environment. The author uses stable, multidecadal monsoon regimes with a higher likelihood of droughts or floods to discover adaptation. There is regional heterogeneity in the timing of these regimes, and they produce medium-run fluctuation in average rainfall. The medium-run rainfall volatility causes farmers to modify their crop portfolios and irrigation investments, according to the author's findings. The earnings farmers have lost as a result of unfavorable climatic fluctuation are only partially recovered by adaptation, however.

(SenGupta & Atal, 2025) [12] The severe and real climate issue makes it imperative to examine India's macroeconomic elements, since it is among the most susceptible nations to climate change. Create a brand-new climate change index that provides a more thorough assessment of climate effects by using data on sea level. According to long-run relationship estimations, there is a substantial 0.463% rise in inflation for every unit increase in our climate change index. When considering fiscal performance, we discover that climate change causes India's budget deficit to decline. Nevertheless, we find that over time, the budget deficit rises by a substantial 0.005 trillion

Indian rupees for every unit of severe climate change. Finally, we conclude that climate change has a short-term and long-term negative impact on GDP. When temperature is employed as the standard indication of climate change, most of our findings remain valid.

(Sharma et al., 2022) [17] Economic development and climate change are topics of relevance to India. Making the transition to a carbon-neutral economy would be a long process for India, despite the country's abundant natural resources (solar power, forests, etc.). Reluctance and economic hardship typically accompany immediate climate change efforts like COP26. Climate change is harming the Indian economy. Not aiming for an emission-free economy would hinder future progress. Climate-change initiatives frequently conflict with energy needs. Climate change affects agriculture, therefore half of India is susceptible. This work addresses the aforesaid difficulties empirically. The Indian government's "Assessment of Climate Change over the Indian Region report 2020" and other reputable research publications provide theoretical data. To demonstrate the impact of climate on the economy is the primary goal of this research. While addressing climate change, it offers economic solutions. India's future depends on adopting green ideals and transitioning to a clean economy.

(Hussain et al., 2023)[16] Extreme weather occurrences have been much more frequent and frequent in India in recent years, putting vulnerable people at risk. The nation was listed among the most polluted cities in the world and had serious air pollution issues in a number of its major cities. With 1.4 billion people—or around 18% of the global total—and an ever-increasing pace of resource use, India has become the most populous nation in the world. To decrease these consequences and assist India in reaching its objective of meeting "the Sustainable Development Goals (SDGs)", the current situation in the country calls for the adoption of various climate mitigation strategies, including solutions derived from nature. In order to determine India's obstacles to accomplishing SDGs 13 and 11, this study attempts to have a comprehensive grasp of how climate change affects various industries. Lastly, it also emphasized the suggestions for further study on climate change from an Indian standpoint.

"Table 1 Table listing projected changes against different climate variables in India [16]**"**

S. No.	Climate variables	Projected changes
1	Sea-level rise in the North Indian Ocean	According to the IPCC Assessment Report 5, "the North Indian Ocean" has seen a rise in sea level due to thermal expansion and the winds of the monsoon season.
2	Warming over Indian ocean	Between 1951 and 2015, the tropical Indian Ocean's mean "sea surface temperature (SST)" increased by 1◦C, and forecasts suggest that this trend will continue throughout the twenty-first century.
3	Warming over India	By the end of the 21st century, India's average temperature is expected to have increased by 2.4 to 4.4°C, accounting for various scenarios of warming brought on by greenhouse gases.
4	Monsoon precipitation	The average, severity, and yearly variability of monsoon showers are expected to increase significantly by the end of the century as a result of increasing temperatures and atmospheric humidity, according to climate models.
5	Tropical cyclonic storms	Due to continuous global warming, it is anticipated that the frequency of very violent "cyclonic storms (VSCS) in the North Indian Ocean" will increase even more in the twenty-first century.
6	Droughts and floods	In the Himalayan river basins, increased stream flow and a higher danger of flooding would result from faster rates of glacier and snowmelt in a warmer planet. It is anticipated that the rivers of the Indus, Ganga, and Brahmaputra rivers in particular would be more vulnerable to more catastrophic floods in the next years if more "adaptation and risk reduction measures are not implemented (Lutz)".
7	Himalayan cryosphere	According to climate forecasts, "the Hindu Kush Himalaya (HKH)" area will continue to have less snowfall throughout the 21st century as warming continues.

(Gupta & Indapurkar, 2021) [18] highlight how India's participation in international climate talks must unavoidably center on preserving the environment and natural resources for coming generations while also taking into account the urgent development requirements of the world's most vulnerable people. This is particularly pertinent to developing nations like India, which is home to an estimated 33% of the 1.2 billion poorest people on the planet. Because growth is not just a social and economic imperative, but also the best way to adapt to climate change, the researcher

suggests that attention be paid specifically to equity, energy availability, and space sharing.

(Husain & Javed, 2019) [19] examines how the Indian economy is affected by climate change using a quantitative research approach utilising "secondary data on GDP, population, and climate change components" between 1980 and 2016. The study's conclusions indicate that population and climate change variables (temperature and rainfall) combined impacted India's economic development, but temperature had no discernible effect on population and rainfall alone. Additionally, there was a negative association found between temperature and GDP and a strong positive relationship found between population and GDP. According to this study, India's economic growth is significantly impacted by climate change since significant increases in temperature and rainfall might increase agricultural productivity, which could in turn strengthen the nation's economy.

(Batra, 2021)[20] The significant effects of global warming on crops throughout the globe are expected to have an impact on food security by decreasing yields and, therefore, food availability, as well as food and feed safety. Mycotoxins are thought to be one of the most significant threats to food safety that climate change will affect. A higher risk of mycotoxin contamination of cereal crops in the field is anticipated with "future changes in temperature, precipitation, and atmospheric CO2 concentration". These changes may also affect the geographic distribution of specific cereals, mycotoxigenic fungi, and their mycotoxins.

(Sandhani et al., 2020) [21] focuses at how economic growth is affected by climate change in India. In this research, the short- and medium-term impacts of climate change on growth are assessed using climatic variable data at the state and district levels and "the growth rate of per capita real GDP". According to state-level research, the data point to detrimental consequences of increasing temperatures on development from 1980 to 2019. The findings from district-level analysis support these aggregate-level findings even more. To begin, "the growth rate of district per capita income" drops by around 4.7% for every 1°C rise in temperature, suggesting that poorer districts are more negatively impacted by warmer weather. Secondly, warmer temperatures produce growth consequences in addition to level effects, particularly in wealthier regions. Access to credit, urbanization and electricity, as well as more roads and a market network, might all be important factors in reducing the adverse effects of climate change.

CONCLUSION

Climate change has significantly altered climatic patterns, causing substantial economic repercussions for India. This review highlights that while farmers attempt to adapt to changing climatic conditions by adjusting irrigation investments and diversifying crop portfolios, these adaptations recover only a small fraction of the profits lost due to adverse climate variations. The findings emphasize the critical need for an integrated approach to assess farmers' perceptions and adaptation strategies to ensure food security and their well-being. In terms of financial performance, climate change reduces India's economic deficit. Furthermore, climate change negatively impacts GDP, both in the short and long term, underscoring its detrimental effects on economic growth. While some variations in temperature and rainfall could temporarily benefit agricultural production and contribute to growth, the broader impacts on economic stability and productivity remain adverse. Additionally, climate change poses significant challenges to India's economic growth, necessitating urgent, effective policies for climate adaptation and mitigation. These policies must prioritize sustainable agriculture, fiscal resilience, and economic diversification to minimize long-term economic risks.

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