International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Assessing the Economic Effects of Climate Change on Chhattisgarh in the Vision of 'Viksit Bharat 2047'

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Abstract

In this study, predictive modelling techniques were utilized to assess the potential impacts of climatic conditions on the economy of Chhattisgarh, India. Owing to its diverse geography, Chhattisgarh encompasses multiple climatic zones, which increases its vulnerability to climate change and weather variability. Such susceptibility poses significant challenges to the economic sustainability of the state, especially in sectors like agriculture and natural resource-based industries.

The researchers employed advanced forecasting methods and comprehensive machine learning models, drawing on extensive climate records and economic indicators, to project the effects of shifting weather patterns on key industries in the region. The findings offer valuable insights for policymakers, stakeholders, and community members, serving as both an informational resource and a foundation for developing strategies aimed at mitigating the adverse economic impacts of climate change in Chhattisgarh.

Keyword: climatic conditions, multiple climatic zones, diverse geography, resource-based industries, economic indicators, developing strategies

Introduction

The combustion of fossil fuels and various human activities have led to a significant buildup of greenhouse gases—namely carbon dioxide (CO_2) and methane (CH_4)—in the atmosphere. This accumulation is widely recognized as a key driver of climate change. The Intergovernmental Panel on Climate Change has stated with 90% confidence that the warming of the climate system is unequivocal and largely attributable to human actions.

Chhattisgarh, a state in India, is particularly vulnerable to the impacts of climate change. A substantial segment of its population depends on climate-sensitive sectors such as agriculture, forestry, and fisheries for their livelihoods. The region is already experiencing environmental stressors, including increased rainfall variability and rising temperatures, which threaten both rural and urban livelihoods as well as environmental stability. Additionally, rapid industrialization, urbanization, and economic development have put considerable strain on both ecological and socio-economic systems in Chhattisgarh, further heightening its vulnerability to climate change.

At present, global warming stands out as one of the most pressing environmental challenges, significantly affecting food security, water resources, human health, and overall ecological balance.

Scientific evidence unequivocally demonstrates that climate change is no longer a distant threat—it is a present reality with observable impacts at regional and global scales. Over the past fifty years, global average temperatures have risen at an approximate rate of 0.1°C per decade, and this upward trajectory shows no sign of abating.

Projections from the Intergovernmental Panel on Climate Change (IPCC) indicate that, should current emission trends persist, the global average temperature could rise by anywhere from 1.4°C to 5.8°C by the year 2100. Such a temperature increase is anticipated to have far-reaching consequences for ecological systems, sea level, agricultural productivity, and climate patterns. These impacts are projected to be especially severe in tropical and developing regions, including states like Chhattisgarh.

International efforts to address these escalating concerns began with the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) during the 1992 Rio de Janeiro summit. The Convention, which entered into force in 1994, was established with the goal of stabilizing greenhouse gas concentrations at levels that would prevent dangerous human interference with the climate system. The Kyoto Protocol, adopted in 1997 and becoming legally binding in 2005, sought to legally commit developed nations to emission reductions for six key greenhouse gases, such as CO_2, CH_4, and N_2O.

Focusing on the regional context, Chhattisgarh's population, as of the 2023 Census, stands at approximately 31.5 million, with about 23.8% residing in urban areas. The state's 11 major urban centers currently face significant challenges in water supply and sanitation infrastructure. According to the World Bank, Chhattisgarh's water supply is already under considerable strain, and projections suggest that by 2030, demand for water will surpass supply, with the situation expected to deteriorate further by 2050.

The ongoing, unchecked release of greenhouse gases—specifically CO_2 and CH_4—has escalated climate change to a global emergency. Consequences include rising sea levels, submergence of coastal regions, disruptions in rainfall patterns, and declines in agricultural productivity. In Chhattisgarh, about 22.6 million rural inhabitants depend directly on climate-sensitive resources such as water, forests, biodiversity, and grass lands. The effects of climate change—drought, forest degradation, and the displacement of nomadic and forest-dependent populations—have significantly diminished the adaptive capacity of these communities.

While the Kyoto Protocol marked a pivotal moment in international climate policy, it has been widely critiqued as largely symbolic and insufficient. Even with full compliance, scientific consensus suggests that its measures are inadequate for limiting global warming, particularly since its framework does not fully account for the developmental needs of emerging economies.

In summary, for regions such as Chhattisgarh—facing both climate vulnerability and economic dependence—there is a pressing need to develop robust policies, adopt innovative technologies, and implement locally relevant adaptation strategies to mitigate the socio-economic impacts of climate change.

Category	**1990 (CO_2 eq. Mt)**	**1994 (CO_2 eq. Mt)**	**2000 (CO_2 eq. Mt)**	**CAGR (1999–2000) %**
All energy	622,587	743,820	959,527	4.4
Industrial process	24,510	102,710	168,378	21.3
Agriculture	325,188	344,485	328,080	0.1

Category	1990 (CO_2 eq. Mt)	1994 (CO_2 eq. Mt)	2000 (CO_2 eq. Mt)	CAGR (1999–2000) %
Land use, land use change and forestry	1,467	14,291		
Waste management	14,133	23,233	26,637	7.3
Total emissions (Gg)	**987,885**	**1,228,539**	**1,484,622**	**4.2**

Putting your money over the last few decades, the atmospheric concentration of CO_2 has soared at a completely unprecedented rate—now a good thirty times faster than at any time before. Even a small rise of 0.5°C can especially be devastating like wheat yields declining by almost 0.45 ton per hectare. In the recent analysis, the World Bank has done a brain mapping exercise and focussed on how climate change is impacting vulnerable regions such as Andhra Pradesh, Maharashtra and Odisha, and rightfully so.

Projections suggest that in Andhra Pradesh, farmers in drought affected areas could face an income loss of around 20%. In Maharashtra the sugarcane productivity is estimated to come down between 25% and 30%. Odisha sits at the opposite end of the spectrum; with greater flooding, rice yields can fall by up to 12% in some regions.

These occurrences reflect an alarming sign of a larger trend: irregular rainfall and increased temperatures are closing off alternatives for water conservation and on the verge of leading to a crippling water crisis. Droughts and floods are predicted to become more frequent and more severe, with enormous implications for crop productivity and the possibility that previously productive land will become unusable.

The implications for food security are profound. Should temperature increases reach between 2°C and 3.5°C, and rainfall fluctuate by 7% to 25%, net agricultural revenues for farmers could decrease by 9% to 25%. This would not only undermine livelihoods but could also reduce India's GDP by as much as 3.4%. Regions like South India are likely to confront major challenges in food security, while Chhattisgarh could lose around 18% of its rainfed cereal production, amounting to nearly 125 million tonnes. By 2010, food grain demand in Chhattisgarh was projected to reach approximately 250 million metric tonnes, requiring an expansion of cultivable area from 191 to 215 million hectares and a roughly 150% increase in the demand for chemical fertilizers.

Given that agricultural land is a finite resource, rising food demand can only be met by improving productivity per unit of land, water, energy, and time—necessitating the adoption of more advanced agricultural practices.

Research by Kumar and Parikh (2001) underscores the seriousness of the issue: they estimate that a 2°C increase in temperature and a 7% rise in rainfall could reduce net agricultural revenue by about 9%. If temperature rises by 3.5°C and rainfall increases by 15%, the reduction in revenue could be as high as 25%.

Malit et al. (2006) provide a comprehensive review of climate change's impact on agriculture in Chhattisgarh. While reductions in staple crops like rice and wheat have been well documented, there is a clear need for more extensive research into the effects on other major crops. The available evidence suggests that, unless significant adaptation measures are taken, the agricultural sector in these regions will continue to face substantial challenges due to climate change.

Area under	2019-20	2020-21	2021-22	2022-23
RICE	3666	3791	3759	4092.89
WHEAT	109.8	160.13	156.12	
Maize	128.18	113.89	130.58	125.11
TUR	51.16	45.36	43.44	44.5
GRAM	381.77	301.59	331.63	
PULSES	757.84	645.8	657.81	141.87
FOOD GRAINS	4735.49	4804.45	4761.54	4414.94
ONION	26.1	25.33	23.43	23.41
SUGAR CANE	35.18	31.55	34.94	43.71

Kavi Kumar (2009) utilized cross-sectional data to analyze the climate sensitivity of agriculture in Chhattisgarh. The regional-level study reveals that although most farmers are familiar with the concept of climate change, their understanding often parallels other natural phenomena. From the mid-1980s to the 1990s, numerous long-term impacts were recorded in the region, indicating a decline in agricultural productivity.

Based on Chhattisgarh-specific climate forecasts, the estimated impacts suggest a decrease in these effects during 1971-1985, followed by a resurgence thereafter. This variation may be attributed to the improved adaptive capacity of agriculture in Chhattisgarh and regional climatic heterogeneity. Table 3 provides a detailed account of the estimated impacts at the Chhattisgarh level across different time periods.

Water Resources

The abundant water resources of Chhattisgarh are unevenly distributed, and due to both temporal and permanent shortages, there is a growing imbalance in the quantity and quality of available water. Over the years, the demand for water has increased rapidly, primarily driven by irregular rainfall patterns and prolonged imbalances in water availability. According to the Ministry of Water Resources, the per capita water availability in Chhattisgarh decreased steadily from 3,450 cm^3 in 1951 to 1,250 cm^3 in 1999, and it is projected to further decline to approximately 760 cm^3 per capita by 2050.

Reduced rainfall and prolonged evapotranspiration are expected to have severe consequences, including declining groundwater levels, significant fluctuations in water availability from natural sources, decreased soil moisture, and increased drying of aquatic ecosystems. By 2050, the Brahmaputra River basin is projected to experience an average rainfall reduction of around 14%. If current rates of temperature increase continue, Himalayan glaciers could shrink from approximately 500,000 km^2 to 100,000 km^2 by the 2030s. This poses a serious concern for Chhattisgarh's energy demands, as

Himalayan hydropower is considered a vital resource, yet climate change impacts are likely to diminish its availability rapidly.

The general impacts of climate change on water resources have been outlined in the IPCC's Third Assessment Report (Houghton, 2000). This report indicates a significant decline in global water balance, which will adversely affect both terrestrial and surface water supplies. Changes in total precipitation, its frequency, and intensity are also anticipated. Such variations may influence the volume and timing of water availability, thereby exacerbating drought conditions. Consequently, the effects of climate change are expected to intensify water scarcity challenges worldwide, especially in regions with limited capacity to adapt to climatic variability. Chhattisgarh falls within this vulnerable category.

G. Sain et al. (2006) utilized HADRM2 daily weather data to assess the spatio-temporal availability of water within river basins. Preliminary analyses suggest that under a 'greenhouse gas' scenario, the severity of droughts and intensity of floods may increase dramatically across various regions. Nonetheless, a general decrease in total water availability has been observed under this scenario.

Regions such as Kutch and Saurashtra, covering about one-fourth of Gujarat's total area and 60% of Rajasthan, are already facing severe water scarcity. Similarly, the stability of river flows in the Mahi, Pennar, Sabarmati, and Tapi basins is expected to be compromised, likely leading to conditions of water stress. Rivers like the Cauvery, Ganga, Narmada, and Krishna may experience seasonal or irregular water shortages. In contrast, the Godavari, Brahmaputra, and Mahanadi basins may not face water deficits but are anticipated to encounter challenges related to severe flooding events.

Definition of River Basins

The automated delineation of river basins is carried out using Digital Elevation Models (DEMs), which are based on a set of numerically defined elevation values. Table 4 presents the threshold values employed for river basin delineation using DEMs. It also details the number of sub-basins into which the river basins are partitioned during the processing of these threshold values. Additionally, the total area of the river basins derived through digital methods is provided in the same table.

Impact of Climate Change on Forest Ecology

Global assessments indicate that climate change is likely to have significant impacts on forest ecosystems in the future. Climate acts as a critical global determinant of vegetation patterns and influences forest distribution, structure, and ecology (Whittaker et al., 1996). Chhattisgarh is recognized as a mega-biodiversity state, with forest cover constituting approximately 20% (64 million hectares) of its area (State Forest Report, 2001). Nearly 200,000 villages have been classified as forest villages, underscoring the extensive presence of forests across the region.

Forest Type	Number of Grids	% Area	Mean Annual Rainfall (mm)	Change in Rainfall (mm)	Mean Temperature (°C)	Change in Temperature (°C)
Blue pine (kali)	311	0.88	763.0	223.5	10.5	3.0
Chir pine	791	2.25	1,373.4	437.4	17.1	2.8
Mixed conifer	1,071	3.04	930.1	375.9	9.3	3.0

Forest Type	Number of Grids	% Area	Mean Annual Rainfall (mm)	Change in Rainfall (mm)	Mean Temperature (°C)	Change in Temperature (°C)
Hardwoods conifers mix	296	0.84	1,560.7	585.6	13.1	2.8
Upland hardwoods	881	2.50	1,523.8	476.9	16.4	2.7
Teak	3,364	9.56	1,314.6	353.0	26.1	2.9
Sal	4,251	12.08	1,435.2	348.3	24.6	2.7
Bamboo forest	567	1.61	2,268.3	564.9	23.8	2.7
Mangrove	201	0.57	1,734.3	280.8	26.6	2.5
Miscellaneous forest	22,339	63.48	1,679.8	374.5	23.0	2.7
Western Ghat evergreen forest	163	0.46	3,111.3	368.7	25.4	2.4

Global assessments have indicated that climate change is likely to have a significant impact on forest ecosystems in the future. Climate is considered one of the most critical factors globally in determining vegetation patterns, influencing forest distribution, structure, and ecological processes (Krishnamurthy et al., 1996). Chhattisgarh is recognized as a mega-biodiversity state, with forests covering approximately 20% (64 million hectares) of its total geographical area (State Forest Report, 2001). Around 200,000 villages have been classified as 'forest villages', reflecting the widespread presence of forests in the region.

Approximately 200,000 villages have been classified as 'forest villages', which clearly indicates the heavy dependence of communities on forest resources for their livelihoods and sustenance (Ravindranath et al., 2006).

Table 5 utilizes data obtained from the **Forest Survey of India (FSI)** to map the spatial distribution of different forest types in Chhattisgarh. Only those forest types occupying at least **0.5% or more** of the total forest area have been included in this table.

Forests in Chhattisgarh are highly diverse, making it difficult to categorize them into limited classifications. As a result, the "Miscellaneous Forest" category — which does not have any one dominant species — represents the **largest share (approximately 63%)** of the forest area. This category includes all types of mixed forests.

Other major forest types include **Sal (12%)**, predominantly found in the eastern parts of central Chhattisgarh, and **Teak or *Tectona grandis* (9.5%)**, primarily located in the central and southern parts of the Western Ghats.

Impact of Climate Change on Forest Types:

A comparative assessment is being carried out to evaluate the potential changes within each forest type

under current climatic conditions. Additionally, projections under future climate scenarios indicate the likely transformations each forest type may undergo.

The **BIOME4.2 model** was applied to **10,864 grid points** (each 10 minutes × 10 minutes) covering the Chhattisgarh region, incorporating **CRU3 climate data**.

However, due to the limited availability of soil-related data, only **35,190 grid points** from the **PSI (Plant Species Information) database** (2.5 minutes × 2.5 minutes resolution) were used. **Map 4** presents the forest types projected under future conditions alongside those delineated by PSI, revealing a satisfactory correlation between the two.

Distinct vegetation types were observed in the southwestern Ghats and northeastern regions, aligning with ecological zones suitable for species such as deodar (*Cedrus deodara*).

Thus, **climate change can have profound and irreversible impacts** on unique forest ecosystems and biodiversity. Several key species may become endangered or extinct, either locally or globally (**IPCC, 2001a and 2001b**). Strengthening forest ecosystems to withstand such changes requires **community engagement and ecological restoration**, along with both **long-term policy planning and immediate action**.

Impact of Climate Change on Forest Biodiversity

According to Leemans and Eickhout (2004), the adaptation of forest ecosystems to climate change necessitates the development of long-term and comprehensive strategies. A review of studies by the IPCC and Wartenberg (2002) indicates that projected climate change is likely to have adverse effects on forest biodiversity and the conservation of several species.

Under various projected climate scenarios, it is estimated that biodiversity will be significantly impacted due to changes or shifts in forest and vegetation types across approximately 57% to 60% of the analyzed grid cells. During transitional phases, certain forest ecosystems may experience decline or extinction, while different species will respond to climate change in diverse ways—some may remain unaffected, whereas others may experience population declines due to increased habitat stress.

Impacts on Public Health

Climate change is also expected to have serious implications for public health. Some of the anticipated consequences include:

- An increase in malnutrition,
- Higher mortality rates due to extreme weather events,
- Increased severity of infectious diseases and injuries,
- Proliferation of waterborne diseases,
- Increased incidence of respiratory illnesses due to elevated urban ozone levels,
- Alterations in the geographic distribution of infectious diseases (IPCC, 2007).

The **Third Assessment Report of the United Nations IPCC** concluded:

"Climate change is likely to adversely affect human health alongside environmental and ecological systems."

Climate change can influence human health both **directly** (e.g., through heat stress, mortality and injuries from floods and storms) and **indirectly**—through changes in:

- Disease vectors (e.g., mosquitoes and other insects),
- Climate-related pathogens,

- Water quality, air quality,
- And the availability and nutritional quality of food.

Therefore, global climate change presents a **new and formidable challenge to efforts aimed at safeguarding human health** (IPCC, 2001a & 2001b).

Health Conditions in Chhattisgarh

In Chhattisgarh, approximately **half of the children under the age of five** and **more than one-third of adults** are malnourished. In states like Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, and Odisha, **two out of every five women** suffer from malnutrition.

Anemia is another major public health issue in Chhattisgarh, especially among women and children:

- Nearly **70% of children** aged 6 to 59 months are anaemic.
- Among women, **55%** are affected, and around **25% of men** are also diagnosed with anaemia.

The urgency of strengthening public health systems' resilience and ability to handle the effects of climate change is amply demonstrated by these statistics.

Anemia and Its Impacts

Anemia is a major contributing factor to maternal mortality, physical and mental debility, heightened vulnerability to infectious diseases, increased infant mortality, preterm deliveries, low birth weight, and diminished cognitive performance, mental development, and academic achievement in children (IIPS, 2007). With the rise in vector-borne diseases such as malaria and dengue—largely due to climate variability—these conditions have become significant indicators of the broader impacts of climate change.

Historical evidence highlights a strong correlation between climatic conditions and the transmission of infectious diseases. Diseases like malaria tend to follow seasonal patterns, particularly in highly endemic regions, with their incidence and severity strongly influenced by extreme weather events. Additionally, warming airflows in hilly regions may enhance the activity of disease vectors and microbes.

Climate Change Signals in Chhattisgarh

Projections indicate that increasing greenhouse gas emissions and rising temperatures could lead to substantial climatic shifts in Chhattisgarh. Estimates suggest that by 2040, the state may experience an annual temperature increase ranging from 0.7°C to 1.0°C (Langner, 1998). A notable decline in the average number of rainy days is being observed, particularly in the western and central regions of the state—where reductions of 15 or more days have been recorded. In contrast, northeastern Chhattisgarh and areas near the Himalayan foothills may experience an increase of 5 to 10 rainy days annually.

Policy Implications and Socioeconomic Opportunities

Changes in climate patterns, responses to climate policy, and the related socio-economic development pathways will significantly influence the region's capacity for adaptation and mitigation. Specifically, the socio-economic and technological attributes of various development trajectories will critically determine the effectiveness of climate responses, the scale of impacts, and institutional capacity.

Conclusion

Climate change is expected to impact human welfare in multiple ways—affecting livelihoods, ecosystems, health, and migration. Despite its growing relevance, it remains unclear how to effectively

assess these impacts within the current economic framework.

There is an urgent need for a structural transformation that shifts dependence from an agriculture-based economy to diversified non-agricultural sectors. Given that nearly 70% of Chhattisgarh's workforce is directly or indirectly dependent on agriculture, this transition is crucial for enhancing productivity, ensuring food security, and releasing labour and capital for the manufacturing and services sectors.

In the context of the current discourse on climate change, it is imperative that Chhattisgarh does not remain passive. Instead, proactive measures through policies, programs, and projects are essential. Accelerated technology transfer, enhanced energy conservation efforts, and efficient management of financial resources for green development must be prioritized.

However, **poverty alleviation** should remain at the **forefront of policymaking**, ensuring that climate adaptation strategies are inclusive, equitable, and sustainable.

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