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### Spatio-temporal analysis of climate change in India: a theoretical perspective

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#### Keywords

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#### ABSTRACT

Climate Change has affected human activities directly and indirectly. There have been several causes and impacts of climate change. Due to climate change, there have been changes in the pattern of rainfall, rise in temperatures, evaporation, and salinization of sources of water due to rising sea levels. Glacial melting is increasing year by year. Climate change is due to the observable but micro level alterations in the Earth's orbit that are responsible for changing the amount of solar energy the planet receives. satellites orbiting around Earth and other related technological advances have given a helping hand to the scientists to be able to capture remotely sensed data so that the planet can be studied from all the angles and aspects. Though climate change is a global concern, its effects are being experienced all over the globe but, at varying degree. It will have negative impacts on agriculture, supply of water, quality of air, coastal areas and health of people. India is the second largest country in terms of population and heavily depends on the various sectors like agriculture, fisheries, and forests which are sensitive to changes in climate. It is, therefore, bound to face the worst adverse impacts of climate change.

#### 1. Introduction

The World Bank suggests that the districts that fall in central India show maximum vulnerability to changes in climate as they lack the required infrastructure and depend on agriculture on a very large scale. The districts in Vidarbha region of Maharashtra state are especially vulnerable to the damages caused by climate change. A major source for the decline in income of the farmers has been the changes in the climate. Increased temperature and disturbed precipitation are found to be damaging the crop yields and, consequently, the wealth of the farmers. Industrialization induced climate change, is the major cause of global warming and changing patterns of rainfall. Also, according to the estimation of the World Bank, unattended climate change would cause the Indian average temperature to rise to 29.1°C in the next few decades. As the aspect of changing climate becomes more intense, it will affect several parts of India extremely. When the average temperature in 2009-18 to the that in 1950-80 are compared, it is found that some pockets have already been affected by climate change by becoming hotter than before. In several parts of states like Rajasthan, Gujarat, Tamil Nadu, Kerala, and the

North-East, it is observed that, there has been a rise of nearly 1° C in the average temperature during the last decade. It is higher than the historical average in the 1950-80 period.

Changes in climate have always been harmful to man. An increase of 0.3 - 0.6 °C is observed in the he average surface temperature of the globe since the several centuries. The rise in temperature may be minimal, but it can be disastrous with unreparable impacts. There are noticeable impacts of changing climate which occur in the form of melting of glaciers, forest fires, changing rainfall patterns, rising of sea levels, coastal cities under water level, floods, and droughts. Tsunami (2004), Uttarakhand flash floods (2013), Kashmir floods (2014), Kerala flood (2018 & 2019) and Krishna River Basin floods (2019) are some examples in various parts of India. India has been able to create a stable platform to discuss and bring in better cooperation between the nations on issues related to climate through its pledge for Paris Agreement. Also, India is an example by committing to bring down its emission intensity of gross domestic product (GDP) by 33-35% of 2005 levels by 2030.

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## 2. Method

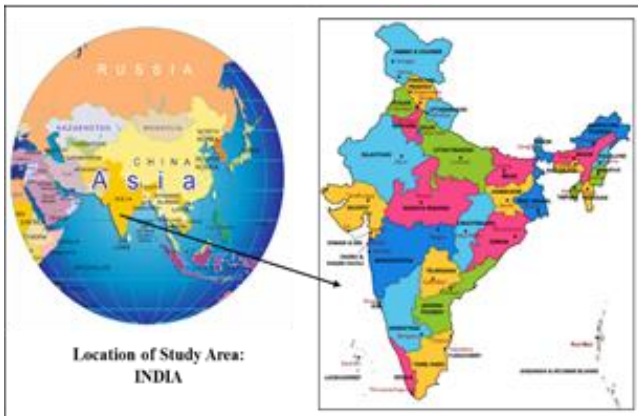
This paper based on secondary data collected from various articles, books, journals, reports and other related material published online and offline.

### 2.1. Research objectives

- To understand the concept of climate change
- To study the major causes of climate change
- To administer the impact of climate change in India

### 2.2. Study area

India is a country in South Asia. It comprises of twenty-nine states and eight union territories. Its population stands second in the world after China. Its latitudinal extension is between 68<sup>o</sup> and 96<sup>o</sup> East and longitudinal extension is between 8<sup>o</sup> and 36<sup>o</sup> North approximately. It is a major developing country in the world and is the largest democracy too. It is highly agrarian in nature due to its fertile soil and favorable climatic conditions. It is however now being affected by changes in climate making it a matter of concern.



**Figure 1.** Location of India with States

### 2.3. Factors leading to climate change greenhouse gases (GHGS)

Major source of climate change is greenhouse effect. The earth's surface warms due to the energy received from the Sun. Most (90 %) of the sun's insolation is absorbed by these gases and radiated back towards the surface. Out of the total energy passing the atmosphere, some of it gets scattered and only some of it gets reflected into the atmosphere from the surface of the Earth. Gases like CO<sub>2</sub>, methane, and Nox and water vapor, comprise less than 1% of the atmosphere. They are called 'greenhouse gases'. Human activities like decomposition of wastes in land fields, agriculture and rice cultivation and release of carbon dioxide during burning of fuels as coal, oil, and natural gas also lead to an increase in greenhouse gases.

#### 2.3.1. Human activities

Most of the population in India is engaged in agriculture. The agro-based activities, various land-uses,

etc., lead to rise in the levels of methane and nitrous oxide. Industries produce greenhouse gases like chlorofluorocarbons, whereas automobiles lead to ozone generation. According to 5<sup>th</sup> Report of IPCC, approximately 95 % human activities over the past 50 years led to global warming. Industrialization and urbanization are major factors in the process.

#### 2.3.2. Emission of CO<sub>2</sub>

Volcanic eruption is one of the most-deadly natural disasters on the Earth's surface. The eruption releases carbon dioxide (CO<sub>2</sub>) in large quantities. It is also emitted through natural processes such as respiration and manmade activities like burning of fossil fuels. This gas directly impacts the environment and human beings.

#### 2.3.3. Ocean currents

71% of the Earth's surface comprises of oceans and water bodies. Hot and cold ocean currents flow along all coastlines. The vast water bodies absorb the sun's insolation twice the atmosphere. Therefore, the oceans form a major component of the climate system.

#### 2.3.4. Water vapor

Atmosphere is getting heated due to solar energy, because of which the amount of water vapor is increasing in the atmosphere day by day. Water vapor rises as the temperature of the Earth's atmosphere rises leading to precipitation. This cycle is very important for the smooth functioning of the ecology on globe.

## 3. Discussion and results

According to scientists, global temperature will continue increasing for few decades, due to the greenhouse gases emitted due to human activities. It has resulted in the loss of glaciers, rise in sea level, huge floods, droughts, shifting of plant and animal ranges and a change in the pattern of floral reproduction and heat waves. Following are the impacts of climate change on environment and human life.

It is observed from table 01 that the annual mean temperatures of states of India have increased considerably in all the states. Only Chhattisgarh, Haryana, Jammu and Kashmir, Meghalaya, Orissa, Punjab, Uttar Pradesh, Uttarakhand and West Bengal do not show an increase. Sikkim (+0.05 o C/year) tops the chart followed by Manipur (+0.03 o C/year) and the least has been observed in Punjab (-0.01 o C/year). The major reasons for the change is the increase of carbon in the atmosphere and other greenhouse gases.

Table 02 represents that from 1901 to 2010, the highest fluctuations are observed in Meghalaya (+14.68 mm/year) and Andaman and Nicobar (-7.77 mm/year). The driving factors for changes in rainfall may include changes in wind direction and wind speed, occurrences of cyclones, changes in temperature, rate of evaporation and alterations in the land use of the areas. The changing trend implies that the states with high differences in average rainfall have undergone the above conditions and will continue to do so.

**Table 1.** Mean Temperature Trends, 1901-2010 (State level annual and seasonal mean temperature trends based upon 282 surface meteorological stations for 1951-2010. Increasing (+) and decreasing (-) trends significant at 95% level of significance are shown in bold and marked with '\*' sign)

State	Mean Temperature Trends in Degree Celsius Per Year				
	Annual	Winter	Summer	Monsoon	Post monsoon
Andaman and Nicobar Islands	<b>+0.01*</b>	<b>+0.01*</b>	<b>+0.01*</b>	<b>+0.01*</b>	<b>+0.01*</b>
Andhra Pradesh	<b>+0.01*</b>	<b>+0.01*</b>	<b>+0.01*</b>	<b>+0.01*</b>	<b>+0.01*</b>
Arunachal Pradesh	<b>+0.01*</b>	<b>+0.02*</b>	+0.01	+0.01	<b>+0.02*</b>
Assam	<b>+0.01*</b>	<b>+0.01*</b>	No trend	<b>+0.01*</b>	<b>+0.02*</b>
Bihar	<b>+0.01*</b>	No trend	No trend	<b>+0.01*</b>	<b>+0.02*</b>
Chhattisgarh	No trend	No trend	-0.01	No trend	+0.01
Delhi	<b>+0.01*</b>	+0.01	<b>+0.01*</b>	+0.01	<b>+0.02*</b>
Goa	<b>+0.02*</b>	<b>+0.02*</b>	<b>+0.02*</b>	<b>+0.02*</b>	<b>+0.03*</b>
Gujarat	<b>+0.01*</b>	<b>+0.02*</b>	+0.01	<b>+0.01*</b>	<b>+0.02*</b>
Haryana	No trend	-0.01	No trend	<b>-0.01*</b>	+0.01
Himachal Pradesh	<b>+0.02*</b>	<b>+0.02*</b>	+0.01	<b>+0.03*</b>	<b>+0.02*</b>
Jammu and Kashmir	-0.01	No trend	-0.02	-0.02	<b>-0.02*</b>
Jharkhand	<b>+0.01*</b>	+0.01	No trend	No trend	<b>+0.02*</b>
Karnataka	<b>+0.01*</b>	<b>+0.01*</b>	No trend	<b>+0.01*</b>	<b>+0.01*</b>
Kerala	<b>+0.01*</b>	<b>+0.01*</b>	<b>+0.01*</b>	<b>+0.01*</b>	<b>+0.01*</b>
Lakshadweep	<b>+0.01*</b>	<b>+0.02*</b>	<b>+0.02*</b>	<b>+0.01*</b>	<b>+0.01*</b>
Madhya Pradesh	<b>+0.01*</b>	No trend	No trend	No trend	<b>+0.03*</b>
Maharashtra	<b>+0.01*</b>	No trend	<b>+0.01*</b>	+0.01	<b>+0.01*</b>
Manipur	<b>+0.03*</b>	<b>+0.04*</b>	<b>+0.02*</b>	<b>+0.02*</b>	<b>+0.03*</b>
Meghalaya	No trend	<b>+0.01*</b>	-0.01	No trend	<b>+0.02*</b>
Mizoram	<b>+0.01*</b>	<b>+0.02*</b>	No trend	<b>+0.02*</b>	<b>+0.02*</b>
Orissa	No trend	No trend	No trend	<b>-0.01*</b>	+0.01
Punjab	<b>-0.01*</b>	<b>-0.02*</b>	-0.01	<b>-0.01*</b>	No trend
Rajasthan	<b>+0.01*</b>	<b>+0.01*</b>	No trend	+0.01	<b>+0.02*</b>
Sikkim	<b>+0.05*</b>	<b>+0.05*</b>	<b>+0.02*</b>	<b>+0.05*</b>	<b>+0.04*</b>
Tamil Nadu	<b>+0.02*</b>	<b>+0.03*</b>	<b>+0.03*</b>	<b>+0.02*</b>	<b>+0.02*</b>
Tripura	<b>+0.01*</b>	<b>+0.01*</b>	<b>-0.01*</b>	<b>+0.01*</b>	<b>+0.03*</b>
Uttar Pradesh	No trend	No trend	-0.01	No trend	<b>+0.01*</b>
Uttarakhand	-0.01	+0.01	-0.02	<b>-0.02*</b>	+0.01
West Bengal	No trend	No trend	<b>-0.01*</b>	<b>+0.01*</b>	<b>+0.01*</b>

**Table 2.** Average Rainfall Trends, 1901-2010 (State level annual and seasonal rainfall trends based upon 1451 rainfall stations for 1951-2010. Increasing (+) and decreasing (-) trends significant at 95% level of significance are shown in bold and marked with '\*' sign)

State	Mean Temperature Trends in Degree Celsius Per Year				
	Annual	Winter	Summer	Monsoon	Post monsoon
Andaman and Nicobar Islands	<b>-7.77*</b>	<b>-2.70*</b>	-0.51	-2.93	-1.35
Andhra Pradesh	+1.31	+0.29	+0.35	-0.14	+0.46
Arunachal Pradesh	-3.63	-0.10	No trend	-2.30	-0.83
Assam	-2.96	0.08	-0.56	-2.19	-0.75
Bihar	+1.41	-0.06	<b>+0.59*</b>	+1.11	+0.11
Chhattisgarh	-2.03	+0.02	+0.04	-2.38	+0.06
Delhi	-0.51	+0.16	<b>+0.40*</b>	-0.32	-0.20
Goa	-3.82	No trend	-0.31	-2.61	+0.04
Gujarat	+1.41	No trend	-0.03	+1.27	-0.02
Haryana	+0.45	+0.07	<b>+0.39*</b>	-0.01	<b>-0.23*</b>
Himachal Pradesh	-3.26	-0.18	+0.31	-2.85	-0.21
Jammu and Kashmir	+2.13	<b>+1.88*</b>	-1.07	-0.16	-0.37
Jharkhand	+0.84	-0.13	+0.43	+0.44	+0.03
Karnataka	-0.05	+0.10	-0.41	+0.61	+0.14
Kerala	-1.43	-0.40	-1.15	-2.42	+1.68
Lakshadweep	+3.22	-0.33	-0.44	+1.73	+0.83
Madhya Pradesh	-1.81	-0.06	No trend	-1.74	+0.03
Maharashtra	-0.71	+0.04	0.15	-0.29	-0.05
Manipur	+1.94	+0.10	+1.63	-0.89	+0.11
Meghalaya	14.68	<b>+0.52*</b>	+2.25	+9.27	+2.04
Mizoram	+0.33	-0.31	+2.80	+7.71	-6.19
Orissa	+0.69	+0.06	<b>+0.65*</b>	-0.23	-0.83
Punjab	-2.41	+0.09	+0.22	-1.49	-0.13
Rajasthan	+0.04	+0.02	<b>+0.17*</b>	-0.09	-0.04
Sikkim	-3.12	-0.12	-0.83	-1.36	-0.11
Tamil Nadu	+0.80	-0.16	-0.47	-1.35*	+1.49
Tripura	+0.77	+0.11	+1.73	-1.11	-0.55
Uttar Pradesh	-4.42*	-0.22	+0.02	<b>-3.52*</b>	-0.33
Uttarakhand	-1.07	-0.01	+0.86	-1.45	-0.63
West Bengal	<b>+3.63*</b>	+0.16	<b>+1.34*</b>	+1.45	+0.19

### **3.1. Impact of climate change on agriculture**

The increasing population has resulted in scarcity of natural resources. Climate change has affected crop productivity due to alterations in temperature and rainfall. It has also caused changes in soil quality due to which the yield of cereals will decline in India.

### **3.2. Impact of climate change on atmosphere**

Climate change may affect health of human beings as it increases ground-level ozone and the particulate matter causing air pollution. Ground-level ozone results in several health issues- diminished lung function, increased hospitalization and fatal incidences of asthma and premature deaths.

### **3.3. Impact of climate change on urbanization**

India's urban system is the second largest on globe. It comprises of 310 million people spread across 5161 urban spaces in 2005. It is surprising to know that 5100 urban centers comprise roughly 30% of the total Indian population which is expected to rise to 40% by 2030. It is projected that the population of 70 urban spaces will rise to 1 million inhabitants by 2025.

### **3.4. Impact of climate change on health**

Climate change affects maximum particularly children, pregnant women and old people. It is expected that between 2030 and 2050, changing climate change may lead to death of 2,50,000 people every year due to problems like malnutrition, malaria, diarrhea, and heat stroke.

### **3.5. Water borne diseases**

Such diseases are vulnerable to climate change and represent variations according to changes in the season. Also, diarrheal diseases are another common occurrence during the monsoon season. Increased variability of rainfall as a result of climate change affect freshwater sources on a large scale globally. It is observed that scarcity of water has already affected 40% people all over the Earth.

### **3.6. Flood borne diseases**

Floods have become common all over the globe which contaminates several freshwater resources and increases the risk of water-borne diseases. If the contamination is due to animal waste, it leads to epidemics of leptospirosis, rotavirus and cholera in the affected areas. Absence of basic sanitation is a major factor in increasing water borne diseases.

### **3.7. Impact of climate change on migration**

Sudden changes in climate lead to migration of people as they become victims of droughts or floods in the rural areas. This leads to overcrowding of the urban spaces and related impacts are experienced. In India, a large chunk of population is estimated to be affected by issues related to global warming in the near future.

### **3.8. Impact of climate change on poor and the vulnerable people**

Climate and weather have a direct and indirect relationship with mankind. Vulnerable and poor populations are mostly affected by climate change due to higher food prices, loss of income, water scarcity, declining health and forced outmigration. The slum dwellers and other migrants and poor who generally live-in vulnerable areas like the riverbeds, flood plains, hill slopes will be extremely affected.

### **3.9. Impact of climate change on food supply**

Temperature is the main component of climate change. Rising temperature and uneven precipitation are responsible to decrease the production of staple crops. Ultimately it will increase the prevalence of malnutrition and under nutrition in most of the country.

### **3.10. Impact of climate change on transportation**

Transportation is very important to human life. Due to disasters like storms, floods, cyclones, coastal flooding, etc., a great damage is caused to the infrastructure of the affected area. The carbon emission in India has always remained very high except the current year 2020 which may be due to the Coronavirus driven lockdown which has reduced the transportation and industrial activities to the minimum in the country.

### **3.11 Impact of climate change on economy**

The World Bank estimates a loss of about 2% in National Gross Domestic Product of the country. It is a result of shortage of clean water and the damage caused to the sectors like agriculture and fisheries, tourism and energy. Therefore, it can be said that when the health is affected, the economy is also affected.

### **3.12. Impact of climate change on coastal area**

According to Aggarwal and Lal, the Indian coast is predicted to undergo a rise in sea level between 30 and 80 cm over the next century. If timely measures are not taken, then, the people living in coastal areas may get affected badly. The coastal cities of Mumbai, Kolkata and Chennai are at an average elevation of 2-10 meters and lie in the Low Elevation Coastal Zone (LECZ) category. Hence, they are most likely to suffer from flooding.

## **4. Conclusion**

From the above, it can be concluded that, in the Indian continent, there has been an increase in the annual mean temperature during the last century. The predicted climate change reveals that the country will experience disastrous events that will enormously impact human life. It must be agreed that the climate is changing and it will surely lead to detrimental impacts. Therefore, thinking about measures for mitigation and adaptation, both is equally important. Same is the case with developed nations who are trying hard to cope with the challenges posed by changing climate. However, with a

very large and diverse population, India needs to put more efforts to counter the impacts.

## 5. Recommendations

Taking into consideration the increasingly changing climate, following are the recommendations to reduce the impact on human race.

- Boosting health care services
- Controlling the growth of vector
- Spreading awareness about health insurance
- Higher investment and greater research in climate change
- Undertaking health risk assessment studies
- Vulnerability mapping using GIS
- Establishment of baseline conditions
- Scenario modeling

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