An Overview on Impact of Climate Change in India

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Abstract:
Climate change poses a significant threat to the sustainable development of nations, with India being particularly susceptible due to its diverse geography, large population, and dependence on climate-sensitive sectors. This research article explores the current status of climate change in India, focusing on its impacts, vulnerabilities, and proposed mitigation strategies. The integrates socio-economic analyses, and policy perspectives to provide a comprehensive overview of the climate change scenario in India.

Introduction:

1.1 Background:

India's vulnerability to climate change stems from its vast geographical and demographic diversity. Rising temperatures, changing precipitation patterns, and extreme weather events are already affecting various sectors, including agriculture, water resources and health.

Climate change is one of the most important global environmental challenges facing humanity with implications for food production, natural ecosystems, freshwater supply, health, etc. According to the latest scientific assessment, the earth's climate system has demonstrably changed on both global and regional scales since the pre-industrial era. Further, evidence shows that most of the warming (of 0.1 o C per decade), observed over the last 50 years, is attributable to human activities (IPCC, 2001a and 2001b).

The Intergovernmental Panel on Climate Change projects that the global mean temperature may increase between 1.4 and 5.8 o C by 2100. This unprecedented increase is expected to have severe impact on the global hydrological system, ecosystem, sea level, crop production and related processes. The impact would be particularly severe in the tropical areas, which mainly consist of developing countries, including India (Jayant et al., 2006).

1.2 **Objectives:**

This research aims to:

- Assess the current impacts of climate change in India.
- Identify the sectors most vulnerable to climate change.
- Evaluate existing adaptation and mitigation strategies.
- Propose recommendations for enhancing India's resilience to climate change.

Impacts of Climate Change in India:

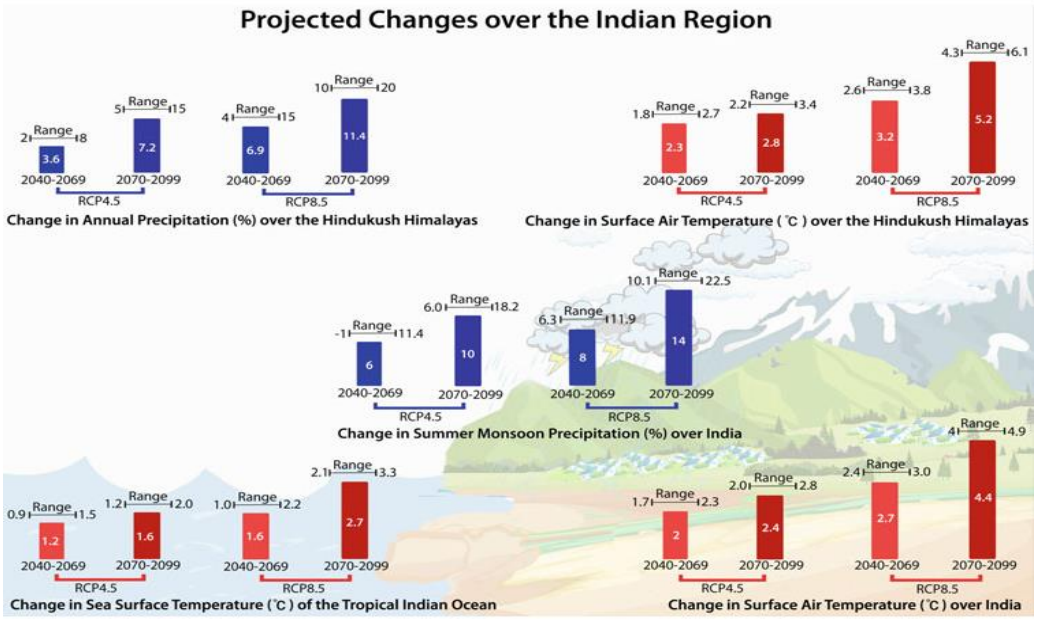
Temperature Rise:

Analysing temperature trends reveals a consistent rise over the past decades, leading to heatwaves, altered monsoon patterns, and disruptions in ecosystems.

The phenomenon of rising temperatures in India is a complex interplay of various factors, both natural and human-induced. Understanding these causes is crucial for formulating informed strategies to address the challenges posed by increasing temperatures.

Temperature Rise Over India

India's average temperature has risen by around 0.7°C during 1901–2018. This rise in temperature is largely on account of GHG-induced warming, partially offset by forcing due to anthropogenic aerosols and changes in LULC. 1 Unless otherwise specified, "temperature" refers to the sea surface temperature (SST) for oceanic areas and near surface air temperature over land areas.



Best estimate and range in climate model projections of future changes in 1. Surface air temperature over India (°C; bottom right panel), 2. Sea surface temperature of the tropical Indian Ocean (°C; bottom left panel), 3. Surface air temperature over the Hindu Kush Himalayas (°C; top right panel), 4. Summer monsoon precipitation over India (% change; centre panel), 5. Annual precipitation over the Hindu Kush Himalayas (% change; top left panel). All the changes are computed relative to their climatological average over the 30-year period 1976–2005. Projected changes are reported for the middle and end of the 21st century under the RCP4.5 and RCP8.5 scenarios. (Krishnan *et al.* 2020)

Anthropogenic Factors:

2.1 **Greenhouse Gas Emissions**:

The burning of fossil fuels for energy, industrial processes, and deforestation contribute to the release of greenhouse gases (GHGs) such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). These gases trap heat in the atmosphere, leading to a warming effect known as the greenhouse effect.

Projected Changes in Global Climate Global climate models project a continuation of human-induced climate change during the twenty-first century and beyond. If the current GHG emission rates are sustained, the global average temperature is likely to rise by nearly 5°C, and possibly more, by the end of the twenty-first century. Even if all the commitments (called the "Nationally Determined Contributions") made under the 2015 Paris agreement are met, it is projected that global warming will exceed 3°C by the end of the century. However, temperature rise will not be uniform across the planet; some parts of the world will experience greater warming than the global average. Such large changes in temperature will greatly accelerate other changes that are already underway in the climate system, such as the changing patterns of rainfall and increasing temperature extremes. (Krishnan *et al.* 2020)

2.2 **Land use and land cover change effect on surface temperature**

Rapid urbanization and changes in land use patterns, such as the conversion of natural landscapes into urban areas and agricultural fields, contribute to localized warming, often referred to as the urban heat island effect.

Through a combination of ground, satellite remote sensing and reanalysis products, we investigate the recent changes to land surface temperature in the Eastern state of Odisha between 1981 and 2010 and assess its relation to LULC. Our analysis reveals that the mean temperature of the state has increased by ~0.3 °C during the past three decades with the most accelerated warming (~0.9 °C) occurring during the recent decade (2001 to 2010). Our study shows that 25 to 50% of this observed overall warming is associated with LULC. Further we observe that the spatial pattern of LULC changes matches well with the independently estimated warming associated with LULC suggesting a physical association between them .(Partha Pratim Gogoi 2019)

2.3 Industrial Activities:

Emissions from industrial activities, including the production of cement and other materials, contribute to the release of GHGs and other pollutants that influence local and regional temperatures.

Natural Factors:

3.1 Solar Radiation:

Variations in solar radiation, driven by changes in solar activity, can influence Earth's temperature. While the sun plays a significant role in the Earth's climate, current temperature trends cannot be solely attributed to natural solar variability.

3.2 Oceanic and Atmospheric Patterns:
Natural climate phenomena, such as El Niño and La Niña, influence temperature patterns in India. These oceanic and atmospheric events can lead to periods of elevated temperatures and altered precipitation patterns.

4.1 Melting Glaciers and Ice Caps:
The retreat of glaciers and ice caps reduces the Earth's albedo, or reflectivity, leading to increased absorption of solar radiation and contributing to temperature rise.

4.2 Changes in Cloud Cover:
Shifts in cloud cover influence the amount of incoming solar radiation reaching the Earth's surface, affecting local and regional temperature patterns.

Regional Influences:
5.1 Himalayan Region:
The Himalayan region, crucial for India's climate dynamics, experiences changes in snowfall patterns and glacier melt, impacting temperature trends in adjacent areas.

5.2 Coastal Areas:
Rising sea levels and changes in ocean currents contribute to temperature variations in coastal regions, affecting both marine and terrestrial ecosystems.

5.3 Changing Precipitation Patterns:
Shifts in monsoon patterns result in erratic rainfall, affecting agricultural productivity and water availability.
Precipitation, a cornerstone of the Indian climate system, is undergoing discernible changes, presenting challenges and opportunities for the nation's diverse ecosystems and human populations. This article seeks to unravel the complexities of changing precipitation patterns, shedding light on the causes, consequences, and potential adaptation strategies.

Monsoon Variability:
2.1. Historical Perspective:
India's monsoon, a crucial determinant of the country's climate, has exhibited variations in intensity, onset, and duration over the years. Historical data reveals shift in the monsoon cycle, impacting regional climates and ecosystems.

2.2. Factors Influencing Monsoons:
Natural phenomena, such as El Niño and La Niña events, the Indian Ocean Dipole, and atmospheric pressure systems, play pivotal roles in influencing the behaviour of the monsoon. Anthropogenic factors, including land-use changes and greenhouse gas emissions, further contribute to the complex dynamics.

Regional Factors:
3.1. Land Subsidence:
In addition to global causes, regional factors play a crucial role in sea level rise in India. Land subsidence, or the sinking of land, is occurring in some coastal areas due to natural processes and human activities such as groundwater extraction and urban development. This local subsidence exacerbates the impact of rising sea levels.

3.2. Tectonic Processes:
India is situated in a seismically active region, and tectonic processes, including subsidence and uplift, influence local sea level variations. Subsidence resulting from tectonic activity can contribute to relative sea level rise in certain coastal areas.

3.3. Changes in Ocean Currents:
Alterations in ocean currents, driven by global climate patterns and local factors, can influence sea levels along the Indian coastline. These changes may result in variations in coastal sea level patterns.

Impact on Coastal Areas:
Climate Change Impacts on Coastal Ecosystems The impacts of climate change on coastal ecosystems have been extensively reviewed. Briefly, these syntheses have found that climate change can strongly affect coastal eco systems at all levels of biological organization. First, climate change can have strong impacts on gene expression, cellular and whole-organism physiology, driving changes in their survival, growth, reproduction, and behaviour. Recent advancements in molecular techniques (e.g., DNA-sequencing technologies and quantitative genetics) are allowing for in-depth characterization of the genomic and physiological responses of coastal organisms to climate change and for deciphering the genetic basis underlying their disparate capacities to acclimatize, adapt and evolve under climate change. Such studies can provide mechanistic bases for understanding biological responses to climate change. Climate change further leads to global redistribution of coastal biota via physiologically driven species range shifts and altered species interactions. To match their physiological tolerances, organisms tend to shift distributions to higher latitudes, deeper depths (in subtidal systems), or higher elevations (in intertidal systems). Rates of range expansion/contraction differ dramatically among

species. Consequently, species may not necessarily interact with the same assemblage as they have in recent history. Climate change may also directly alter species interactions by, for example, changing species behaviour and diet, introducing novel and more potent herbivores, breaking down mutualisms, or reversing winners and losers in competition. Range shifts and altered species interactions then act together to reshuffle communities, leading to tropicalization of temperate zones and borealization of polar zones. Effects of climate change on community dynamics, however, can vary greatly among tropical, temperate, and polar zones, and global- and regional-scale comparative studies are needed to assess large-scale variation in the effects of climate change on distributional and compositional changes in coastal marine communities

3.4 Extreme Weather Events:
Increased frequency and intensity of cyclones, floods, and droughts pose significant risks to infrastructure and livelihoods. India is increasingly experiencing a surge in the frequency and intensity of extreme weather events, posing significant challenges to its socio-economic fabric. This article aims to explore the various types of extreme weather events witnessed in India, their causes, and the far-reaching impacts on the nation's diverse regions.

Types of Extreme Weather Events:
2.1. **Heatwaves:**
Rising temperatures, a consequence of climate change, contribute to more frequent and intense heatwaves across India. These events can have severe implications for public health, agriculture, and water resources.

2.2. **Floods:** Monsoon rains, often erratic and intense, result in flooding in various parts of the country. Flash floods and riverine floods impact communities, agriculture, and infrastructure, leading to loss of life and property.

2.3. **Cyclones:**
Coastal regions, especially those along the Bay of Bengal and the Arabian Sea, are prone to cyclones. These storms bring strong winds, heavy rainfall, and storm surges, causing extensive damage to infrastructure and disrupting livelihoods.

2.4. Droughts:
Irregular monsoons and changing precipitation patterns contribute to prolonged droughts in certain regions, affecting agriculture, water availability, and rural livelihoods.

3.1 Impact on Agriculture:
Indian agriculture, heavily dependent on monsoons, faces yield uncertainties, changing cropping patterns, and increased pest and disease incidence.
Indian agriculture, a cornerstone of the nation's economy, is increasingly vulnerable to the changing nature of the climate. This article aims to examine the evolving climate impact on agriculture in India, analysing the challenges faced by farmers and exploring adaptive strategies to ensure food security and rural sustainability.

Temperature Changes:
2.1. Rising Temperatures:
Climate change has led to a consistent rise in temperatures across India. Higher temperatures can impact crop growth cycles, affecting flowering, pollination, and ultimately, crop yields.

2.2. Heat Stress:
Extended periods of high temperatures contribute to heat stress in crops, particularly during critical developmental stages. This can result in reduced yields and quality of produce.

Altered Precipitation Patterns:
3.1. Erratic Monsoons:
Changing precipitation patterns, characterized by erratic monsoons, pose challenges for rain-fed agriculture. Inconsistent rainfall affects crop planning and water availability.

3.2. Intense Rainfall and Flooding:
Increased intensity of rainfall events leads to soil erosion, waterlogging, and flash floods, causing damage to crops and infrastructure.

3.3. Droughts:
Conversely, periods of prolonged drought have become more frequent, leading to water scarcity and crop failure in several regions.

3.2 Impact on Water Resources:
Changing precipitation patterns impact water availability, affecting agriculture, urban areas, and ecosystems.

Climate change is significantly altering the hydrological cycle, affecting water resources worldwide. In the context of India, a country highly dependent on monsoonal rains and glacial melt, the impact on water resources is profound. This article delves into the complex interplay between climate change and water resources in India, exploring the challenges and proposing adaptive strategies.

Changes in Precipitation Patterns:

2.1. Erratic Monsoons:

Climate change has led to increased variability in the Indian monsoon, resulting in unpredictable and erratic rainfall patterns. This poses challenges for water resource management, affecting agriculture and water supply.

2.2. Changing Rainfall Intensity:

Intensification of rainfall events contributes to flash floods, soil erosion, and waterlogging, impacting both rural and urban water systems.

Glacier Melt and Himalayan Water Sources:

3.1. Retreat of Glaciers:

Rising temperatures accelerate the retreat of glaciers in the Himalayas, a crucial source of freshwater for many rivers in India. This affects the timing and volume of river flows.

3.3 Impact on Health:

IMPACT ON HUMAN HEALTH Eighteen heat-waves were reported in India between 1980 and 1998, with a heatwave in 1988 affecting ten states and causing 1300 deaths. Heat-waves in Odisha, India, in 1998, 1999 and 2000 caused an estimated 2000, 91 and 29 deaths respectively and heat-waves in 2003 in Andhra Pradesh, India caused more than 3000 deaths temperatures can lead to coastal flooding, which can force the communities to use contaminated water, inadequate sanitation systems, or trigger migration into areas with insecure water and sanitation availability which can lead to the spread of Cholera9. Rising temperatures and changing patterns of rainfall are projected to decrease crop yields in many developing countries, stressing upon food supplies. There are 13 coastal states and Union territories susceptible to sea-level rise in the country, with about 84 coastal districts affected by tropical cyclones. States like Tamil Nadu, Andhra Pradesh, Odisha and West Bengal, Gujarat and Union Territory of Puducherry are most affected by cyclonic activities. Under-nutrition and related disease is currently the greatest contributor to the global burden of disease, killing over 3.5 million people a year, mostly children in developing countries. With much dependence on natural resources and climate sensitive sectors such as agriculture, water and forestry, India may face a major threat from scarcity of vital resources

. Major health effects due to changing climate can be broadly classified as follows:

1. Extreme weather-related health effects
2. Air pollution-related health effects
3. Water and food-borne diseases
4. Vector-borne diseases
5. Effects of food and water shortages

Impact of climate change on Human health in India

Year	Acute Diarrheal Diseases		Malaria		Acute Respiratory Infection		Japanese Encephalitis		Viral Hepatitis	
	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths
2005	8870507	2918	2031790	931	-	-	2593	556	153034	1038
2006	9289558	2787	2085484	1005	-	-	2061	479	149262	1147
2007	9441456	3475	1842019	973	-	-	1765	466	135859	914
2008	10510476	4709	1869403	1006	-	-	2568	707	151287	1006
2009	-	-	1915363	949	25571757	5223	1697	367	203939	1122
2010	-	-	1816569	963	-	-	6669	1682	-	-
2011	10079263	3124	1785129	1707	25807722	3467	2871	663	146433	673
2012	10993639	3603	1508927	1311	36171496	6948	4110	995	110055	544
2013	11408666	2865	1526210	1055	27451421	5321	3839	684	92291	536
2014	11224319	1762	1533169	1068	26544613	2813	4482	774	110586	586

Source: Compiled from National Family Health Survey

6.Psycho-social impacts on displaced populations 7. Health impacts from conflicts over access to vital resource (IMPACT OF CLIMATE CHANGES ON HUMAN HEALTH IN INDIA Dr.D. Amutha)

Climate change can result in increased temperatures in both ocean water and ambient air rise in sea level due to increased Agriculture and Food Security:

Impact on Crop Yield and Nutrition:
Climate change affects agricultural productivity, leading to changes in crop yields and nutritional quality. This, in turn, has implications for human health, particularly in communities where agriculture is a primary source of livelihood and nutrition.
With melting glaciers, flood risks would increase in the near future. In the long-term, there can be no replacement for the water provided by glaciers that could result in water shortages on an unparalleled scale. Floods and drought are thus projected to multiply as a consequence of climate change. This will lead to a huge crop loss and leave large patches of arable land unfit for cultivation. To sum up, it will threaten food security. Due to a 2 to 3.5 o C rise in temperature accompanied by a 7% to 25% change in precipitation, farmers may be losing a net revenue between 9% and 25% which may adversely affect the GDP by 1.8% to 3.4% (Kavi Kumar and Parikh, 1998). There will be serious consequences for food security in the south and India stands to lose a massive 125 mt equivalent to some 18% of its rainfed cereal production (Fisher et al., 2001)

Conclusion:
This research article examines India's climate change situation, focusing on impacts, vulnerabilities, and mitigation strategies, integrating socio-economic analyses and policy perspectives to provide a comprehensive overview. Climate change significantly impacts coastal ecosystems at all biological levels, affecting gene expression, cellular and whole-organism physiology, survival, growth, reproduction, and behaviour. Advancements in molecular techniques allow for in-depth characterization of genomic and physiological responses and understanding their genetic basis for adaptation and evolution.

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