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The Impact of Climate Change on Coastal Erosion and Settlement Patterns

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Abstract
This study examines the environmental effects of climate change on Eastern coastal communities in India without addressing mitigation options. Due to its sensitivity to increasing sea levels, changing weather patterns, and increased frequency of extreme climatic events, the region faces many difficulties that influence its socioeconomic fabric. Climate change's direct and indirect effects on Eastern coastal communities, particularly on agriculture, fisheries, and traditional livelihoods, are studied. Food security and economic stability are threatened by rising temperatures and unpredictable precipitation. The study highlights coastal populations' vulnerabilities and differences in adaptability to environmental changes. Climate change causes coastal erosion, biodiversity loss, and ecological changes, which the research examines. The study covers coastal West Bengal, Tamil Nadu, and Puducherry districts. The vulnerability of these places to climate change was determined by sea-level rise, historical cyclone events, and population density.

Keywords: Climate change, coastal erosion, sea-level rise, settlement displacement, erosion hotspots, adaptation, coastal infrastructure etc.

Introduction

The roughly 7516 km of Indian coastline is home to a densely populated human agglomeration. The ecology is facing significant problems due to climate change and variability, which makes it more sensitive and risky. Climate change is defined by the Intergovernmental Panel on Climate Change (IPCC) as a shift in the long-term condition of the climate that can be detected (for example, using statistical tests) by variations in the mean and/or variability of its attributes. According to a different definition provided by the United Nations Framework Convention on Climate Change (UNFCCC, 2011), climate change is defined as a change in the global atmospheric composition that is either directly or indirectly caused by human activity and that results in an increase in long-term natural climate variability. Carbon dioxide (CO2) is the primary cause of climate change, according to the IPCC's 6th Assessment Report (AR6) 2021. Since 2011 (measurement report AR5), concentrations of CO2 have been steadily rising, reaching 410 parts per million (ppm), 1866 parts per billion (ppb) for methane (CH4), and 332 parts per billion (ppb) for nitrous oxide (N2O) annually in 2019, which led to significant global warming. The IPCC stated in the same report (AR6) that the global surface temperature increased by 0.99 °C during the last two decades (2001-2020) of the 21st century compared to 1850-1900, and that each of the last four decades has been warmer than any other decade since 1850. The land and sea surfaces are not the only things being altered by this unavoidable change in climate. Known for its thriving communities, abundant wildlife, and economic dynamism, India's East Coast is currently facing significant difficulties brought on by the complex interactions of population increase, human activity, and climate change. Rapid urbanization has made coastal areas more susceptible to a variety of environmental hazards, such as cyclonic surges, rising sea levels, and erratic weather patterns. This is especially true in megacities like Chennai and Kolkata.

Methodology

This study investigates how climate change affects coastal erosion and settlement trends using a qualitative secondary data analysis methodology. Peer-reviewed journals, government publications, satellite imagery, and international climate studies (IPCC, UNEP, and NOAA) were the sources of the data. To comprehend regional risks, case studies from erosion-prone areas like the Sundarbans, Gulf Coast, and Nile Delta were studied. Patterns connecting storm strength, human displacement, and sea level rise were found using content analysis and comparative review. The study lacks real-time primary field observations and is constrained by the accuracy and availability of current datasets, despite the fact that it benefits from a variety of worldwide data.

Impact Assessment

- **Impact on fisheries:**

the effects of climate change on coastal fisheries, with particular emphasis on the difficulties Eastern India faces. Because fishing is the main source of income in this area, it is especially vulnerable to the negative effects of rising sea surface temperatures (SST) brought on by greenhouse gas (GHG) emissions. Because aquaculture-reared species in Eastern India are poikilothermic, their metabolism and growth are at risk from even little variations in SST. The Bay of Bengal is particularly highlighted in Zacharia et al. (2016)'s study, where fishermen have had to adjust by casting their nets deeper as a result of rising SST. Additionally, the Indian Ocean's tuna catch has decreased due to variations in wind speed and direction during specific months, which has an effect on Eastern India's traditional fishing methods. Furthermore, the Indian East Coast of Eastern India is predicted to have a significant decline in ecosystem services by 2050 due to the shifting climatic regime, with an estimated total loss of 17 billion US dollars. This emphasizes how urgent it is to put appropriate mitigation plans into place in Eastern India in order to handle the unique difficulties encountered by coastal people and maintain the fishing industry. In conclusion, changes in fishing methods, a decline in catch as a result of shifting weather patterns, and anticipated financial losses are some of the effects of climate change on fisheries in Eastern India. Region-specific mitigation methods are needed to address these issues and safeguard the ecosystem services and livelihoods that are essential to the coastal inhabitants of Eastern India.

- **Impact on agriculture:**

The agriculture industry in Eastern India faces particular difficulties that set it apart from other areas due to the region's unique exposure to shifting weather conditions. Eastern India's coastal agriculture is especially vulnerable to the negative effects of climate change, with cyclones, rising soil salinity, and seawater intrusion all posing serious risks. The drastic shift in climatic conditions has had a negative impact on the phenology of plants in coastal areas of Eastern India. Traditional agricultural practices have been disturbed by erratic rainfall patterns and an elevated temperature regime. The output of maize and irrigated paddy in the coastal regions of East India is seriously threatened by the excessive rise in temperature. This suggests a clear and immediate effect on the region's staple crops, influencing local agricultural communities' economic stability as well as food security. The livelihoods of smallholder agricultural communities in Eastern India are more broadly impacted by the interruption of the customary cropping schedule. Most people in Eastern India's coastal regions work as smallholder farmers because they lack the funds to adopt costly climate-smart practices. Their sensitivity to the changing climate is increased by this lack of resources, which makes it difficult for them to adjust successfully. In conclusion, climate change presents particular difficulties for coastal agriculture in Eastern India, such as cyclones, soil salinity, and seawater intrusion. Disrupted cropping patterns, hazards to staple crops, elevated insect risks, and difficulties for smallholder farming groups are all

clear indications of the effects. To improve the resilience of coastal agriculture in Eastern India, unique methods and support networks are needed to address these region-specific issues.

Cyclonic Activity

- Due to the high frequency of severe cyclones along the Bay of Bengal coast, West Bengal is considered to be one of India's most climate-vulnerable states.
- Between 1891 and 2018, there were the most cyclones in the Bay of Bengal region in May and November, with 41 severe cyclonic storms and 21 cyclonic storms in May and 72 severe cyclonic storms and 55 cyclonic storms in November.
- Out of 22 cyclones that occurred in the Bay of Bengal region between 2000 and 2018, 16 were Category 4 or stronger, suggesting a rise in the frequency of very severe and extremely severe cyclonic storms.

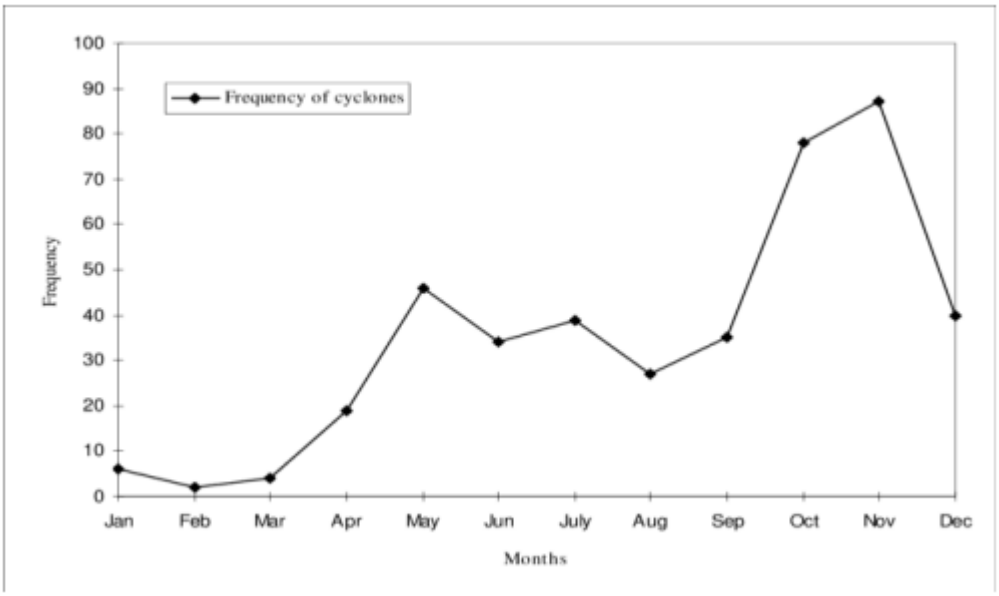

Fig -: Monthly variation of the frequency of cyclones over the Bay of Bengal during 1891-1991

Shift in Cyclone Genesis Locations

According to the paper, during postmonsoon seasons, there is a notable eastward shift in the Bay of Bengal region's tropical cyclone genesis locations, which could increase the risk for West Bengal's coastal areas.

Landfall of Severe Cyclones:

- Two extremely powerful storms, Cyclone Bulbul in November 2019 and Cyclone Amphan in May 2020, made landfall in West Bengal. Both touched down close to Sagar Island in the western Indian Sundarbans.
- The greatest wind speeds of Cyclone Bulbul and Cyclone Amphan were 155 and 185 kilometers per hour, respectively.

Flood Risk:

The east coast of India, encompassing West Bengal, eastern Uttar Pradesh, Gujarat, the Konkan region, and key cities like Mumbai, Kolkata, and Chennai, is at higher danger of flooding, according to the report.

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Sea Surface Temperature and Thunderstorms:

- Between 1951 and 2015, the tropical Indian Ocean's sea surface temperature increased by an average of 1°C, more than the 0.7°C world warming average.
- The severity of cyclones and thunderstorms is associated with an increase in ocean temperature. Intense thunderstorm storms and significant casualties occurred in West Bengal between 1978 and 2012.

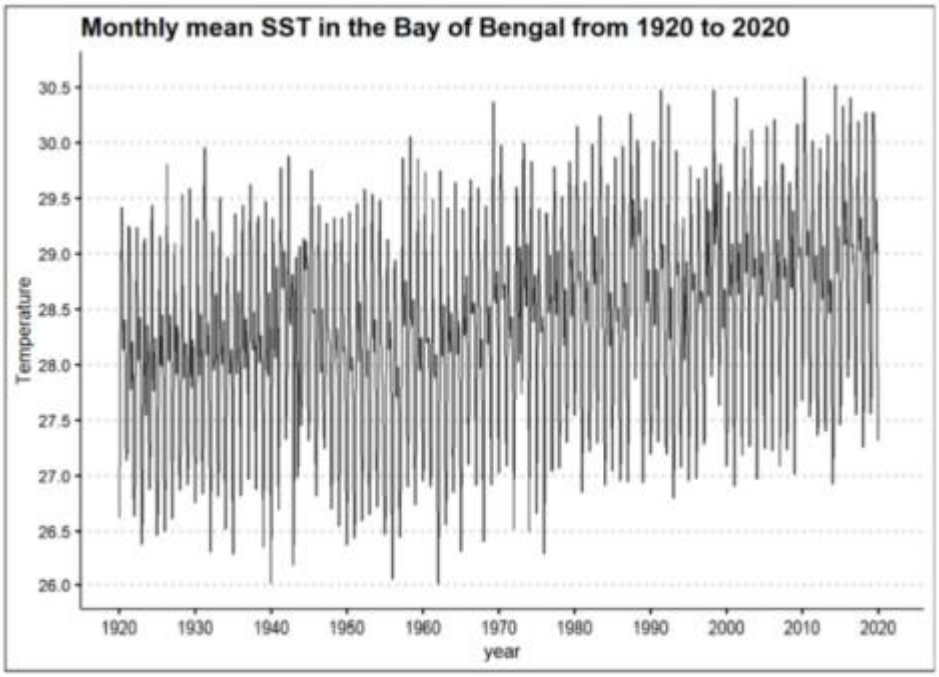

Fig -: Sea surface temperature (Bay of Bengal during)

Sea Level Rise:

The rate of sea level rise off the coast of Bengal is the greatest in the nation, reaching five millimeters every ten years. Coastal regions are at risk from the long-term effects of climate change.

Biodiversity Loss:

West Bengal, a state renowned for its abundant biodiversity, is predicted to experience a decline in biodiversity as a result of climate change. Ecosystems and human livelihoods may be significantly impacted if numerous species become extinct.

Coastal Erosion:

Rising sea levels brought on by climate change may cause coastal erosion throughout West Bengal's extensive coastline. This poses significant threats to coastal communities, infrastructure, and the economy.

Water Scarcity:

West Bengal is susceptible to changes in precipitation patterns brought on by climate change because of its reliance on rainfall. A key source of income for the state, agriculture, could be impacted by water scarcity brought on by altered precipitation patterns.

Heat Waves:

The expert predicts that West Bengal would experience heat waves more frequently as a result of climate change. Increased temperatures may be harmful to people's health, especially for those who are more susceptible.

Discussion

In light of the growing effects of climate change, especially along India's fragile Eastern coast, this study has conducted a thorough investigation of the various difficulties that coastal populations face. This study's importance stems from its careful analysis of real-world environmental effects, particularly in West Bengal, Tamil Nadu, and Puducherry, which illuminates the complexities of an area dealing with rising sea levels, changing weather patterns, and an increase in the frequency of extreme weather events.

Key Findings

The study clarifies the direct and indirect effects of climate change on the ecological and socioeconomic structure of coastal settlements in the East. The study offers a detailed perspective of the current concerns to food security and economic stability by focusing only on disruptions in agriculture, fisheries, and traditional livelihoods. The inequalities in coastal people' potential for adaptation are highlighted, as is their susceptibility.

- **Environmental Consequences:** Examining the environmental effects, the study shows the concerning damage to coastal ecosystems, which includes ecological changes, biodiversity loss, and coastal erosion. The geographic scope, which includes a few districts, allows for a focused analysis of areas that are particularly vulnerable to climate change, taking into account variables like population density, previous cyclone events, and sea level rise.
- **Unique Challenges and Impacts:** The urgency is further shown by the West Bengal case study, which highlights the increased dangers of severe cyclones, floods, and sea level rise.
- **Impacts on Fisheries and Agriculture:** The study focuses on the crucial areas of agriculture and fisheries, clarifying the special difficulties faced by coastal agriculture as well as the susceptibility of Eastern India's fisheries to rising sea surface temperatures. A clear picture of the far-reaching effects of climate change is provided by the estimated financial losses in the fishing industry and the changes in cropping patterns.

Conclusion

To sum up, this study makes a substantial contribution to our knowledge of how climate change affects coastal communities in the East. The study offers a useful basis for policymakers, researchers, and local stakeholders to create focused policies because it only considers the environmental effects. The suggestions take a comprehensive approach, supporting sustainable agriculture, robust infrastructure, prudent land use planning, and the protection of coastal habitats. The urgency of action is clear. This study emphasizes how urgent and well-coordinated action is required to solve the multifaceted problems brought on by climate change. The study is a clear call to action for strategic interventions, adaptation plans, and mitigation techniques that put the resilience and sustainable development of Eastern coastal towns first as they traverse a changing climate landscape. The knowledge gained from this study opens the door for well-informed decision-making and coordinated action to protect the health of the ecosystems and populations along India's eastern coast in the face of an unpredictable climatic future.

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