A Study on the Rising Climate Vulnerabilities in Northeast India: Emphasizing the State of Assam

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Abstract

Climate change has emerged as a formidable challenge worldwide, with its impacts particularly pronounced in ecologically sensitive regions. Northeast India, recognized for its unique topography, rich biodiversity, and socio-cultural diversity, is increasingly vulnerable to the adverse effects of climatic shifts. This study critically examines the rising climate vulnerabilities in the Northeastern region of India, with a specific emphasis on the state of Assam. Assam has been experiencing erratic rainfall, increased frequency of floods and droughts, shifting monsoon patterns, and rising temperatures—all of which severely affect agriculture, health, biodiversity, and the socio-economic well-being of the population.The research employs both primary and secondary data sources to analyze climate trends, environmental impacts, and adaptive responses. Government reports, climate models, and satellite imagery were used to understand long-term changes, while interviews and field observations helped gauge local perceptions and indigenous coping strategies. The findings reveal a significant increase in flood-prone areas, changing cropping patterns, and heightened vulnerability among marginalized rural communities. Furthermore, the state's inadequate infrastructure and planning mechanisms compound the risks posed by climate change. The study also highlights the role of traditional knowledge and community-based adaptation practices in enhancing resilience. However, it emphasizes the urgent need for integrated climate policies, investment in resilient infrastructure, early warning systems, and climate education. A collaborative approach involving state agencies, local communities, and researchers is essential to mitigate the escalating climate risks. This analytical study contributes to the broader discourse on regional climate resilience by focusing on Assam as a representative microcosm of the challenges facing Northeast India.

Keywords: Climate Change, Assam, Northeast India, Environmental Vulnerability, Adaptation Strategies

Introduction

Climate change in the 21st century poses a significant threat to ecosystems and human well-being worldwide. Both natural processes and human activities are accelerating environmental change, making climate change one of the most pressing and debated global challenges. The Northeast region of India, especially Assam, is particularly vulnerable due to its delicate geo-ecological setting, proximity to international borders, location within the Eastern Himalayas, transboundary rivers, diverse ethnic populations, and socio-economic disparities. Assam's vulnerability is compounded by the lack of localized climate modeling. General Circulation Models (GCMs) fail to provide high-resolution data for smaller regions, leaving the future climate scenarios of Northeast India underexplored and uncertain. This limits effective risk management and adaptive planning. Warming trends in India have intensified since the 1970s, with Northeast India experiencing a rise in annual maximum temperatures at +0.11°C per decade and average temperatures increasing by 0.04°C per decade (Assam SPACC, MoEFCC, 2014).

While overall rainfall patterns have not shown significant change, seasonal variations have intensified. The meteorological subdivision comprising Nagaland, Manipur, Mizoram, Tripura, and parts of the Barail Hills has seen a decline in monsoon rainfall by approximately 11 mm per decade. Drought-like conditions have also affected several districts in Assam, with rainfall deficits nearing 40% below normal. These hydrological shifts are altering river systems, erosion rates, and sedimentation patterns, especially in the Himalayan catchments.Flash floods, often triggered by intense rainfall or upstream cloudbursts in Meghalaya, Arunachal Pradesh, and neighboring countries like Bhutan and China, have become more frequent. Major flood events in districts such as Goalpara, Dhemaji, and Lakhimpur have resulted in loss of life, infrastructure damage, and displacement. Open-cast coal mining in areas like Tikok and Ledo-Tirap in Upper Assam has led to large-scale deforestation, soil loss, and water pollution. The mining industry has often neglected environmental safeguards, causing irreversible damage to agricultural fields and water systems. Combined with natural hazards like erosion and landslides, these anthropogenic pressures intensify the region’s environmental insecurity, undermining sustainable development and human health.

Objectives of the study

1. To assess climate change impacts on Assam’s environment and livelihoods.

2. To identify key vulnerabilities across rural and urban areas.

3. To evaluate and suggest adaptive strategies for climate resilience.

Research Methodology

The current study focuses on examining the challenges and implications of climate change in Assam. A doctrinal research approach has been adopted, which primarily relies on qualitative data gathered from secondary sources. The aim is to present a comprehensive understanding of how climate change has emerged as a critical threat to Assam's environmental stability and sustainability in the 21st century.Relevant data and insights were obtained from secondary literature, including scholarly books, academic journals, published articles, and credible online platforms. These sources were critically analyzed to outline the multifaceted impacts of climate change across various sectors in Assam. The analysis draws attention to environmental vulnerabilities and aims to contribute toward identifying effective adaptive and policy responses for climate resilience in the region.

Climate Change Challenges in Assam

Assam, situated in the Himalayan foothills, faces significant environmental threats linked to climate change. The region is increasingly vulnerable due to planned hydropower development, especially in Arunachal Pradesh, where over 100 of the proposed 168 dams will be located. The rising frequency of extreme weather events—such as intense rainfall, glacial lake outburst floods (GLOFs), and landslide dam outburst floods (LDOFs)—poses serious risks to the downstream populations. Assam is regularly affected by floods, which severely damage its ecology, disrupt agriculture, and lead to large-scale displacement. Flash floods often stem from deforestation, rapid urbanization, and dam failures. Soil erosion and landslides are exacerbated by the region's hilly terrain, affecting both land productivity and biodiversity. Open-cast mining in areas like Ledo and Margherita also contributes to environmental degradation and health issues. Bioenergy offers a potential solution to fossil fuel dependency. Plants like *Jatropha curcus* and *Nahar* have been identified as renewable energy sources that can produce biofuels, which may reduce carbon emissions and enhance energy security in Northeast India. However, large dam projects, including Bhutan's Mangdechhu Hydroelectric Project and others on the Sonkosh River, could intensify flood risks due to their proximity to glacial zones prone to GLOFs. Population growth, urban air pollution from vehicular emissions, and particulate matter have further stressed Assam's environment. Studies show that air quality in places like Dispur, Gopinath Nagar, and Santipur frequently exceeds prescribed safety limits.Climate change is also making Assam more susceptible to vector-borne diseases like

malaria. Deforestation and forest degradation contribute to this vulnerability. Despite some increases in total crop production, per capita food grain availability has declined. Floods, erratic weather, and reduced glacial runoff have altered the hydrology of rivers like the Brahmaputra and its tributaries, threatening the livelihoods of agricultural communities and the ecosystems that support biodiversity in areas like Kaziranga and Manas.

Forest fires, often human-induced, are becoming more frequent, especially in biodiversity hotspots. There is an urgent need to adopt nature-integrated conservation efforts, such as community-based wildlife programs. Assam's water resources are under pressure due to decreasing rainfall, rising temperatures, and unsustainable groundwater extraction. Without proactive water conservation strategies, the region will face increasing water scarcity. The impacts of climate change on infrastructure could significantly raise maintenance and reconstruction costs. By 2050, climate-related damages to infrastructure may cost Assam 0.3–0.9% of its GDP annually. Unplanned urbanization further exacerbates the problem, reducing the quality of life and undermining sustainable development. Migration to cities continues to strain urban resources. These challenges, a collective commitment to reducing greenhouse gas emissions and promoting renewable energy is essential. India can potentially meet 20–25% of its electricity needs through renewable sources, a goal vital for both national energy security and environmental sustainability.

Agriculture and Environmental Issues in Assam

Agriculture is a cornerstone of Assam's economy, with approximately 28.76 lakh hectares—constituting 36.66% of the state's geographical area—used for agricultural purposes (Statistical Handbook, Assam, 2008). However, the sector faces mounting challenges due to increasing climatic irregularities. Unpredictable monsoons, frequent flooding, drought-like conditions, and warmer winters have disrupted the agricultural calendar. Notably, several districts experienced drought-like conditions in 2005, 2006, and 2009. Since farming in Assam largely depends on rainfall, any major deviation in regional weather patterns is likely to negatively impact crop productivity. Variations in rainfall distribution, temperature, humidity, and sunlight exposure have led to changes in pest and disease patterns, which further influence yields. Agriculture remains the dominant land-use category in Assam, covering around 54.11% of its total land area. Over 80% of the population, including those involved in plantation crops, rely on agriculture for their livelihood. Technological advances and population growth have led to

a notable expansion in the net and gross sown areas, often at the cost of forest land, raising ecological concerns about land-use shifts.

Assam is a biodiversity-rich zone for several field and horticultural crops. Known as the center of rice diversity, the state's germplasm is well represented at the Central Rice Research Institute, Cuttack, which maintains over 2,000 rice varieties from Assam. In addition, the state has a wide range of legume crops preserved at the Regional Agricultural Research Station (RARS), Shillongani—including green gram, black gram, lentils, pigeon pea, and field peas. Furthermore, 1,074 sugarcane germplasm species are conserved at the Toklai Experimental Station in Jorhat, while diverse banana and citrus fruit varieties, as well as aquatic crops like *Euryale ferox* (makhana), thrive across the region. Assam also supports a range of temperate, tropical, and subtropical vegetables, with notable genetic diversity in cucurbits, solanaceous crops, and tubers.The "Bringing the Green Revolution to Eastern India" initiative has significantly improved rice productivity in states like Assam, Bihar, Chhattisgarh, and West Bengal. As part of this effort, a fund of ₹1,000 crore was allocated in 2013–14 (Government of India, 2014) to strengthen agricultural development in these states. These advancements, agricultural activities in Assam contribute to environmental pollution. Practices such as pesticide spraying, irrigation, livestock grazing, harvesting, and fertilization release pollutants like sediments, nutrients, pathogens, pesticides, and salts into the environment. These activities degrade stream habitats and cause erosion. Additionally, burning of crop residues such as straw and husk—both in fields and industrial settings—aggravates air pollution, especially under extreme weather conditions where the rising warm air facilitates wider dispersion of pollutants.

Climate Change and Its Impact on Natural Resources in Assam

Assam is part of India's green belt and is endowed with abundant natural resources, including oil, natural gas, minerals, and expansive forests. The state's major industries—such as tea, crude oil, natural gas, silk, bamboo, and handicrafts—heavily depend on these resources. The total proven oil reserves in the Northeast are estimated at 158 million tonnes. High rainfall, dense forests, wildlife sanctuaries, and rivers like the Brahmaputra contribute to Assam's rich natural heritage. The state is home to endangered species like the one-horned rhinoceros and Asian elephants, placing it within the Indo-Myanmar biodiversity hotspot—one of 25 globally recognized biodiversity. However, deforestation, forest fires, shifting cultivation (jhum), poaching, overuse of chemical pesticides, and the lack of effective legal safeguards have triggered a severe loss of biodiversity. Solid waste mismanagement, especially open dumping,

further deteriorates the environment (Parsua et al.). These factors collectively threaten ecosystems, reduce mineral productivity, and call for urgent biodiversity conservation policies—particularly for endemic species.

Assam and the broader Northeast region host one of the highest concentrations of bird species in Asia, with about 850 species recorded. The Eastern Himalayas and Assam plains have been classified as an Endemic Bird Area (EBA) by the Royal Society for the Protection of Birds and the International Council for Bird Preservation (ICBP), UK. Spanning over 220,000 square kilometers, this EBA includes parts of Bangladesh, Bhutan, Nepal, China, Myanmar, and Indian states such as Arunachal Pradesh, Sikkim, and Meghalaya. The region's unique climatic conditions—warmer temperatures, fewer frost days, and high rainfall—foster a diverse avian population, including 24 restricted-range bird species. As of 2013, 15 bird species in India were listed as critically endangered by the International Union for Conservation of Nature. Their decline is attributed to habitat loss, degradation, fragmentation, and environmental pollutants. Climate change also disrupts the phenological cycles of flora, disturbing species interactions and habitat patterns across eco-regions. The state's oil and fertilizer industries also contribute to environmental degradation. Drilling operations—mostly in paddy fields, wetlands, and near water sources—often damage local ecosystems, affecting agriculture, vegetation, and potable water. Fertilizer industries in Upper Assam, which produce ammonia, urea, sulphuric acid, and ammonium sulphate, release pollutants such as ammoniacal waste, arsenic- and chromium-laden effluents, and sulfur dioxide emissions into the air and water.

Role of the State Action Plan on Climate Change (SAPCC) for Assam

The Intergovernmental Panel on Climate Change (IPCC) has emphasized the urgent need for sub-national entities to formulate comprehensive strategies that address both climate change adaptation and mitigation, alongside long-term developmental goals. In response, India's National Action Plan on Climate Change (NAPCC) mandated each state to develop its own State Action Plan on Climate Change (SAPCC), aligning with national climate priorities while addressing localized vulnerabilities and impacts. Assam, as a climate-vulnerable state in Northeast India, initiated its SAPCC process under the leadership of the Assam Science Technology and Environment Council (ASTEC), with technical and institutional support from the Department of Science and Technology (DST), Government of Assam. The plan aims to enhance the resilience of ecosystems and communities by building awareness, facilitating local

participation, and promoting climate-resilient development practices. To ensure inclusive and evidence-based policy formulation, multiple stakeholder consultations were held in key locations across Assam—Silchar, Guwahati, and Tezpur since 2011, with subsequent consultations in Jorhat and Dibrugarh in later phases. These dialogues engaged a diverse range of participants including scientists, researchers, academicians, NGOs, civil society organizations, and corporate representatives. The discussions yielded significant insights and policy recommendations, which were systematically compiled into thematic reports.

The first draft of Assam's SAPCC was prepared by the Climate Cell under ASTEC in 2011, identifying sectoral vulnerabilities and proposing targeted strategies for sectors such as agriculture, water resources, biodiversity, health, forestry, and energy. The document was further revised in line with updated climate models, scientific inputs, and national guidelines. In the revised SAPCC (Version 2.0, published in 2021), Assam expanded its focus areas to include disaster risk reduction, urban resilience, and livelihood security, especially for vulnerable and marginalized communities. As per the Ministry of Environment, Forest and Climate Change (MoEFCC), Assam's SAPCC is among the few state plans recognized for integrating climate justice, gender sensitivity, and indigenous knowledge systems into policy design.The SAPCC also aims to synergize with national schemes such as the National Adaptation Fund for Climate Change (NAFCC) and global frameworks including the Paris Agreement and Sustainable Development Goals (SDGs). As of 2024, Assam is in the process of finalizing SAPCC Version 3.0, which will incorporate updated climate vulnerability assessments based on IPCC AR6 (2023), satellite-based geospatial mapping, and district-level action plans. New sectors like climate-smart infrastructure, renewable energy transition, and youth climate engagement are also being integrated. The Assam SAPCC is a dynamic document that continues to evolve with emerging scientific data, policy inputs, and stakeholder feedback. It reflects the state's commitment to a climate-resilient future and ensures that policy actions remain grounded in community needs, scientific evidence, and global climate priorities.

Finding of the study

The study reveals that Assam is experiencing a marked rise in temperature, aligning with the broader warming trend driven by climate change. This has been accompanied by noticeable shifts in seasonal rainfall patterns, contributing to frequent climate anomalies across the state. In recent years, districts such as Nagaon, Darrang, and Karbi Anglong have faced acute

drought-like conditions, adversely affecting agriculture and water availability. Additionally, Assam has witnessed an increase in the frequency and intensity of flash floods, often triggered by extreme rainfall events or cloudbursts—such as those recorded in 2022 and 2023—resulting in severe disruption to rural livelihoods. These events have also accelerated soil erosion, widespread deforestation, and recurring landslides, particularly in hill districts like Dima Hasao and Kamrup (M), which further aggravate land degradation and threaten agricultural productivity. Although several governmental initiatives, including climate adaptation schemes under the State Action Plan on Climate Change (SAPCC), afforestation programs, and public awareness campaigns, have been launched to address ecological imbalance, ground-level implementation remains inconsistent and often hampered by administrative delays, poor community engagement, and lack of monitoring. Strengthening institutional mechanisms and localized action is urgently needed to mitigate the long-term consequences of environmental degradation in the state.

Suggestion and Conclusion

Assam's environment is facing serious degradation due to unchecked human activities, deforestation, industrial pollution, and recurring floods. Despite being industrially less developed, the state suffers from ecological threats that endanger vital ecosystems like Majuli and Kaziranga. The increasing use of fossil fuels has worsened the situation, making biofuels a sustainable alternative. Climate change is also impacting livestock productivity, fisheries, and wetland ecosystems, calling for urgent adaptation strategies in agriculture and water management. Sustainable conservation must prioritize community participation, forest protection, and equitable resource sharing. Philosophical and ethical views, such as those by Gandhi and Aldo Leopold, stress harmony with nature and the moral duty to preserve biodiversity for future generations. Environmental stewardship must go beyond laws, rooted instead in collective consciousness and long-term ecological responsibility.

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