

Environmental Impact of Climate Change on the Brahmaputra River Basin, Assam: A Review of Hydrological, Ecological and Socio-Economic Dimensions

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Abstract

The Brahmaputra River Basin, one of the largest and most sediment-dynamic river systems in the world, sustains the ecological, economic, and cultural life of Assam and the wider Northeast Indian region. This paper examines the environmental impact of climate change on the basin, drawing on secondary data from peer-reviewed literature, intergovernmental assessments, and government reports. The study finds that rising temperatures, accelerated Himalayan glacier retreat, and increasingly erratic monsoon rainfall are intensifying flood frequency and severity, accelerating riverbank erosion, and disrupting sediment dynamics across the basin. These hydrological changes are, in turn, degrading wetlands, forests, and aquatic habitats that support globally significant biodiversity, including the one-horned rhinoceros, Asian elephant, and Gangetic river dolphin. The paper further finds that climate-induced stress is undermining agricultural productivity, deteriorating water quality, and heightening the socio-economic vulnerability of riverine and char-dwelling communities through recurrent displacement and loss of livelihoods. Adopting a descriptive-analytical method, the study synthesises existing evidence to argue that integrated river basin management, climate-resilient infrastructure, ecosystem restoration, strengthened flood forecasting, and regional transboundary cooperation are essential to building environmental resilience. The paper concludes that safeguarding the Brahmaputra River Basin requires coordinated action across scientific, policy, and community domains to secure the long-term ecological and socio-economic stability of one of South Asia's most climate-sensitive river systems.

Keywords: *Brahmaputra River Basin; Climate Change; Environmental Impact; Riverbank Erosion; Biodiversity Loss; Flood Vulnerability; Assam; River Basin Management*

1. Introduction

The Brahmaputra River Basin is one of the largest and most dynamic river systems in the world, playing a vital role in the ecological, economic, and cultural life of Northeast India, particularly the state of Assam. Originating in the Tibetan Plateau as the Yarlung Tsangpo, the river flows through China, India, and Bangladesh before joining the Bay of Bengal. In Assam, the Brahmaputra traverses approximately 650 kilometres, forming an extensive floodplain that supports rich biodiversity, fertile agricultural lands,

fisheries, forests, and millions of livelihoods. The river also gives rise to Majuli, widely described as the world's largest inhabited river island, and nourishes protected ecosystems such as Kaziranga National Park and Dibru-Saikhowa National Park, which host globally significant species and unique wetland habitats. However, the environmental sustainability of the Brahmaputra River Basin is increasingly threatened by the growing impacts of climate change.

Climate change has emerged as one of the most pressing environmental challenges of the twenty-first century, influencing river systems through rising temperatures, changing precipitation patterns, glacier retreat, and an increased frequency of extreme weather events. The Brahmaputra Basin is particularly vulnerable because of its dependence on monsoon rainfall and Himalayan glaciers: roughly 60 percent of the river's inflow is estimated to originate from rainfall, with the remainder from glacial melt, snowmelt, and base flow, meaning the basin is sensitive to disruption in both systems simultaneously. Scientific studies indicate that changing climatic conditions are altering the river's hydrological regime, resulting in more intense floods, prolonged dry spells, riverbank erosion, and shifting sediment dynamics. These environmental changes have profound consequences for Assam, where annual floods and erosion already affect thousands of hectares of agricultural land and displace large numbers of people each year.

The environmental impacts of climate change extend beyond physical changes in the river system. Wetlands, forests, and aquatic ecosystems are experiencing habitat degradation, biodiversity loss, and declining water quality. Many native fish species and migratory birds face increasing threats due to altered water flow, rising temperatures, and pollution. Climate-induced changes also affect the productivity of agriculture, increase soil degradation, and reduce the resilience of local communities that depend heavily on natural resources. Furthermore, vulnerable populations living along the riverbanks and on shifting sandbar settlements known locally as chars are exposed to repeated displacement, loss of livelihoods, and heightened socio-economic insecurity.

Understanding the environmental impact of climate change on the Brahmaputra River Basin is essential for developing effective adaptation and sustainable management strategies. Integrated river basin management, climate-resilient infrastructure, ecosystem restoration, improved flood forecasting, and community-based conservation initiatives are increasingly recognised as key approaches to reducing environmental risks. Strengthening scientific research and regional cooperation among the basin countries is equally important for ensuring the long-term sustainability of this transboundary river system.

This study examines the environmental impacts of climate change on the Brahmaputra River Basin in Assam by analysing changes in hydrology, biodiversity, ecosystems, and natural resources. It also highlights the challenges faced by the region and explores potential adaptation and mitigation measures that can enhance environmental resilience and promote sustainable development. Through a comprehensive understanding of these issues, the study aims to contribute to informed policy-making and effective environmental management in one of South Asia's most climate-sensitive river basins.

2. Aims and Objectives

- To examine the environmental impacts of climate change on the Brahmaputra River Basin in Assam.
- To assess the effects of climate change on the river basin's ecosystem, biodiversity, and the livelihoods of local communities.
- To explore existing adaptation, mitigation, and policy measures relevant to strengthening environmental resilience in the basin.

3. Review of Literature

Existing scholarship consistently identifies the Ganges-Brahmaputra system as among the most climate-vulnerable river basins globally, owing to the combined effects of glacier melt, extreme monsoon rainfall, and downstream sea-level rise. Hydrological modelling by the Intergovernmental Panel on Climate Change and allied researchers indicates that glaciers in the upstream Brahmaputra basin could shrink substantially by the middle of the century, even as overall river runoff is projected to rise in the near term due to a combination of accelerated melt and increased precipitation. Research led by Immerzeel and colleagues has similarly shown that meltwater plays a comparatively modest but still important role in the Brahmaputra's water balance relative to basins such as the Indus, while cautioning that reduced flows later in the century could threaten the food security of tens of millions of people dependent on the basin. Studies specific to Assam further note that nearly two-fifths of the state's land area is flood-prone, and that floods increasingly result from compounding drivers acting together, including intense local rainfall, upstream precipitation in Arunachal Pradesh, Bhutan, and Tibet, accelerated glacier and snowmelt, and riverbank erosion. Reports from the World Bank, the Ramsar Convention, and India's national disaster management and water resources agencies reinforce these findings, documenting parallel pressures on wetland ecosystems, agricultural productivity, and community resilience across the basin. Collectively, this body of literature underscores the need for basin-wide, evidence-based adaptation strategies of the kind this paper seeks to synthesise.

4. Study Area

The study focuses on the Assam stretch of the Brahmaputra River Basin, extending roughly 650 kilometres from the state's eastern border with Arunachal Pradesh to its western border with West Bengal and Bangladesh. Within Assam, the river is fed by numerous tributaries, including the Subansiri, Kameng, Manas, Dhansiri, and Burhi Dihing, and supports a wide floodplain of agricultural land, wetlands (beels), grasslands, and forests. The basin encompasses ecologically significant protected areas such as Kaziranga National Park (a UNESCO World Heritage Site and habitat of the one-horned rhinoceros), Dibru-Saikhowa National Park and Biosphere Reserve, and Majuli river island, alongside dense riverine and char (sandbar) settlements that are directly exposed to seasonal flooding and erosion.

5. Methodology

This paper is descriptive and analytical in nature. It relies entirely on secondary data compiled from peer-reviewed journal articles, books, intergovernmental and governmental reports, and institutional assessments

concerning climate change and the Brahmaputra River Basin. Sources were selected for their relevance to the hydrological, ecological, and socio-economic dimensions of climate change in the basin, and findings were synthesised thematically to address the paper's stated objectives. As a review-based study, the paper does not generate primary field data; its conclusions are accordingly framed as a synthesis of existing scientific and institutional evidence rather than original empirical findings.

6. Discussion and Analysis

The Brahmaputra River Basin is one of the largest and most dynamic river systems in the world. Flowing through Tibet, India, and Bangladesh, the river plays a crucial role in supporting agriculture, fisheries, transportation, biodiversity, and the livelihoods of millions of people. In Assam, the Brahmaputra is not only a source of economic development but also an integral part of the state's cultural and ecological identity. However, climate change has significantly altered the river basin's environmental conditions, resulting in severe ecological and socio-economic consequences, discussed thematically below.

6.1 Glacier Retreat and Flood Intensification

One of the most noticeable impacts of climate change is the increase in the frequency and intensity of floods. Rising global temperatures have accelerated the melting of Himalayan glaciers, while changes in monsoon rainfall patterns have increased the volume of water flowing into the Brahmaputra. Modelling by international research bodies suggests that glaciers feeding the upstream basin could shrink by roughly 20 to 55 percent by mid-century, with total runoff correspondingly projected to rise by up to about 13 percent over the same period as accelerated melt temporarily augments flow before glacial reserves diminish. Heavy and erratic rainfall often causes devastating floods across Assam, affecting agricultural land, settlements, infrastructure, and public health. Annual floods displace thousands of people and damage crops, leading to economic losses and food insecurity.

6.2 Riverbank Erosion and Sediment Dynamics

Riverbank erosion is another major environmental challenge linked to climate change. The Brahmaputra carries an enormous sediment load, and stronger river currents during floods accelerate erosion along its banks. Many villages and agricultural fields are lost every year due to continuous erosion. This not only destroys fertile land but also forces people to migrate, creating social and economic hardships. Climate change has intensified this process by increasing the variability of river flow and the frequency of extreme weather events.

6.3 Biodiversity and Ecosystem Impacts

Climate change has also had a profound impact on biodiversity in the Brahmaputra River Basin. Assam is home to unique ecosystems, including wetlands, grasslands, and forests that support diverse plant and animal species. Changes in temperature, rainfall, and flooding patterns threaten these habitats. Wildlife species such

as the one-horned rhinoceros, Asian elephant, Gangetic river dolphin, and numerous migratory birds face increasing pressure due to habitat degradation and changing environmental conditions. Wetlands, which act as natural flood regulators and biodiversity hotspots, are shrinking or becoming degraded because of altered hydrological cycles.

6.4 Agriculture and Rural Livelihoods

Agriculture, the primary livelihood for a large proportion of Assam's population, is highly vulnerable to climate change. Irregular rainfall, prolonged dry spells, floods, and rising temperatures reduce crop productivity and soil fertility. Farmers face uncertainty in crop planning and harvesting, while increased pest infestations and plant diseases further affect agricultural output. These challenges threaten food security and reduce household incomes, particularly among small and marginal farmers and char-dwelling communities with limited land tenure security.

6.5 Water Quality and Public Health

Water quality in the Brahmaputra River Basin has also been affected. Floodwaters often carry sediments, agricultural chemicals, and waste into rivers and wetlands, leading to water pollution. Rising temperatures can reduce dissolved oxygen levels in water, affecting fish populations and aquatic biodiversity. Communities that depend on the river for drinking water, fishing, and domestic purposes face increased risks to health and livelihoods.

6.6 Extreme Weather Events and Compound Flooding

Climate change also contributes to more frequent extreme weather events such as heat waves, heavy rainfall, and storms. Nearly 40 percent of Assam's land area is estimated to be flood-prone, and research increasingly describes the state's floods as the outcome of 'compound flooding' — the simultaneous action of intense local rainfall, heavy precipitation in upstream catchments across Arunachal Pradesh, Bhutan, and Tibet, accelerated glacier and snowmelt, swollen tributary flows, riverbank erosion, and landslide-related debris blockages that later release large volumes of water. This compounding of drivers increases flood peaks, prolongs inundation, and makes forecasting substantially more difficult despite technological progress in early warning systems, which remains constrained by sparse observations and limited transboundary data sharing.

6.7 Socio-Economic Vulnerability

These environmental pressures increase the vulnerability of both rural and urban communities in Assam. Damage to roads, bridges, embankments, schools, and healthcare facilities disrupts daily life and slows economic development. Vulnerable groups, including women, children, and economically weaker households — particularly those in char and riverine settlements — are often the most severely affected, facing repeated cycles of displacement and asset loss that erode long-term resilience.

7. Adaptation, Mitigation, and Policy Recommendations

Addressing these challenges requires integrated river basin management and climate-resilient development strategies. Based on the evidence reviewed, the following measures are recommended:

- Strengthening flood forecasting and early warning systems through improved hydrological monitoring and transboundary data sharing among basin countries.
- Restoring and protecting wetlands, which serve as natural flood regulators and biodiversity reservoirs.
- Promoting afforestation and catchment-area soil conservation to reduce sediment load and erosion intensity.
- Reviewing and reinforcing embankment design and maintenance in light of changing flow and sediment patterns, rather than relying solely on legacy infrastructure.
- Encouraging climate-resilient agricultural practices, including flood- and drought-tolerant crop varieties and diversified cropping calendars.
- Building community-based disaster preparedness and participatory resource management, particularly in char and riverine settlements.
- Deepening regional cooperation among Brahmaputra basin countries — China, India, Bhutan, and Bangladesh — for coordinated water resource management and disaster preparedness.
- Investing in continued scientific research to reduce uncertainty in long-term flow projections and support evidence-based policy.

Together, these measures highlight the urgent need for sustainable management and climate adaptation across the basin. Protecting the Brahmaputra River Basin is essential not only for conserving Assam's rich natural heritage but also for ensuring the long-term well-being and sustainable livelihoods of millions of people who depend on this vital river system.

8. Conclusion

Climate change has emerged as one of the greatest environmental challenges affecting the Brahmaputra River Basin in Assam. The basin, which supports millions of people through agriculture, fisheries, transportation, and biodiversity, is becoming increasingly vulnerable due to rising temperatures, changing rainfall patterns, glacier melting, and frequent extreme weather events. These climatic changes have intensified floods, riverbank erosion, sediment deposition, and drought-like conditions in some areas, causing widespread environmental degradation and socio-economic losses.

The impacts of climate change extend beyond the physical environment. Agricultural productivity has declined due to irregular rainfall and crop damage, while biodiversity has been threatened by habitat destruction and changes in ecosystem dynamics. Wetlands, forests, and aquatic ecosystems are under increasing stress, affecting both wildlife and the communities that depend on natural resources for their livelihoods. Water quality deterioration and the displacement of people due to floods and erosion further highlight the seriousness of the issue.

Addressing these challenges requires a comprehensive and integrated approach involving government agencies, researchers, local communities, and international cooperation. Strengthening flood management systems, restoring wetlands, promoting afforestation, adopting climate-resilient agricultural practices, and improving disaster preparedness are essential steps toward reducing environmental risks. Public awareness,

scientific research, and sustainable river basin management policies will play a crucial role in enhancing resilience against future climate impacts.

In conclusion, protecting the Brahmaputra River Basin is vital for ensuring the ecological balance, economic stability, and social well-being of Assam. While climate change poses significant threats, timely adaptation and effective mitigation measures can reduce its adverse impacts and promote sustainable development. A coordinated effort at local, national, and regional levels is essential to safeguard the basin's natural resources and secure a resilient future for present and future generations.

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