

# **Title: Ground Realities of the Brahmaputra River: Past and Present Management, Emerging Challenges, and a Way Forward**

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## **Abstract**

The Brahmaputra River is one of the most dynamic transboundary rivers in the world and remains a lifeline for millions across China, India, and Bangladesh. However, recent research from 2021 to 2025 highlights escalating challenges, including more frequent and severe flooding, accelerated sedimentation, and deepening political tensions. This research note critically examines the evolution of river management practices, identifies emerging environmental and governance vulnerabilities, and proposes a forward-looking strategy grounded in cooperation and technological innovation. Addressing future risks will require a coordinated, real-time, and data-driven management framework that bridges national divides and strengthens basin-wide resilience.

**Key Words:** Brahmaputra River, River Management, Transboundary Cooperation, Flood Risk, Sediment Transport, Climate Change, Underwater Domain Awareness (UDA)

## **1. Introduction**

The Brahmaputra River, one of the world's most dynamic transboundary rivers, sustains ecosystems and economies across China, India, and Bangladesh. Its seasonal flow patterns, influenced by the monsoon and glacial melt, make it prone to devastating floods and rapid changes in channel dynamics. Mounting evidence between 2021 and 2025 indicates that traditional approaches to river management are proving inadequate in the face of accelerating risks. Recent studies have confirmed a sharp increase in flood hazards, driven by climate change and intensified monsoon variability (Palash et al., 2023; Vegad et al., 2024). Simultaneously, reach-scale analyses reveal growing sediment loads and pronounced morphological instability, especially around critical areas like Majuli Island (Nandi et al., 2023; Prasujya & Nayan, 2021).

The geopolitical complexity of the Brahmaputra Basin further complicates management efforts. Despite the river's criticality to all three riparian countries, political mistrust and

limited data sharing remain major barriers to coordinated action (Baruah et al., 2023; Wang et al., 2023). These emerging patterns underscore the urgent need to rethink flood-risk governance, sediment control, and cooperation frameworks.

This research note critically synthesises literature published between 2021 and 2025, tracing shifts in management paradigms, highlighting operational and political gaps, and proposing a forward-looking strategy grounded in technological innovation and institutional collaboration.

## **2. Historical River Management**

Management efforts during the colonial era and into the 20th century focused primarily on flood control through the construction of embankments (Pradhan et al., 2021). However, while embankments protected specific areas temporarily, they often increased riverbank erosion and disrupted natural flow patterns. In the 21st century, management priorities shifted towards large-scale infrastructure projects like hydropower dams. China's upstream developments and India's Subansiri project have added to concerns about downstream flow alterations (Wang et al., 2023).

## **3. Emerging Challenges**

### **3.1 Rising Flood Risks**

Climate change models predict that the Brahmaputra basin will experience more frequent and intense monsoon flooding, driven by changes in rainfall patterns and glacial melt (Palash et al., 2023; Vegad et al., 2024). This indicates more frequent and intense monsoon floods (Palash et al., 2023). Continental-scale modelling also confirms the Brahmaputra is among South Asia's highest-risk rivers by mid-century (Vegad et al., 2024). Integrated flood risk management approaches are now being recommended, combining early warning systems, land-use planning, and community-based adaptation to better address these growing threats.

### **3.2 Sediment Overload and Channel Instability**

The Brahmaputra transports one of the world's largest sediment loads. Recent satellite-based studies reveal growing instability in river channels and floodplains (Nandi et al., 2023; Prasuja & Nayan, 2021), which complicates flood control efforts and accelerates erosion. Process-based reach studies document rapid braid-bar migration and thalweg shifts (Nandi et al., 2023). Detailed morphodynamic work around Majuli shows post-2004

acceleration in channel change (Prasujya & Nayan, 2021), corroborated by remote-sensing evidence of delayed planform adjustment to discharge peaks (Xue et al., 2025). Tectonic anabranching further complicates stability (Mahanta et al., 2024)

### **3.3 Data Deficiency and Geopolitical Risks**

Limited real-time data sharing between China, India, and Bangladesh continues to be a significant obstacle for effective river management. Lack of transparency weakens disaster preparedness and heightens mistrust among the countries (Baruah et al., 2023; Wang et al., 2023).

### **3.4 Public Health and Water Quality**

Heavy sediment loads have been linked to increased groundwater contamination with arsenic and other toxic metals, posing serious risks to the millions dependent on the river (Pradhan et al., 2021).

## **4. Governance and Cooperation Challenges**

Despite the Brahmaputra's critical role in the region, a comprehensive basin-wide treaty remains absent. Cooperation is mainly limited to ad hoc data-sharing during monsoon floods (Wang et al., 2023). Encouragingly, recent research suggests new opportunities for formal transboundary cooperation frameworks, emphasising the need for transparent and equitable data-sharing platforms (Wang et al., 2023).

## **5. Limitations**

This research note draws exclusively on peer-reviewed, open-access literature published between 2021 and 2025. Literature in Chinese and classified technical reports were not accessible. While technological solutions like UDA offer great potential, their practical application in river management remains largely untested.

## **6. The Way Forward**

Adopting Underwater Domain Awareness (UDA) offers a promising strategy for improving real-time monitoring and cooperation. Initially developed for maritime applications (Pannerselvam et al., 2024), UDA can be adapted to large rivers to enable:

- Real-time sediment and flow monitoring.
- Open-access data platforms to build trust.
- Smarter flood forecasting and reservoir management.
- Stronger community-based adaptation mechanisms.

Immediate actions should include:

- Setting up a pilot UDA sensor network at strategic locations like Nuxia, Pasighat, and Bahadurabad.
- Drafting a trilateral data-sharing agreement modelled after the Mekong River Commission.
- Launching community-based adaptation labs to integrate local knowledge into early warning systems.
- Publishing an annual sediment and flood status report accessible to all stakeholders.

## 7. Conclusion

The literature reviewed in this research note clearly demonstrates that the Brahmaputra River is entering a period of intensified flood risk, accelerated morphological changes, and growing strategic tensions. Rising climate volatility, increasing sedimentation, and persistent political mistrust are collectively undermining the effectiveness of fragmented, country-specific management approaches.

Traditional hard-engineering solutions—such as embankments and isolated dams—have repeatedly fallen short of delivering basin-wide resilience. Instead, recent studies consistently call for integrated approaches: real-time data sharing, coordinated sediment and flood-risk monitoring, and stronger, cooperative governance mechanisms (Wang et al., 2023; Palash et al., 2023; Vegad et al., 2024).

This research highlights that integrating Underwater Domain Awareness (UDA) technologies with proactive, transboundary collaboration offers a promising path forward. Initiatives such as joint monitoring stations, dynamic reservoir operation frameworks, and community-centred adaptation programs could begin to rebuild the scientific and political trust necessary for effective basin stabilisation.

Ultimately, a decisive shift toward integrated, climate-resilient, and cooperative river governance is no longer a strategic preference—it is an urgent necessity for securing the future of the Brahmaputra region.

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