Climate Vulnerability: Engineering Geology for Safeguarding Archaeological Heritages of the GBM or Bengal Delta in Bangladesh

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Abstract: South and Southeast Asian deltas, formed by rivers originating from the Himalayan–Tibetan-Burman tectonic system—from the Indus to the Yellow River—have supported human civilizations for millennia, including the Indus Civilization (2600–1900 BCE). Their evolution has been shaped by sediment supply, monsoonal climate, Holocene sea-level changes, and subsidence, making them among the most complex and vulnerable landforms under modern climate stress. Global warming has intensified heatwaves, floods, droughts, and sea-level rise. In 2024, Earth's surface temperature surpassed the 1.5 °C limit of the Paris Agreement, marking the hottest year on record. Rapid Himalayan ice melt adds uncertainty to sediment dynamics, water availability, and delta stability. Among the world's 44 sinking cities, 30 are in Asia, many located on these deltas. Bangladesh, positioned in the world's largest delta—the Ganges–Brahmaputra–Meghna (GBM) Delta—is highly exposed to climate impacts such as flooding, drought, salinity, coastal inundation, and heat stress. Its ancient archaeological sites, including Mahasthangarh, Wari-Bateshwar, and Paharpur, are threatened by ground instability, salinity, and extreme weather. Without timely conservation efforts, these invaluable heritages may deteriorate irreversibly. Engineering geology, through multidisciplinary and climate-resilient approaches, offers essential tools for safeguarding and managing the archaeological and cultural heritage of the Bengal Delta and other South Asian deltas.

Keywords: ***Climate resilience, Archaeological heritage; Bengal delta; South asian deltas.***

Introduction

South and Southeast Asian deltas are formed by rivers draining the Himalayan–Tibetan Burman region, including the Indus, Ganges, Brahmaputra, and Mekong systems (Figure 1). The initiation of most deltas occurred around 8000–9000 years ago, coinciding with human settlement and civilization (Truschke, 2025). Delta evolution depends on sediment supply, monsoonal variability, Holocene sea-level change, and subsidence. These dynamic systems are increasingly affected by anthropogenic climate change, manifesting as heatwaves, irregular rainfall, flooding, and sea-level rise (Eslami et al., 2025). Earth's average temperature rose by 1.52 °C in 2024, exceeding the Paris Agreement threshold. Himalayan glacier melt is altering river discharge and sediment transport, influencing deltaic subsidence and stability.

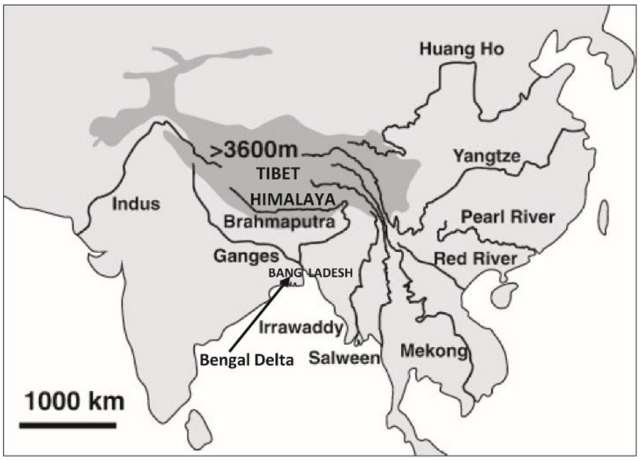

Figure 1, Major rivers of south and southeast Asia and Bengal Delta.

Study Area

The Ganges–Brahmaputra–Meghna (GBM) or Bengal Delta extends across Bangladesh and the Indian state of West Bengal. About 80% of Bangladesh comprises floodplains and deltaic plains, 8% uplifted terraces, and 12% hilly terrain. These regions consist of unconsolidated Holocene sediments, Pleistocene residual soils, and Tertiary folded rocks. Subsidence, differential tectonic movement, and sediment dynamics have created a complex geomorphology. Major cities—Dhaka, Chattogram, and Khulna—are subsiding, increasing flood vulnerability and salinity intrusion, triggering migration and social insecurity (Haque et al., 2024).

Methodology

This study synthesizes published geological, climatic, and archaeological research (Bakr, 1977; Alam, 2019; Hu et al., 2020; Sen and Alam, 2023) along with recent climate and sea-level data (DoE, 2023). A cross-disciplinary review approach was used to establish links between deltaic evolution, climatic variability, and archaeological site vulnerability. Historical settlement data and geomorphological mapping were integrated to understand human–landform interactions.

Result

Bangladesh faces multiple climate hazards—extreme heat, erratic rainfall, drought, salinity intrusion, and riverbank erosion. Recent observations show sea-level rise exceeding 3.42 mm/year, and temperature increasing by 0.7–1 °C, over six decades. Ancient settlements such as Mahasthangarh, Wari-Bateshwar, and Paharpur were established on distinct geological units (uplifted terraces, floodplains, and deltaic plains). Each responds differently to changing temperature, humidity, and salinity, affecting soil behavior and archaeological stability (Figure 2). Subsidence and seismicity further endanger structural integrity. Warming may even influence tectonic fault activity, potentially triggering earthquakes.

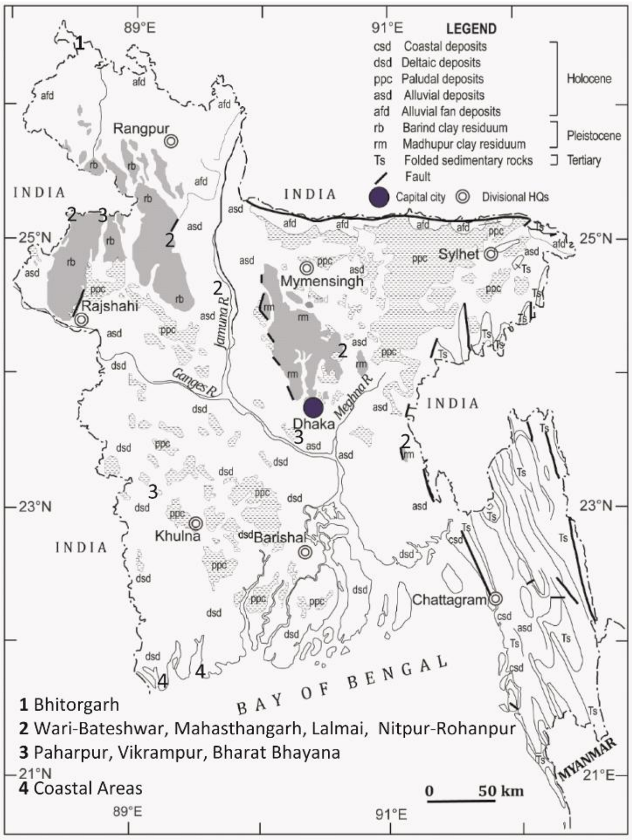

Figure 2, Major Archaeological sites showing on Geological Map of Bangladesh.

Conclusion

The GBM Delta exemplifies the intersection of geological, climatic, and cultural vulnerability. Climate change intensifies deltaic hazards, threatening millennia-old archaeological heritages. Without proactive measures, heat, floods, salinity, and subsidence will accelerate heritage loss. Engineering geology provides essential tools to assess ground behavior, stability, and conservation planning. Multidisciplinary collaboration and regional cooperation are imperative to safeguard the rich archaeological and cultural legacy of the Bengal Delta and other South Asian deltas.

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