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How tree rings revealed a 700-year record of flooding in Bangladesh

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Tens of millions of people in Bangladesh and northeastern India rely on summer monsoon rains, which annually swell surface waterways and slake dry soils, for their basic water needs and for agricultural productivity. However, the monsoon can also bring destruction, as seen in summer 2020 when many regions of Bangladesh were devastated by extreme flooding.

Earth system models are mathematical representations of the climate system that help scientists and officials investigate how flood hazards and risks might change by simulating future climate and surface hydrology, allowing scientists to better anticipate what areas will experience greater flooding amid global warming. To improve the models' accuracy, they must be validated by historical records and environmental evidence, which in some parts of the world are sparse or lacking entirely. For example, records of streamflow, an important indicator of flood hazard, go back less than 70 years in Bangladesh and northeastern India.

Together with colleagues, we recently completed a study that integrated observations from tree ring patterns with climate model projections to construct a 700-year history of water discharge from the Brahmaputra River [Rao et al., 2020], one of several major rivers that flow through the region. We demonstrated that the river was wetter – it carried more water – in the past than it is today and that with climate change, it will likely be wetter in the future. Moreover, a comparison of tree rings with available observations of streamflow shows that the recent past has been one of the driest intervals of the past seven centuries. This comparison further suggests that despite the massive impacts of major floods in the past several decades, the long-term flood hazard – that is, the frequency of flooding events – in the Brahmaputra River is currently underestimated by roughly 30%.

This is a sobering result. Given the expectation that climate change and warming will increase streamflows in the 21st century, it suggests that the flood hazards will become an increasingly problematic environmental stressor in the region.

The long and short of flooding on the Brahmaputra

The Brahmaputra River originates in the Lake Manasarovar region in southwestern Tibet and flows eastward until it bends south and enters northeastern India. In India, it flows westward before making a right-angle turn south again at the border with Bangladesh, where the river is known as the Jamuna.

Upon reaching central Bangladesh, the Jamuna joins the Ganga and Meghna Rivers to form the third-largest river system in the world, after the Amazon and Congo (it is similar in size to the Río Orinoco system in Venezuela). The Brahmaputra River swells every June through September – the monsoon season – becoming as wide as 8-13 kilometers, then shrinking to a width of 2-3 kilometers after the rains subside. This annual rhythm of expansion and contraction deposits fresh fertile soil for rice farming and creates critical opportunities for fishing, important activities that support the livelihoods of 60 million people in Assam (India) and Bangladesh.

In some years, however, heavy precipitation along the southern margin of the eastern Himalayas can result in catastrophic flooding that displaces people, damages property and crops, and causes the loss of lives and livelihoods farther downstream in Bangladesh and northeastern India. For example, in 1998, nearly 70% of Bangladesh was inundated by monsoon-related flooding, affecting more than 31 million people and claiming more than 1,000 lives. The resulting economic losses amounted to $2.5 billion [Dewan et al., 2003]. Most recently, in July 2020, a combination of heavy rainfall from Cyclone Amphan and a stronger-than-normal monsoon inundated more than 25% of Bangladesh, affecting nearly 5 million people in the region.

Accurate records of streamflow and flooding along the Brahmaputra River have been available only since the mid-1950s. Such a short record makes it challenging to evaluate the relative severity of recent monsoons and flood events compared with those in the past, to estimate the frequency of and risk from such events in the present, and to understand how climate change will affect the river system in the coming decades.

Trees record the past, climate models foretell the future

For our study, we supplemented the limited records from modern hydrologic monitoring with natural records from trees and with computer simulations of the climate system. Integrating information from these approaches provides a long-term perspective on streamflow variability and change from the past to the future that can inform us about both natural variability in the climate system and how things may change with continued warming.

As trees grow, they create annual patterns of concentric tree rings. Studying tree rings – a field called dendrochronology – not only tells us the age of a tree but can also inform us about the climatic and environmental conditions a tree experienced during its lifetime.

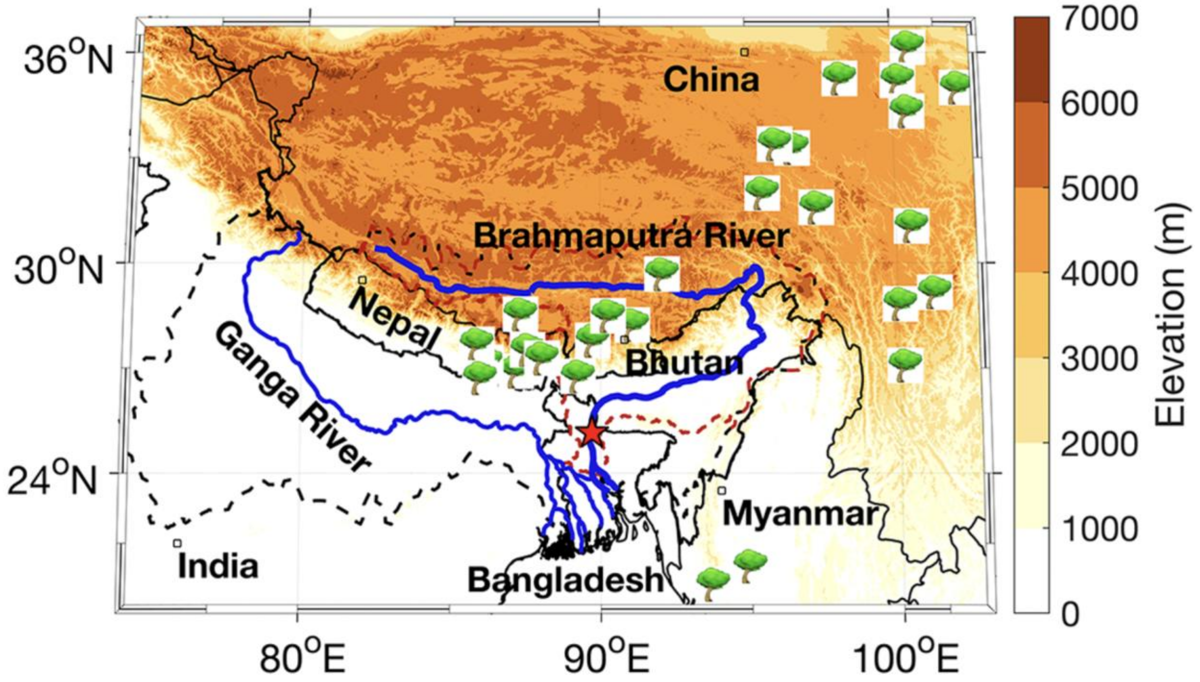
For example, an abundance of moisture during wet monsoon years helps trees in the eastern Himalayas and southern Tibetan Plateau, upstream of Bangladesh, grow more and produce wide rings. Conversely, in dry years these same trees grow less and produce narrow rings. Changes in the strength of the monsoon influence the volume of water flowing through the Brahmaputra River. Because some trees can live for many centuries, analyzing the rings of these trees allows us to develop records of past wetness and dryness in the region [Nguyen et al., 2020], including streamflow in the Brahmaputra River. This information from tree rings can date back well before humans began systematically collecting hydrologic information with modern instrumentation like streamflow gauges.

To better understand how streamflow and flood hazards in the Brahmaputra River in recent decades compare to those in past centuries, we assembled tree ring data from a network of 28 forested locations across the upper Brahmaputra watershed (Figure 1). Information from about half of these sites was collected by colleagues over the past few decades, using an increment borer to extract tree ring records without injuring the trees. The remaining data were obtained from the International Tree-Ring Data Bank (ITRDB) a large public archive that has been in operation for more than 4 decades [Zhao et al., 2019]. We used these data to reconstruct monsoon season discharge from the Brahmaputra from 1309 (the date of the oldest tree ring from this region) to the present.

To build this reconstruction, we first developed a statistical model relating tree growth to observed streamflow from the mid-1950s to the present. The model revealed strong correspondence between these factors over this period, allowing us then to harness the much longer tree ring record to estimate streamflows dating back to 1309. Because trees add one ring for each year of growth, we could estimate mean July–September discharge for each year during this 7-century-long interval [Rao et al., 2020].

We then compared our seven-century tree-ring-based reconstruction to the instrumental record of streamflow and to climate models for the 21st century that simulate many important hydrologic processes related to flood hazard, including precipitation, evapotranspiration, and runoff [Rao et al., 2020]. In our modeling, we evaluated how Brahmaputra River discharge will change under scenarios in which global climate warms by 3°C–4°C near the end this century relative to preindustrial times

(1850-1880). (For context, Earth's temperature has already warmed 1.2°C since the late 19th century.)



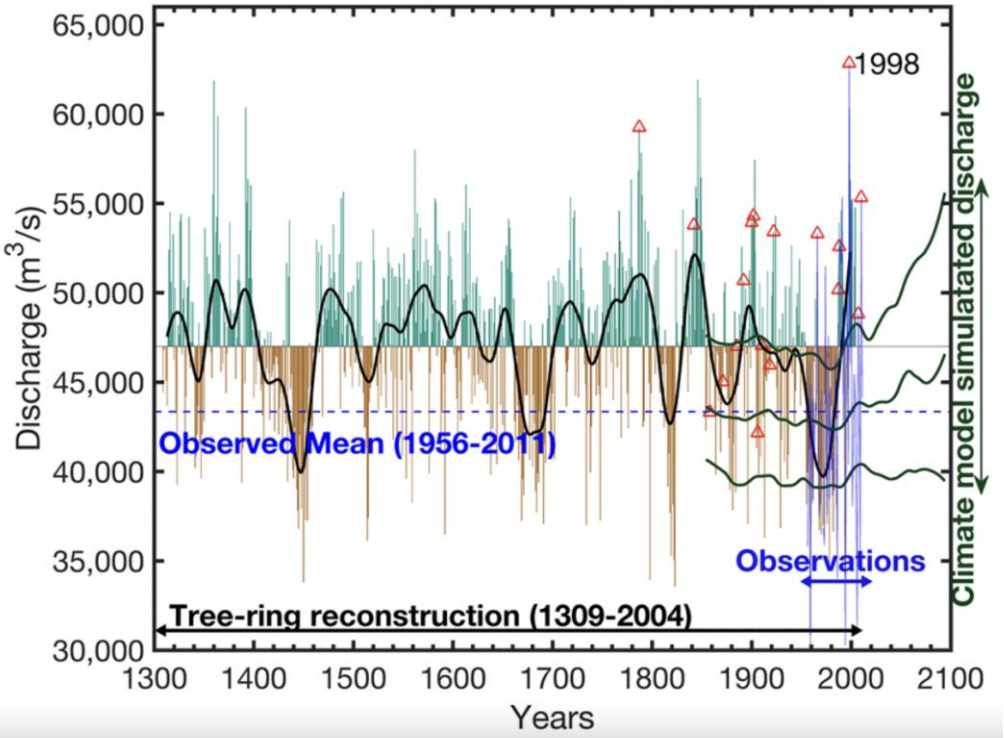
To our surprise, we found that the earliest decades from the period of instrumental observations (1956–1986) ranked among the driest intervals of the past 7 centuries (Figure 2). We also found that long-term (seven-century) baseline flow conditions in the Brahmaputra River watershed were much wetter than at any period since the 1950s.

Further, we were able to use modern and historical [e.g., Mahalanobis, 1927] records of past floods to demonstrate that unsurprisingly, years when high streamflow conditions prevail are strongly associated with flooding in the region. The extremely dry conditions during recent decades relative to the past therefore indicate that the present-day flood hazard along the Brahmaputra, estimated from the instrumental record alone, is likely underestimated by 24%-38% relative to the past 700 years. In other words, we expect high-streamflow events typically associated with flooding on the Brahmaputra to occur nearly 1.5 times more frequently if we use the tree ring reconstruction as a baseline for hazard analysis instead of the short observational record.

As humans continue to emit greenhouse gases, scientists anticipate a strengthening of the monsoon and increased incidences of extreme rainfall events. Our climate models indeed project more regional wetting as we progress through the 21st century, suggesting that flood hazards will also increase. Together, the tree ring reconstruction and projections of higher discharge relative to those seen in the instrumental period lead to the conclusion that we may be underestimating the frequency of high-discharge events and, consequently, potential flooding in the Brahmaputra River watershed.

What can we do if flooding gets worse?

A stronger monsoon contributes only one component to increased flood risks for people throughout the region. Exposure and vulnerability are also influenced by regional urbanization, land use, and population density, and they correlate with various socioeconomic factors. Even with flood hazards amplified by climate change and other factors, effective policies to reduce exposure and vulnerability can mitigate negative effects of flooding, which is especially vital in severe events.



Accurate early-warning forecasts from the Bangladesh Meteorological Department and the India Meteorological Department can help people proactively prepare for flood events. Improved regional cooperation and information sharing among the countries within the river basin (Bangladesh, Bhutan, China, India, and Nepal) could enhance these forecasts. These nations must also continue to monitor and reassess flood mitigation structures such as embankments and polders (low-lying regions reclaimed from or adjacent to a river and protected by dikes) to ensure that they can withstand floods today and in the future and that they do not inadvertently shift flood risks to other locations.

It is also important, however, to understand variability in long-term flood hazards because this information informs development of a variety of mitigation and adaptation measures, including flood protection structures and insurance. Our monsoon seasonal streamflow reconstruction helps extend the short instrumental record to better understand this variability in the Brahmaputra system and provide a more accurate view of long-term hazards and risks.

Combined with climate model projections for the 21st century, this work demonstrates that both natural variability and greenhouse warming will likely contribute to a greater likelihood of high-discharge events and risk of flooding. Therefore, we recommend that the basis considered for policy decisions and mitigation scenarios should not be limited to floods similar to those observed in recent decades. Severe and recurrent high-discharge events likely occurred in the past and are expected to occur again under climate change, and these events must factor into future plans.

Source: https://science.thewire.in/the-sciences/how-tree-rings-revealed-a-700-year-record-of-flooding-in-bangladesh/