Comment

Flooding of coastal regions in Bangladesh has increased soil salinity and killed off plants and trees.

Avert Bangladesh's looming water crisis through open science and better data

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Intensive irrigation and climate change are depleting groundwater reserves in this fast-developing nation. To improve its water security, researchers need more information on water use, quality, flows and forecasts.

Bangladesh is home to a network of hundreds of rivers and the world's largest river delta, the Ganges Delta. Historically, the nation has been water rich. But that is changing owing to declining rainfall, more-intensive irrigation and heavier use of water upstream. Contamination from arsenic and sewage is also on the rise.

To feed our future planet, it is crucial that water is used more sustainably in agricultural regions such as Bangladesh. Other agricultural hotspots face similar water stresses, including the Western and Central United States, northern India and Brazil[1,2], where falling water tables punish farmers and grab headlines.

Bangladesh has taken some steps to address the problem. In 2018, its Ministry of Planning published the Bangladesh Delta Plan 2100 (BDP; see go.nature.com/3s26anc). This outlines a long-term strategy for the country's sustainable and resilient socio-economic development in a changing climate. Water security is a key part of this plan. Although the BDP rightly identifies the main issues facing the nation's water, it is vague on effective actions. These will require heavy investments and more supporting research.

Our analysis of water resources from satellite and local data reveals under-appreciated risks. Here we set out what is known, define pressing questions and describe how to put that knowledge to use.

State of flow

Bangladesh is one of the fastest-growing economies in the world – its total gross domestic product has increased almost eight-fold since 2000. To encourage food security, the government has promoted agriculture. This has motivated farmers to cultivate rice not just during the wet monsoon season from June to October, but also during the dry season. Rice productivity has skyrocketed, almost doubling since 1990. Today, Bangladesh yields 4.8 tonnes of rice per hectare annually, compared with 2.9–3.9 tonnes per hectare for other leading rice producers such as India and Thailand (see go.nature.com/3s74a33).

This self-sufficiency has a high price. The country now irrigates about 5 million hectares of land during the dry season, with 73% of that water sourced from groundwater[3]. At the same time, groundwater is being pumped extensively in India, which is upstream from Bangladesh, so adds strain to water resources.

Our analysis of satellite data shows that 37.5 billion cubic metres of terrestrial water storage (the sum of surface water across rivers, lakes, wetlands, soil moisture, groundwater and snow) have been lost across the country since 2002 (see 'Water in Bangladesh: Storage'). The vast majority of those losses are due to groundwater depletion, mostly driven by irrigation. In some spots, including northwestern Bangladesh and metropolitan Dhaka, aquifers have been dropping by roughly 1 metre each year since 2000 (see 'Water in Bangladesh: Groundwater'). This means that some farmers now pump groundwater from 20 metres deeper than they did two decades ago.

Optimistic recent studies show that groundwater pumping can accentuate the land's ability to absorb monsoon rains, helping to replenish aquifers in Bangladesh[4]. But we are sceptical, given the long-term declines revealed by ground and satellite data.

Climate change also exerts pressure on the country's water supply. Extreme rains are now more likely. For example, in June, a massive flood killed at least 22 people in Bangladesh and stranded another 4 million. However, satellite data show that annual rainfall rates in Bangladesh have fallen by about 10% over the past two decades, or by 10 millimetres per year (see 'Water in Bangladesh: Rainfall'). This worrying decline has been noted in the literature[5,6] since the early 1950s.

Our analysis of river-gauge data also shows that the winter water flow of the Ganges, Brahmaputra and Meghna rivers combined has halved between 1993 and 2021 (see 'Water in Bangladesh: Rivers'). This astounding decrease is likely to be a result of declining rainfall[5] and increased groundwater pumping upstream in India for agriculture.

Many of Bangladesh's natural water resources also face contamination from geological and human pollutants. Bangladesh's rocks contain high levels of arsenic – a poison and carcinogen. Arsenic leaches naturally into groundwater, which can contaminate irrigated crops and soils. Some 17% of the population of Bangladesh – about 29 million people – have been found to be exposed to arsenic[7], mostly from contaminated shallow wells that constitute the backbone of the country's rural water supply.

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Sanitation is also an issue. The country successfully reduced the proportion of people practising open defecation from 42% in 2003 to almost zero in 2015, but untreated sewage is still often released into surface waters. In addition to untreated domestic sewage, rivers across Dhaka receive a striking 60 million litres of untreated or partially treated industrial wastewater each day[8]. A 2019 survey coordinated by Bangladesh's government and the United Nations children's charity UNICEF concluded that 82% of the population is exposed to water contaminated with *Escherichia coli* bacteria[7].

Finally, low-lying Bangladesh is highly vulnerable to sea-level rise. Our analysis of satellite data shows that sea levels have been rising at a rate of almost 5 mm per year (see 'Water in Bangladesh: Seas'), and that this, combined with land subsidence and other issues, has led to the loss of 490 square kilometres of coastal land since 2001 (see 'Water in Bangladesh: Coastlines'). This makes both groundwater and surface water saltier farther inland.

Three priorities

The following efforts should improve assessments of water supplies, help to make water use sustainable and mitigate damage from floods.

Manage rain and river waters with good data. Managing the flow of transboundary rivers is one of the biggest challenges for Bangladesh – both in the dry season, while the country faces acute shortages of surface water, and in the rainy season, when catastrophic flooding occurs.

Over the past few decades, Bangladesh has benefited from World Bank initiatives, in partnership with local authorities, which have added thousands of cyclone shelters and water-control structures, several thousand kilometres of dikes and hundreds of polders. As a result, 333,000 people are now better protected from tidal flooding and storm surges. More investments are needed to protect against the increasing risks posed by climate change.

All of these efforts require good data to inform understanding of water supplies, flows and forecasts, so that the right infrastructure can be built in the right places.

Access to data is a huge problem. Bangladesh collects a large amount of hydrological data, such as for stream flow, surface and groundwater levels, precipitation, water quality and water consumption. But these data are not readily available: researchers must seek out officials individually to gain access. India's hydrological data can be similarly hard to obtain, preventing downstream Bangladesh from accurately predicting flows into its rivers.

Bilateral scientific collaboration between Bangladesh and water-sharing nations, including India, Nepal, Bhutan and China, would be mutually beneficial. The decades-long Mekong River Commission between Cambodia, Laos, Thailand and Vietnam is one successful transboundary agreement that could serve as a model.

Publishing hydrological data in an open-access database would be an exciting step. For now, however, the logistics, funding and politics to make on-the-ground data publicly available are likely to remain out of reach.

Fortunately, satellite data can help to fill the gaps. Current Earth-observing satellite missions, such as the Gravity Recovery and Climate Experiment (GRACE) Follow-On, the Global Precipitation Measurement (GPM) network, multiple radar altimeters and the Moderate Resolution Imaging Spectroradiometer (MODIS) sensors make data freely available and can provide an overall picture of water availability across the country (this is what we used in many of our analyses). The picture is soon to improve. In December, NASA and CNES, France's space agency, plan to launch the Surface Water and Ocean Topography

(SWOT) satellite mission. SWOT will provide unprecedented information on global ocean and inland surface waters at fine spatial resolution, allowing for much more detailed monitoring of water levels than is possible today. The international scientific community has been working hard over the past 15 years to get ready to store, process and use SWOT data.

New open-science initiatives, particularly NASA's Earth Information System, launched in 2021, can help by supporting the development of customized data-analysis and modelling tools (see go.nature.com/3cffbh9). The data we present here were acquired in this framework. We are currently working on an advanced hydrological model that will be capable of representing climate-change effects and human impacts on Bangladesh's water availability. We expect that the co-development of such a modelling system with local partners will support decision-making.

SERVIR, a joint programme of NASA and the US Agency for International Development that focuses on capacity-building, could also help improve forecasting of severe weather for Bangladesh, for example. This could improve the flood monitoring and forecast system operated by the Bangladesh Water Development Board, which is limited in geographical scope – flooding is monitored only at specific locations, not across the country. Such efforts will help with short-term adaptation and emergency responses to flood conditions, and with long-term planning for infrastructure.

Adapt agriculture. More research is needed on groundwater dynamics to better understand recharge rates and future precipitation patterns. Groundwater level data, combined with a comprehensive and updated water-use catalogue, could then be used to determine sustainable agricultural and domestic pumping rates for different regions in Bangladesh.

Satellite-based irrigation advisory systems can help by determining the volume of water actually needed by crops. One of us (N.K.B.) has helped to implement one such system in northern India and eastern Pakistan. This was developed at the University of Washington in Seattle, in partnership with the Indian Institute of Technology in Kanpur and the Pakistan Council of Research in Water Resources in Islamabad. They estimate that such a system could save more than 200 billion litres of groundwater annually in these two regions combined[9]. This is a small proportion of the total demand for water for irrigation, but would be enough to supply, for example, about 4–5% of Bangladesh's domestic water needs.

A prototype system to use such estimates to avoid overwatering has been developed for northeastern Bangladesh, with plans to expand it to the northwest of the country and to incorporate the system into Bangladesh's Agro-Meteorological Information System, run by the Department of Agricultural Extension.

These irrigation advisory systems could be improved further by increasing the spatial resolutions of input data – some of which currently come from coarse-resolution global forecast models – and doing further validation on the ground.

Other ways that Bangladesh could reduce its water strain from agriculture include: developing better rainwater harvesting systems, restricting rice production in groundwater-vulnerable areas and switching to crops that consume less water than rice does, such as wheat and legumes.

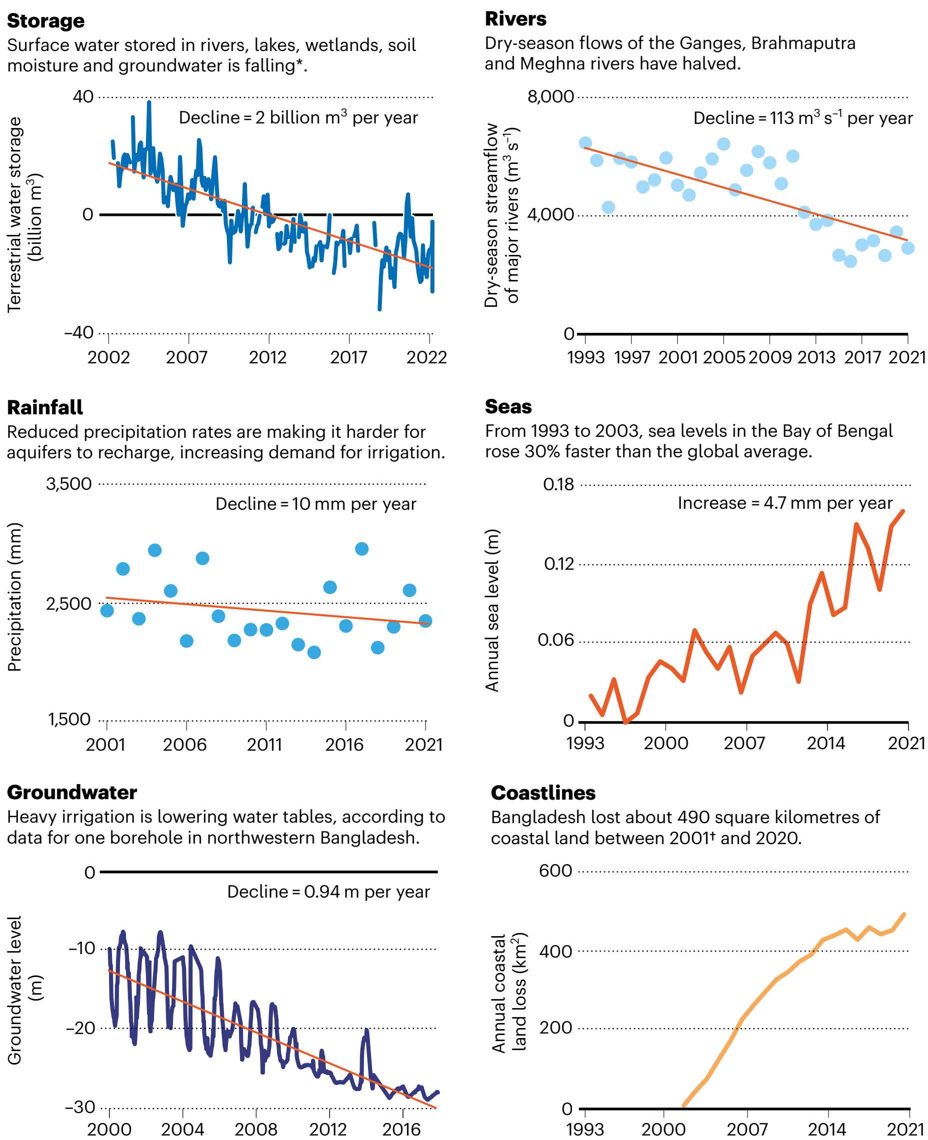
Another strategy is to adapt to sea-level rise and incursions of salt water. On the coast, rising salinity levels have already forced many farmers to discontinue cultivation of oilseed, sugar cane and jute[10] and to switch to shrimp aquaculture[11]. Local fish species cannot tolerate salty conditions, which has put fish farmers in conflict with rice farmers as they compete for fresh water. Introducing brackish aquaculture of non-local species of fish would be a beneficial addition to this system.

Several salt-tolerant plants, such as *Atriplex* species, tamarisk (*Tamarix* species), mangrove (*Avicennia marina*), Korean lawn grass (*Zoysia japonica*), *Euphorbia* and *Salicornia*, are now commercially available and grow well in saline coastal areas. As well as providing food and fodder, these plants have the capacity to desalinate soils. They are widely used in coastal areas of countries in the Middle East and South Asia; research should be conducted to assess their suitability for Bangladesh.

Inform the fight against contamination. A centralized sewerage system is likely to be too costly for Bangladesh, and is viable only in the long term. For now, many urban

WATER IN BANGLADESH

Data from satellites, wells and sensors reveal water insecurity, highlighting the need for sustainable use.



*Gaps are months in which the GRACE satellite did not acquire data; †No data before 2001, because MODIS sensor was not operational.

SOURCES: STORAGE: GRACE/GRACE FOLLOW-ON/B. D. LOOMIS *ET AL. J. GEODESY* 93, 1381–1398 (2019); RAINFALL: GLOBAL PRECIPITATION MEASUREMENT MISSION/G.J. HUFFMAN *ET AL.* HTTPS://GO.NATURE.COM/3SD3KFZ (2015); RIVERS AND GROUNDWATER: BANGLADESH WATER DEVELOPMENT BOARD; SEAS: TOPEX/POSEIDON AND JASON SATELLITE SERIES (HTTPS://GO.NATURE.COM/3EJVWXW); COASTLINES: MODIS/M. FRIEDL & D. SULLA-MENASHE HTTPS://DOI.ORG/GKRG53 (2019).

MAMUNUR RASHID/NURPHOTO VIA GETTY

Irrigation of a rice field in Jamalpur, Bangladesh.

residences have simple, low-cost septic tanks on site. But most are inadequately designed and constructed, and release partially treated effluent into surface waters and aquifers. Researchers can help by improving surface- and ground-water quality monitoring and by assessing the financial costs of such systems, to help governments to understand trade-offs.

Ongoing efforts to deal with arsenic contamination include drilling deeper wells, piping clean surface waters or helping people to switch to lower-arsenic sources where available. These efforts would be greatly assisted by large-scale, low-cost, real-time monitoring systems for water quality.

Some of this work is under way. In Dhaka, remote sensors installed across the city's 414-kilometre water-supply network have cut physical water losses from 40% to 15% by automatically rationing water supply according to demand[12]. Public water authorities and partner agencies have begun to install monitoring systems[13] through which citizens will be able to check water quality in real time on their mobile phones. As of August, Dhaka had installed metering systems in 78 of 145 water-supply districts. Each metering system costs less than US$1,000; a full installation in Dhaka should carry a price tag of just $0.66 per person. Such systems should be extended.

Bangladesh has shown the political willingness to tackle its challenges around water insecurity. Success now depends on a more-comprehensive understanding of the water systems from good-quality, open-access data, research and increased funding for infrastructure.

Implementation of the Bangladesh Delta Plan up to 2030 is estimated to cost $38 billion. The World Bank has invested $1.8 billion to fund initial infrastructural enhancements; the rest will have to come from domestic and international sources to help this fast-growing nation to meet its urgent water-sustainability goals.

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