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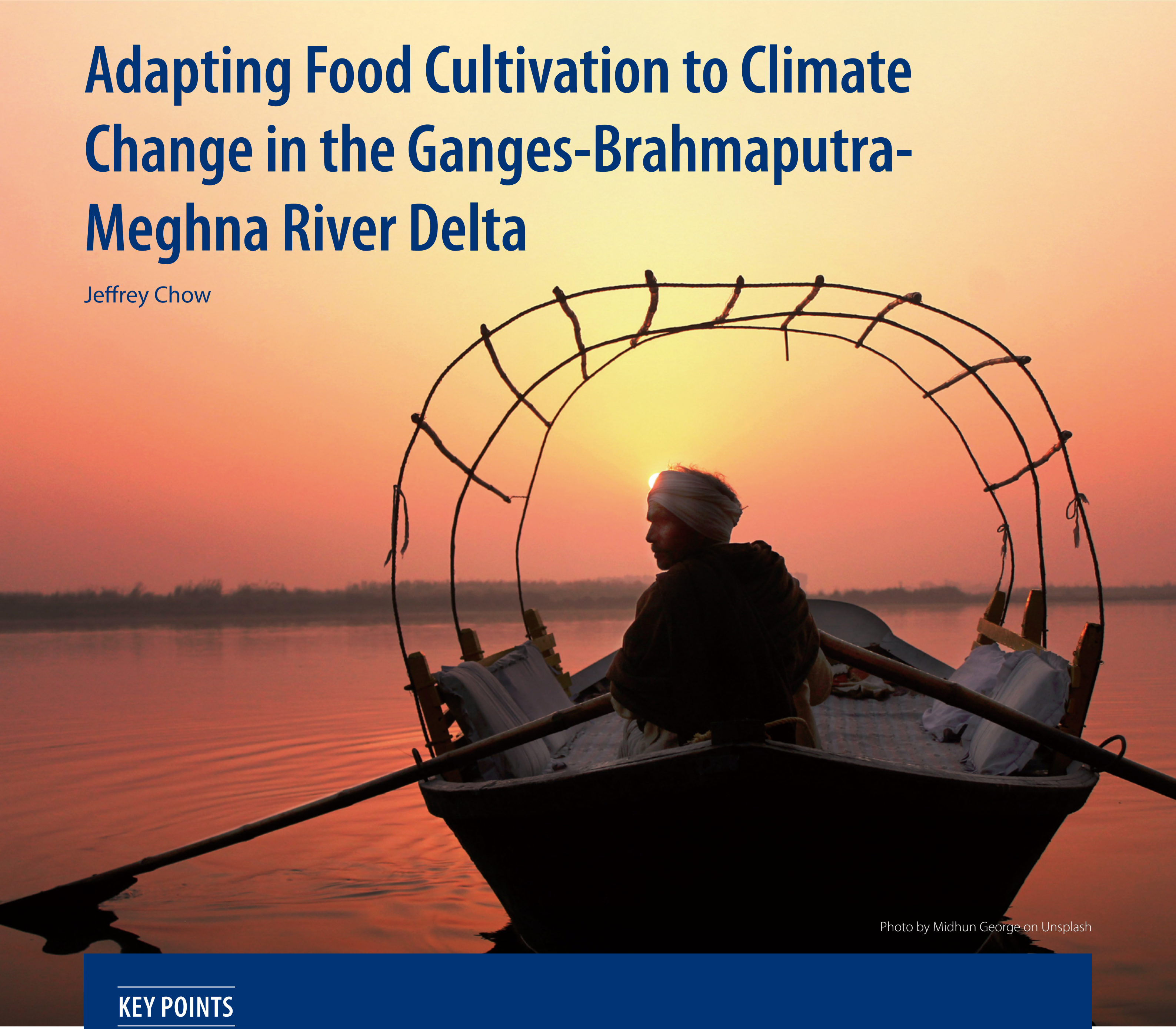


Adapting Food Cultivation to Climate Change in the Ganges-Brahmaputra-Meghna River Delta

Jeffrey Chow

Photo by Midhun George on Unsplash

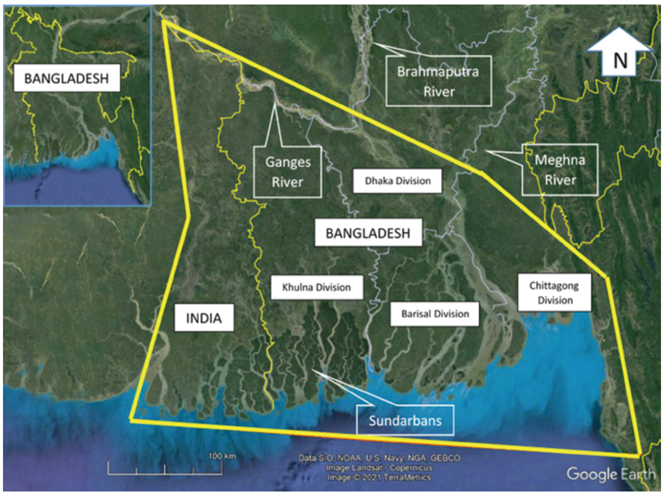
KEY POINTS

- The Ganges-Brahmaputra-Meghna River Delta is a vital region for agriculture and aquaculture production, but is also highly vulnerable to climate change impacts including altered temperature and precipitation regimes, increased riverine flooding, intensified tropical storms, and rising coastal soil salinity.
- Prevailing adaptation strategies have limitations and drawbacks, thus the development of new climate change resilient crop varieties and methods is urgent and must be coupled with rapid and widespread education and dissemination campaigns to enhance adoption.
- Poorer or landless cultivators with fewer options need programs that support alternative non-cultivation adaptation strategies such as consumption smoothing, income diversification, and migration.

ISSUE

Spanning most of Bangladesh and parts of West Bengal in India, the Ganges-Brahmaputra-Meghna (GBM) delta is the world's second geographically largest and first most populous delta system (Figure 1). The region is characterized by wide seasonal variations in rainfall, with the bulk (70-80%) falling during the summer monsoon between July and September. The low topography, generally <3m above sea level, renders many areas vulnerable to monsoonal flooding. The fertile flood plains have continued to be sites of intensive agriculture, industrial, and fishery production. Within Bangladesh, the GBM delta yields approximately a third of the country's total rice production and a quarter of the country's total wheat production.

Figure 1. The GBM Delta (Polygon) Spans Lower Bangladesh and West Bengal, India.



Source: Google Earth.

Geophysical and socioeconomic conditions have made populations living in the GBM delta uniquely exposed to an array of climate change impacts. In addition to changes to temperature and precipitation regimes, the region is also vulnerable to natural hazards expected to intensify with climate change, such as sea level rise, coastal erosion, riverine flooding, and tropical storms. This brief examines the impacts of climate change on agriculture and aquaculture production in the GBM, as well as the potential adaptation strategies for reducing climate damages and enhancing resilience. The following assessment draws from Chow et al. (2022), where additional information can be found regarding the analytical methodology for evaluating the effect of climate factors on cultivation profits.

ASSESSMENT

The interaction between climate and rice farming is especially crucial given the importance of this crop to food security at the household and national levels. There are three rice growing seasons in the GBM delta: boro, aman, and aus. Boro rice, which constitutes about 54% of total rice production in Bangladesh, is a dry season crop sown in the fall or winter and harvested throughout the spring. Aman rice (39%) is planted either in the spring or summer and harvested either in the fall or winter, to overlap with the monsoon. Aus rice (7%) is sown in the early spring, matures with the summer rains, and harvested in the late summer. Households in high rainfall areas tend to favor rain-fed aman rice as their dominant crop, whereas farmers with less rain tend to cultivate boro rice with irrigation.

Fish are also an important source of food security, constituting 50-60% of animal protein consumed. About 73% of rural households engage in some form of aquaculture. Three types of aquaculture are prevalent, though most ponds are created from packed soil formed into ditches regardless of species (Figure 2). In type I, land is intercultured in the summer with aman rice and freshwater fish and shrimp, which are harvested in the fall. Saline fish and shrimp are then produced from winter until the following summer. In type II, ponds are converted from rice fields in the early summer, producing saline fish and shrimp until being reconverted back to boro rice fields in the winter. In type III, ponds produce shrimp and fish only, from December to October.

Figure 2. Typical Aquaculture Pond Utilized in Southern Bangladesh.

Source: Author.

Increased Temperatures and Precipitation

Chow et al. (2022) find that agriculture profits in the GBM delta are sensitive to climate, specifically increasing with higher spring temperatures and fall precipitation, and decreasing with higher summer and winter temperatures and greater spring precipitation. Higher spring temperatures increase aus rice productivity and greater fall rainfall provides irrigational input for dry season crops. In contrast, higher summer and winter temperatures reduce yields of aman rice and winter wheat crops, respectively. Greater spring rainfall also depresses aus rice yields and interferes with the spring sowing of aman rice. Farmer adaptation to greater overall temperature and precipitation would likely result in a shift away from highly climate-sensitive aman to irrigation-based boro and aus varieties.

As for aquaculture, greater spring precipitation and higher summer temperatures also depress profits. Heavy rainfall reduces working days, and may decrease water salinity during spring post-larvae stocking periods and increase vulnerability to disease. Shrimp producers also report that higher temperatures increase shrimp mortality and disease. Diversification of aquaculture to integrate more species of fin fish and shellfish may help cultivators hedge against these climate impacts, though such options are not without climate risks and are typically available mainly to wealthier operators.

Greater Riverine and Rain Floods

Riverine flooding can have countervailing impacts on agricultural productivity. Severe or prolonged flooding can reduce crop yields, whereas moderate flooding increases productivity by replenishing groundwater and supplying nutrients. Hence, lowland areas which receive these inputs have significantly greater farm profits. However, areas that are vulnerable to severe river flooding yield lower farm profits. Poor soil drainage also reduces farm profits by prolonging floods.

To cope, flood-vulnerable farmers have altered cropping patterns, such as shifting from inundation-sensitive crops like rice and vegetables to those that better tolerate high floodwater such as jute and sugar cane. Additionally, the cultivation of vegetables, flowers, and seedlings on floating platforms is a traditional practice in inundated areas. However, these adaptation strategies are not suitable for large-scale production of staple cash crops like rice and wheat.

Aquaculture ponds also are vulnerable to flood damage since pond overflow results in loss of stock. Profits decrease the closer operations are located to rivers, since these are more flood prone. To adapt, cultivators mainly raise or reinforce embankments with bamboo and nets in ways that are generally ineffective for protecting against severe floods.

Intensified Tropical Storms and Surges

Tropical storms of cyclonic strength are the most destructive form of natural disaster in the GBM delta. Storm surge floods cause most of the damage, as surges hit coastal areas and propagate inland along rivers. Besides causing loss of life, surges can also breach embankments and ruin agriculture, livestock, and aquaculture operations that cannot withstand the saltwater inundation. Consequently, areas that are vulnerable to moderate tidal surge yield lower farm profits.

In anticipation of various climate change impacts including storm surge inundation, organizations such as the Bangladesh Rice Research Institute have developed salt- and submergence-tolerant varieties of rice and other grains, oilseeds, fruits, and vegetables. However, wealthier farmers are more likely to have the resources to adapt by employing various agricultural adjustments, whereas small and landless farmers have fewer choices.

Table 1. Adaptation Strategies for Climate Hazards in the GBM River Delta.

Climate Hazard	Cultivation Adaptation Strategies	Drawbacks and Limitations
Altered temperature and precipitation	Shift rice varieties; develop temperature-robust rice varieties	Dissemination of new varieties often limited
	Diversify aquaculture species to integrated multi-trophic aquaculture	Available mainly to wealthier cultivators
Greater riverine and rain floods	Shift to inundation tolerant crops (e.g., jute and sugarcane)	Not staple food crops
	Cultivate on floating platforms	Mainly feasible for vegetables and horticulture only
	Optimize water management with sowing dates and rice varieties	Slow dissemination of new practices
	Increase rice imports	Vulnerable to export bans
	Reinforce aquaculture pond embankments	Generally ineffective against severe floods
Intensified tropical storms and surges	Establish embankments and foreshore afforestation	Mixed evidence of effectiveness against severe storms
	Build cyclone shelters and evacuation and early warning systems	Saves lives but not crops or property
	Sow winter season crops earlier to avoid saline water	Lands must be adequately drained and groundwater must be available
	Develop salt and submergence tolerant varieties	Has not kept pace with the rapid onset of salinity, low scale of adoption
	Relocate aquaculture operations inland, build higher dikes around ponds and irrigation facilities	Marginally effective for small scale operators
Salinity intrusion	Shift from native to high-yield rice varieties	Require more fertilizer and pesticide inputs
	Shift from mixed aquatic agriculture systems to purely aquatic cultivation	Lower profits, reduced availability of traditional rice and vegetable crops
	Use field drainage and cropping with irrigated shallow groundwater	Groundwater availability and salinity subject to climate change and human activities

Aquaculture operations at risk of storm surge inundation also have significantly lower profits. Surges cause physical damage that allows shrimp to escape and predatory wild fish to infiltrate into the ponds. Aquaculture operators have also adopted a variety of adaptation strategies, including mixed culture of prawn-shrimp to address salinity intrusion, building higher dikes around ponds, developing irrigation facilities, and relocating operations inland. However, such strategies are only marginally effective for small scale operators that are most vulnerable.

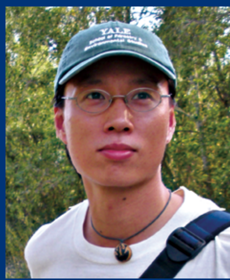
Salinity Intrusion

Very strongly saline soils are associated with lower farm profits. Salinity is most pronounced in the coastal zone during the winter months, when the lack of rainfall causes soils to draw brackish water to the surface via capillary action. Besides storm surges, soil salinity is also exacerbated by sea level rise. To mitigate high soil salinity, farmers employ land management practices such as field drainage and polder drainage canals. Another adaptation approach is the adoption of salt-tolerant species and varieties. However, the development and dissemination of new varieties generally has not kept pace with the rapid onset of salinity. Few new varieties have been introduced in practice and the scale of adoption has been low.

Aquaculture profits have a nonlinear relationship with salinity, since slightly saline areas have lower profits but moderately saline areas have higher profits than non-saline and strongly saline areas. Aquaculture operations which rely on tidal flows to bring saline or brackish water into ponds may have a positive feedback relationship with soil salinity. Prolonged trapping of tidal water within aquaculture ponds exacerbates soil salinity by increasing seepage of saline water into nearby paddy plots. Hence, moderate soil salinity may be an indicator of greater availability of tidal brackish water, whereas slight soil salinity may be an indicator of its lesser availability, for lucrative shrimp operations.

IMPLICATIONS AND RECOMMENDATIONS

Due to the complex, interacting nature of multiple climate risks, as well as the limitations created by prevailing socioeconomic and governance conditions, adaptation strategies for food cultivation face numerous drawbacks and limitations (Table 1). Recent experiments have demonstrated that farmers can profitably intensify the cultivation of staple, high-yielding rice, maize, and sunflower crops in waterlogged areas by combining water management with optimization of sowing dates matched with suitable rice varieties. Crop research also has shown that earlier sowing of dry season crops would allow farmers to use water stored in canals and ponds while it is relatively less saline from tropical storm inputs, but only if lands are adequately drained. Field experiments have shown that dry season cropping with irrigated shallow groundwater can also reduce topsoil salinity. In practice, though, wide scale adoption of such practices has been slow. Therefore, the development of new climate change resilient crop varieties and methods must be coupled with rapid and widespread education and dissemination campaigns. Poorer farmers and aquaculture operators often have fewer adaptation options. For such households, programs must be implemented that support alternative non-cultivation strategies such as consumption smoothing, income diversification, and migration.



Jeffrey Chow is a Postdoctoral Research Associate at the Hong Kong University of Science and Technology Institute for Emerging Market Studies and at the HKUST Institute for Public Policy. Prior to joining HKUST, Dr. Chow served as a Fulbright-Clinton Public Policy Fellow and Special Assistant to the Chief Conservator of Forests for the Bangladesh Forest Department; Research Scientist and Technical Program Manager at Conservation International Hong Kong, and Consultant at Civic Exchange Hong Kong and Environmental Resources Management, Ltd.

Dr. Chow holds a PhD from Yale University and Master of Environmental Management and Master of Forestry degrees from Duke University. His peer-reviewed publications have appeared in Science, PLOS One, Land Economics, the Journal of Sustainable Forestry, Forest Policy and Economics, the Journal of Environmental Policy and Planning, and elsewhere. His research focuses on land economics and policy, as well as on the role of natural capital in climate change adaptation.

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