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The Impact of Climate Change and Submergence on Rice Yields – A Study from Coastal Bangladesh

Flooding caused by heavy rainfall and river over-flow has serious implications for rice production in Bangladesh. As this problem is predicted to worsen as a result of climate change, this Brief discusses some of the current impacts of flooding on rice productivity, identifies implications for the future and suggests ways for the country to adapt and respond. This analysis is based on research undertaken by Afsana Haque and Sarwar Jahan from the Bangladesh University of Engineering and Technology.

Examining rice production in coastal Barisal district, Haque and Jahan find that rice yields are, on average, some 10% lower in high submergence areas compared to low submergence areas. Both the depth and the duration of flooding have a negative effect on rice yields. However, interestingly, local varieties of rice seem to better cope with submergence. The study ventures that coastal Barisal is likely to see a 5% reduction in total Aman rice production in 2050 relative to 2010, unless there are technological and productivity improvements. It therefore recommends the introduction of submergence-tolerant rice cultivars and low-cost water control technologies. These moves should provide ways for farmers to adapt to the climate change challenge.

Assessing the Impact of Submergence on Rice

Data for this study came from a comprehensive survey undertaken in 2011 of 120 farmers in coastal Barisal district in the south-central part of Bangladesh. The district, which is about 136 km away from the national capital Dhaka, is crisscrossed by many rivers and faces submergence due to heavy monsoon rains, high tides and cyclonic storm surges. This district contains the least salt-affected areas among Bangladesh's five coastal regions. So, unlike other coastal regions, rice yields in Barisal district are not significantly affected by soil salinity. During the study's field survey, farmers reported that storm surge, high tide and rainfall were the main reason for submergence of rice fields. This is an important issue because almost 54% of the inhabitants of Barisal district earn their living from agriculture and rice cultivation occupies around 80% of the district's cropped area.

To choose the participants for the study, the Upazilas of Barisal district were first categorized into high and low submergence-prone regions. Base maps for ten Unions, identified within these Upazilas, were sub-divided into 250 m x 250 m grids. 12 grids in rice production areas were randomly identified in each of the ten Unions. Finally one plot from each of the 12 grids was randomly selected for detailed investigation; and 120 farmers who were owners or tenants of the plot were surveyed.

Rice Cultivation at Risk

The study found that rice cultivation in Barisal district is at risk as fields experience continuous submergence with high levels of water for considerable periods of time. On average, the farmers who took part in the study faced a maximum of nine days of submergence of their main rice crop (Aman crop in the *Kharif II* season) in 2010. Eighteen percent of the Aman fields in the study were under 0.5–1 meters of water for 3–7 days, while 31% of the fields were under 1–3 meters of water for the same number of days. Some plots suffered

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This policy brief is based on SANDEE working paper No. 81-13, 'Climate Change, Submergence and Rice Yield: Evidence from Coastal Barisal, Bangladesh.' Afsana Haque, Bangladesh University of Engineering and Technology (BUET). Email: afsanahaque@urp.buet.ac.bd, e_haque2@yahoo.com; Sarwar Jahan, Bangladesh University of Engineering and Technology (BUET). Email: sarwarjahan@urp.buet.ac.bd, sjahan50@gmail.com
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Rice Farming and its vulnerability in Bangladesh

Bangladesh is the largest deltaic country in the world. Its ecology and climatic conditions offer fertile land for agricultural production. However, the land is also vulnerable to water submergence, sea-level rise (SLR) and intense storm surge events.

By the year 2030, global climate models estimate that Bangladesh's annual mean temperature will increase by 1°C, accompanied by a 5% increase in annual precipitation and a 14 cm rise in sea level. These climatic changes will, in all likelihood, affect more than 70 million people in Bangladesh. They will have a particularly severe impact because of Bangladesh's high population density, poor infrastructure, poverty, limited technological options and dependency on natural resources.

This SANDEE study focuses on the impact of climate change on coastal agricultural production in Bangladesh. This is a key issue as some 22% of Bangladesh's rice producing area is in the coastal region; an area that produces 18% of national rice output. Given the vulnerability of coastal farming to climatic changes, the study explores in detail how water submergence affects crop productivity.

Submergence and Rice Yield

Coastal agriculture in Bangladesh has three rice cropping seasons with different seed varieties subject to different forms of flooding. T. Aman rice is grown during the monsoons from July to January (also called the Kharif II season), irrigated Boro rice is grown from December to May (Robi season) and T. Aus is grown from April to August (Kharif I season). Complete and partial submergence of rice fields can occur from heavy rainfall during the monsoon season, rain in the upper basin during the wet season, and daily high tides.

Flooding and submergence have a complicated effect on rice yields. Rice can grow under submerged conditions as rice seed can germinate without oxygen and because the plants can grow fast enough to keep apical parts above slowly rising water. However, rice plants cannot survive when they face sudden and total inundation for multiple days. This is because, when submerged, rice cultivars face reduced oxygen supply, which limits respiration, and limited carbon dioxide supply, which affects photosynthesis.

even more flooding for even longer durations. As expected, yields in low submergence-prone regions were higher (by 10% on average) than those in high submergence-prone regions.

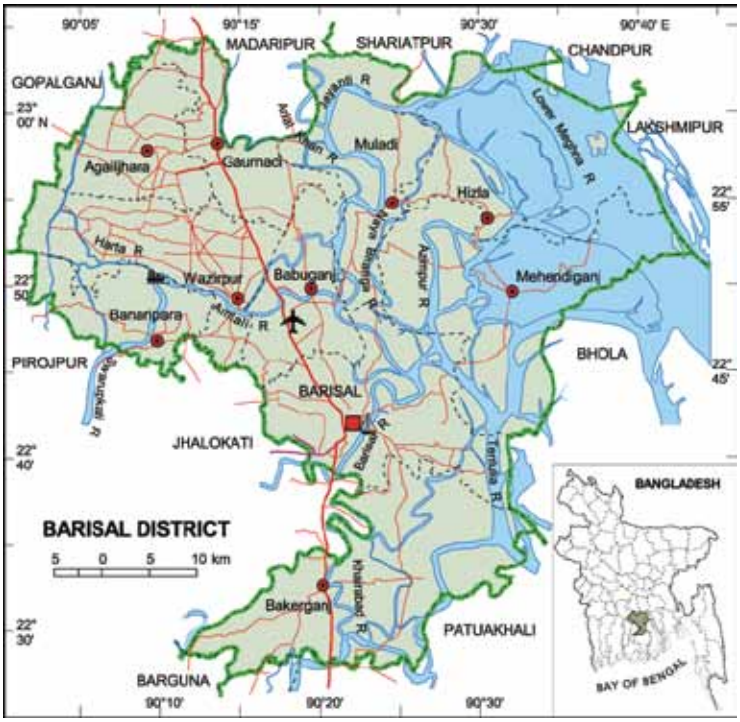
Factors that Affect Rice Yields

The study reinforces the understanding that rice yields significantly decrease when plants are submerged under deeper levels of water. Plants facing more than 3 meters of inundation show an almost 66% decline in yield relative to those covered by less than half a meter of water.

Yields also decrease as cultivars become submerged for longer durations. The duration of submergence seems to have a stronger negative effect on HYV Aman rice than on the local Aman rice. For example, at low water depths (i.e. 0.5–1 meter) the productivity of HYV Aman decreased by nearly 50% in plots with 15 days of continuous submergence relative to plots with 3–7 days of submergence. In contrast local Aman yield declined by only 24% under the same scenario.

The study also found significant seasonal differences. Robi crops were highly sensitive to water levels in the field. The average Robi yield decreased by almost 49% when water depths increased from 0.5 meter to 1.0 meter. In contrast, average yield rates in the *Kharif I* season decreased by 26% when water levels rose by half a meter.

Figure 1: **Map of Barisal District**



The Picture in 2050

To assess potential rice yield losses due to submergence in 2050, the study used a model developed by IWM and CEGIS to estimate the area currently under rice cultivation in Barisal district that is likely to be submerged in the future as a result of sea level rise and storm surge. Based on the 3rd IPCC predictions for a 'high emission' scenario, the study calculated that SLR and increased storm surge events would submerge an additional 13,564 hectares of Aman fields in Barisal district in 2050.

Using the 2010 yield information to project rice production losses in 2050, the study estimated that there would be a production loss of 10,856 tons of Aman rice in 2050 because of submergence (assuming three to seven days submergence of varying heights). This loss amounts to about 5% of total Aman production in Barisal district in 2009–2010. Unless there are technological and productivity changes, this means that there will be a 5% reduction in total Aman (HYV and local Aman) production in 2050 relative to 2010.

Local Cultivars Less Vulnerable to Submergence

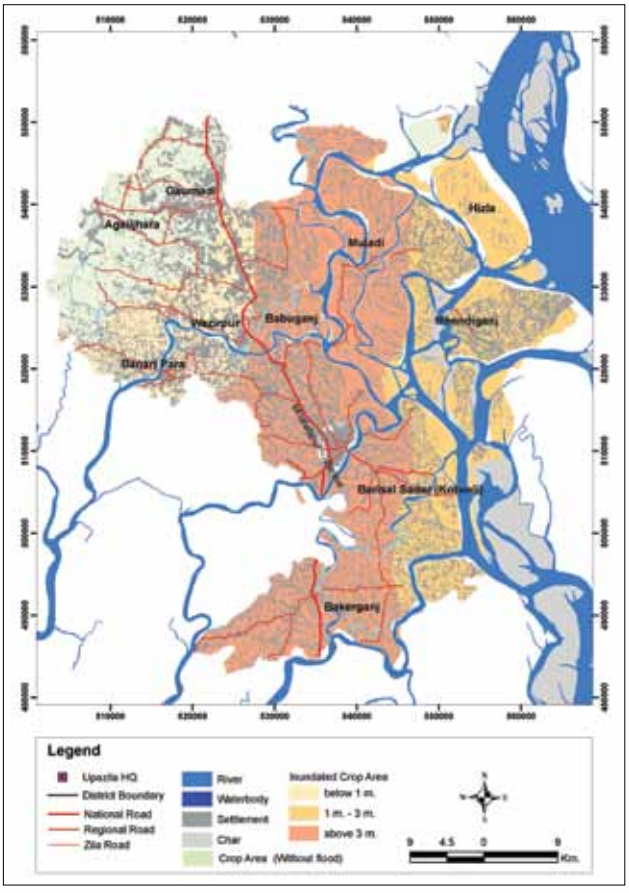
The study results suggest that high yielding rice cultivars in Barisal district are more vulnerable to water stress than local low yielding varieties. For example, in areas where there was 1–3 meters of inundation for 3–7 days, HYV Aman production was on average 20% lower than local paddy production.

It is not surprising that about 41% of the farmers in the district use local Aman during the main *Kharif II* season in high submergence areas, in comparison to 17% of farmers in low submergence areas. In addition, about 57% of farmers in the sample survey indicated a preference for local Aman during the monsoon season. This may also be due to cash constraints and/or flood related uncertainties in the region or even in some cases because of poor drainage within embankment-protected areas.

Helping Farmers to Adapt

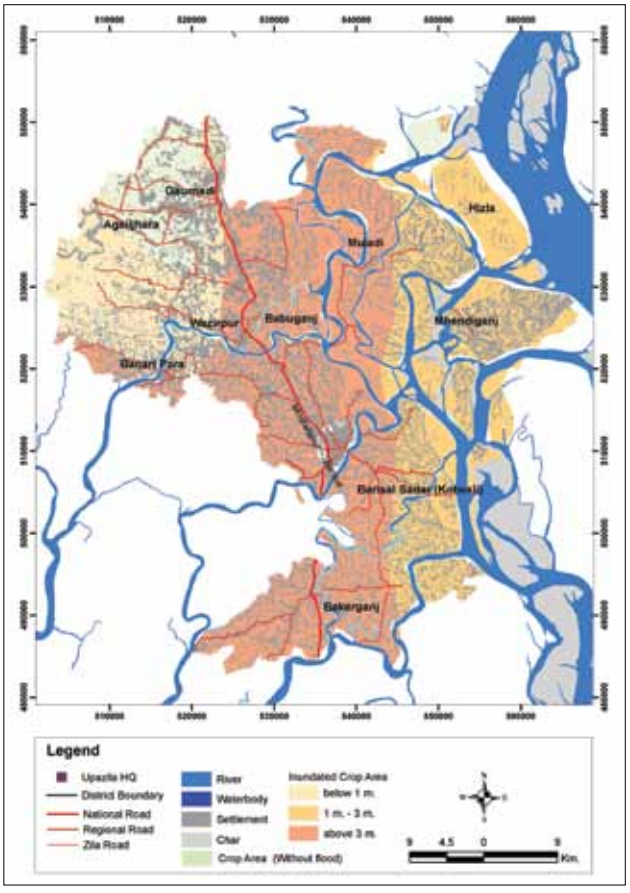
The study concludes that sustainable harvesting in Barisal may be possible with the use of modern submergence-tolerant rice varieties accompanied by proper agricultural management practices. Possible options may be in the pipeline:

Figure 2a: **Inundated Aman cropped area in Barisal District, 2005**



Source: Prepared by CEGIS

Figure 2b: **Predicted Inundated Aman cropped area in Barisal District, 2050**



Source: Prepared by CEGIS

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Author
Afsana Haque
Sarwar Jahan

Editor
Rufus Bellamy

Series Editor
Priya Shyamsundar

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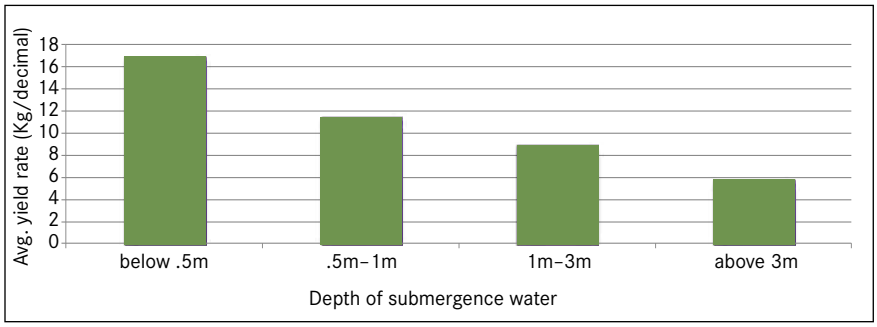

Figure 3: **Average rice yield by depth of submergence water, Barisal district, 2010**

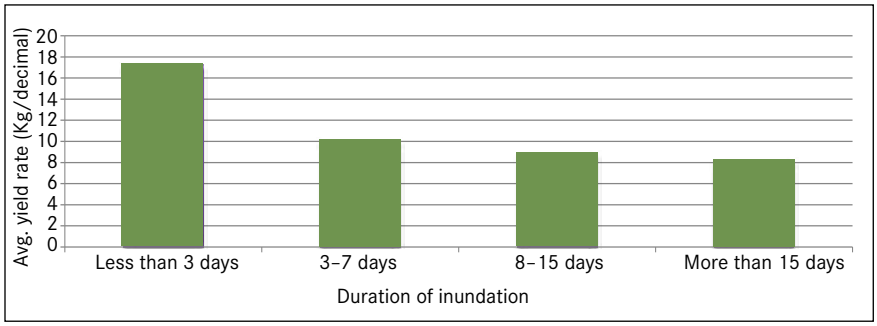

Figure 4: **Average rice yield by duration of inundation, Barisal district, 2010**

In 2010, the Bangladesh Rice Research Institute developed two submergence-tolerant rice varieties, Dhan51 and Dhan52, for flash flood prone areas. Whether these crops will be adopted will depend on the field productivity of these two varieties and on farmers' perceptions.

As well as suggesting the development of more flood-resistant rice cultivars, the study also suggests that policy makers should encourage the development and introduction of low cost water control technologies, such as rain water harvesting and water conservation. Instruments such as micro-credit loans may also be helpful in enabling farmers buy rice varieties that are more resistant to submergence.

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SANDEE | P.O. Box 8975, E.P.C 1056 | Kathmandu, Nepal
Street address: c/o ICIMOD, Khumaltar, Lalitpur, Nepal
Tel: 977 1 5003222, Fax: 977 1 5003299
Email: info@sandeeonline.org Website: www.sandeeonline.org