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# Bio-economic evaluation of cropping systems for saline coastal Bangladesh: III Benefits of adaptation in current and future environments

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ABSTRACT

Climate change and salinisation present substantial challenges to the sustainability of cropping systems in south-west coastal Bangladesh. This is the third paper in a series reporting a study to assess the impacts of climate change and salinity on the productivity and economic viability of ten current and potential rice-based cropping systems in two coastal villages in Khulna District. In this paper, possible adaptations are assessed, including novel dry-season crops, changed fertilizer use, and changed sowing dates, across five climate and three salinity scenarios. Farmers' estimated, APSIM-simulated, and extrapolated yield distributions were incorporated in budgets for the ten cropping systems, using current and projected salinity levels. Current and projected future prices and costs were used to estimate different measures of profitability. Estimated variability in yields and prices was used to generate probability distributions for these profitability measures, permitting comparison of cropping systems based on profitability and risk. Adaptation through changed fertilizer use (higher or lower, depending on the crop) was projected to give higher returns for some cropping systems. However, larger improvements were obtainable with changes in sowing dates to avoid the worst stresses imposed by climate change and salinity. The loss of production of all crops except watermelon and pumpkin due to salinity was more than offset with changed sowing dates for 2030 and 2060 conditions, irrespective of season. With such adaptations, and allowing for risk, the rice/shrimp system maintained the top ranking in terms of net income per hectare in 2030 and 2060 and the rice/sunflower system maintained the second ranking. The rice/pumpkin/rice system ranked third for 2030 and fourth in 2060 while the rice/maize system moved up to third in 2060.

## 1. Introduction

Climate change and salinization present substantial challenges to the sustainability of cropping systems in south-west coastal Bangladesh. This is the third paper in a series reporting a study to assess the impacts of climate change and salinity on the productivity and economic viability of current and potential rice-based cropping systems in two representative coastal villages. The first paper (Kabir et al., 2017a) used biophysical modelling to project crop yields across five climate and three salinity scenarios and the second paper (Kabir et al., 2017b) incorporated these biophysical results into crop budgets to model the economic impacts. In both papers, the modelling assumed a continuation of farmers' current practices (other than the incorporation of new crops). However, there is clear evidence that farmers are already adapting to climate change and salinization, drawing on their own innovations as well as externally-provided technologies (Kabir et al., 2016, 2017c). Hence it is important to incorporate adaptive responses at the farm level in assessing the sustainability of cropping systems. Although, a number of studies have been undertaken on the impacts of climate change on agriculture in Bangladesh (Alam and Ahmed, 2010; Yu et al., 2010; Hussain, 2011; Ruane et al., 2013; Hassan et al., 2014; Lázár et al., 2015), none of these has incorporated possible adaptation options. In this paper, two broad adaptation options are assessed – changes in fertilizer application and changes in sowing dates.

## 2. Methodology

### 2.1. Study locations and cropping systems

Two coastal villages with contrasting farming systems in Dacope Sub-district, Khulna District, were selected for the study – Shaheberabad, cultivating rice in the wet season, non-rice crops in the

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**Table 1**
Cropping systems assessed for Shaheberabad and Uttar Kaminibasia.

| Cropping system | Wet season | Dry season | Early wet season | Status |
|---|---|---|---|---|
| P1 | Rice | Watermelon | Fallow | Existing |
| P2 | Rice | Fallow | Fallow | |
| P3 | Rice | Pumpkin | Fallow | |
| P4 | Rice | Watermelon | Rice | |
| P5 | Rice | Pumpkin | Rice | |
| P6 | Rice/fish | Shrimp | Shrimp | |
| P7 | Rice | Rice | Fallow | Former |
| P8 | Rice | Maize | Fallow | Potential |
| P9 | Rice | Sunflower | Fallow | |
| P10 | Rice | Wheat | Fallow | |

dry season, and some rice in the early wet season, and Uttar Kaminibasia, cultivating rice in the wet season and brackish-water shrimp in the dry season. Details about the villages and methods of farm-level data collection were presented in Kabir et al., 2017b. Secondary data included historical (1984–2013) climate data (daily mean, maximum, and minimum temperatures, precipitation, and radiation) obtained from the Bangladesh Meteorological Department (BMD). Moreover, historical (2004–2014) soil salinity data were obtained from the Soil Resource Development Institute (SRDI), Bangladesh. Ten cropping systems were examined – six existing, one former, and three potential cropping systems (Table 1). These were described in Kabir et al., 2017a. In this paper, each system is reassessed with some possible adaptation options.

### 2.2. Adaptations evaluated

As farmers become aware of changes in climate and salinity, they adapt their cropping systems where possible. There are many ways farmers can adapt their cropping systems:

1. Choice of crop varieties and alternative crops
2. Planting time and cropping season duration of rice and dry-season crops
3. Nutrient management (e.g., fertilizer application rates)
4. Timing, amount, and application method of supplementary irrigation
5. Tillage management (e.g., zero till, strip till, reduced till, or raised beds)

Strategy 1 in the list above has already been systematically evaluated insofar as we explored the feasibility of three new crop rotations (P8 to P10 in Table 1) in the preceding papers (Kabir et al., 2017a,b). In this paper, we expand this to include an evaluation of Strategies 2 and 3. Strategy 4 was not explored because widespread access to irrigation for dry-season cropping is constrained in coastal Bangladesh due to saline groundwater, while Strategy 5 requires investment in new machinery that was considered to make this adaptation less attractive than Strategies 1–3.

Key informants interviewed to help select feasible adaptations mentioned that farmers mostly follow their own experience-based fertilizer management for cropping. Scientists often claim that their recommended fertilizer practices will reduce the yield gap. Hence the effects on crop yields of a 10% and 20% increase in nitrogen application over farmers' practice were simulated, along with the doses recommended by researchers from the Bangladesh Rice Research Institute (BRRI) and the Bangladesh Agricultural Research Institute (BARI) for each crop (Table 2).

Changing the sowing date is already a widely-adopted adaptation to climate change in the case-study villages. The key informants noted that farmers regulate the sowing date of crops in order to fit the cropping system with the shift in wet season based on their own experience. Coastal farmers now usually plant their WS rice crop around 2–3 weeks beyond the sowing date recommended by the BRRI due to their experience of a delay in the WS (Kabir, 2016; Kabir et al., 2017c). However, farmers' reported crop yields were mostly lower than potential yields (Kabir, 2016). Hence yields were simulated for early (15 July), recommended (1–15 August), farmers' practice (1–10 September), and very late (15 September) sowing options. Various sowing options were modelled for EWS rice, DS rice, sunflower, maize, and wheat as shown in Table 2.

The above adaptations were subjected to an analysis across five climate scenarios to assess their current and future technical feasibility, together with an assessment of their current and future economic viability, assuming on-going salinization of the environment as estimated in Kabir et al. (2017a).

### 2.3. Modelling

As described in Kabir et al. (2017a), the Agricultural Production Systems Simulator (APSIM) crop simulation model was used to simulate biomass and grain yields over a 30-year period for both historical and projected future climate and salinity scenarios. Scenarios were developed for 2030 and 2060 based on the IPCC's A1 (pessimistic) and B2 (optimistic) emissions scenarios. The historical simulation outcomes were validated using the farm-level data collected during the case studies. For calibration of crop varieties in this study, the calibrations already used in the Adaptation to Climate Change in Asia (ACCA) project were applied. This process is described in detail in the ACCA Final Report (Van Wensveen et al., 2015) and in Gaydon et al. (2013, 2017). The impact of salinity, in particular on dry season (DS) and early wet season (EWS) crops, was assessed across historical (2004–2014) and two future (2030 and 2060) salinity scenarios as soil and water salinity substantially affect the crops grown in those seasons. However, only the "without-salinity" scenario was developed for wet season (WS) rice as soil and water salinity fall to very low levels in the WS after the

**Table 2**
Adaptation options evaluated through possible planting time and nutrient management of rice and dry season crops.

| Adaptation options | | Crops | | | | | |
|---|---|---|---|---|---|---|---|
| | | WS rice | EWS rice | DS rice | Sunflower | Maize | Wheat |
| Sowing/planting date[a] | Early | 15 Jul | | 15 Nov–25 Dec | | | |
| | Recommended | 1–15 Aug | Mar 15–April | 1–15 Jan | 15 Nov–15 Dec | 15–30 Nov | 15–30 Nov |
| | Late | | | | 15 Dec–15 Jan | 7–21 Dec | 7–15 Dec |
| | Farmers' practice | 1–7 Sep | 1–15 May | 1–15 Feb | 21–30 Jan | 21 Dec–5 Jan | 21 Dec–5 Jan |
| | Very late | 15 Sep | Jun 1 | 28 Feb | 28 Feb-31 Mar | 30 Jan – 28 Feb | |
| | Extreme late | | | Mar–Apr | | 30 Mar–April | 21–30 Jan |
| Nitrogen dose | Recommended dose compared to farmers' practice | 133% increase for P3, P4, and 6% increase for others | 30% increase | 7% increase | 16% decrease | 33% decrease | 8% decrease |

[a] Transplanting date for WS and DS rice,