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Bio-economic evaluation of cropping systems for saline coastal Bangladesh: II. Economic viability in historical and future environments

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ABSTRACT

The objective of this study was to assess the impacts of climate change and salinity on the economic viability of rice-based cropping systems under farmers' current management across current and future climate and salinity scenarios in south-west coastal Bangladesh. Detailed case studies were conducted in two contrasting coastal villages in Dacope Sub-district, Khulna District. Enterprise budgets were developed using APSIM-simulated and extrapolated yields together with crop management, cost, and price data obtained from the villages and estimated from various sources. The projected impact of climate change and salinization on the economic viability (profitability and riskiness) of most cropping systems was not pronounced. Thus rice-based cropping systems are likely to remain viable in both optimistic and pessimistic climate scenarios in coming decades, even allowing for salinization, because some of the positive effects of climate change were projected to offset the sizeable losses due to salinity. Moreover, where small yield declines were projected these were often offset by higher future prices. Sustainably-managed rice/shrimp cropping systems are likely to remain the most profitable option in locations with access to tidal saline water. In other sites, given adequate freshwater for irrigation in the dry season, rice/non-rice cropping systems were projected to be the most viable options, especially incorporating newer crops such as sunflower and maize. Dry-season rice and wheat were not projected to be viable options.

1. Introduction

Climate change and associated environmental change (particularly salinization) are the greatest threats to agricultural sustainability in low-lying coastal regions such as in much of Bangladesh (WB, 2013b). The sustainability of rice-based farming systems in the coastal districts is expected to be highly challenged by both internal constraints (e.g., existing farming practices, households' adaptive capacity, and socio-economic features of the farming population) and external shocks and trends (e.g., climate change and variability, sea-level rise, cyclones, floods, and salinity intrusion) (Agrawala et al., 2003; BBS, 2014; IPCC, 2014; MoEF, 2009; WB, 2013b; Yu et al., 2010). An assessment of the current viability and future sustainability of cropping systems in the coastal zone will contribute to developing policies and practices to strengthen the resilience of vulnerable coastal communities.

Conducting such an assessment under current conditions is a formidable task, let alone under projected long-term climate and environmental change. A number of biophysical modelling studies have applied cropping systems models to estimate the sensitivity of rice and wheat productivity to projected changes in temperature, precipitation, and atmospheric carbon dioxide, based on generic farming practices (Alam and Ahmed, 2010; Hassan et al., 2014; Hussain, 2011; Lázár et al., 2015; Ruane et al., 2013; Yu et al., 2010). However, the viability and sustainabilty of agriculture in the coastal zone depends not only on biophysical responses but also on the economic returns to alternative cropping options. Moreover, sustainability is a forward-looking concept, requiring projections of future trends in key indicators.The integration of expert opinion (of both farmers and scientists) and the careful use of biophysical simulation to underpin projections of economic outcomes can help to quantify the trade-offs between profitability, risk, and long-term (i.e., decades-long) persistence of agricultural systems.

Previous economic studies of cropping systems in coastal Bangladesh (Ahmed et al., 2010; Azad et al., 2009; Gain et al., 2015; Kanij and Miah, 2011; Karim et al., 2014; Rahman et al., 2011) have focused on the impacts of brackish-water shrimp farming on profitability, food security, and salinity intrusion. Some have assessed the profitability of integrated rice-fish/shrimp systems relative to shrimp

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farming alone. Other studies (Ahmed and Garnett, 2010; Ali, 2006; Chowdhury et al., 2010; Rasul and Thapa, 2004; Sabiha et al., 2016) have assessed the economic viability of coastal agriculture through enterprise budgeting based mostly on tabular analysis of cross-sectional data. None of the previous studies has incorporated crop simulation or conducted scenario analysis to assess the effects of climate change and salinization on the productivity, profitability, and risks to current and potential future cropping systems.

The first paper in this series (Kabir et al., 2017a) incorporated biophysical modelling of 10 cropping systems under five climate scenarios – historical (1984–2013), 2030 pessimistic (A2), 2030 optimistic (B1), 2060 pessimistic (A2), and 2060 optimistic (B1) – and three salinity scenarios – historical (2004–2014), 2030, and 2060. The details of these scenarios are given in that paper. The modelling, using the Agricultural Production Systems Simulator (APSIM) and extrapolation techniques, indicated that the net effect of climate and salinity change on most crops was not projected to be severe for forecast 2030 and 2060 conditions. This is because the adverse effects of increased salinity and rising temperature were partly or wholly offset by the beneficial effects of increased CO_2 and precipitation. However, the yield loss of most crops due to salinity alone was substantial under both historical and future climates. In this paper we present an economic analysis of the viability of the 10 cropping systems simulated (Table 1), building on the outputs of the biophysical modelling and extrapolations presented in Kabir et al. (Kabir et al., 2017a) and assuming farmers' current management practices (Kabir et al., 2016). The third paper in the series (Kabir et al. 2017b) analyses the economic impacts of climate change and salinity assuming adaptive responses at the farm level.

2. Methodology

2.1. Study locations and data collection

Two coastal villages with contrasting farming systems were selected for this study – Shaheberabad and Uttar Kaminibasia in Dacope Sub-district, Khulna District (Fig. 1). Between them, the two villages encompass the main types of farming that are currently practised in the south-western coastal zone. In Shaheberabad, arable land was intensively used for wet-season (WS) rice and dry-season (DS) non-rice cropping because of low levels of salinity, the availability of freshwater irrigation for DS cropping, and better access to extension services and markets. In Uttar Kaminibasia farmers practised WS rice/fish farming and brackish-water shrimp farming in the DS due to high levels of salinity with no fresh water for irrigation. This village had better access to tidal water throughout the year but poorer access to markets and extension services. Farm-level data were collected through 18 key informant interviews, interviews with a local expert panel, and collection of soil and water samples for laboratory analysis. The fieldwork was conducted during February–March 2013 and May–December 2014. Secondary data included historical (1984–2013) climate data (daily mean, maximum, and minimum temperatures, precipitation, and radiation) obtained from the Bangladesh Meteorological Department (BMD). Full details are reported in Kabir (Kabir, 2016).

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	

Kabir et al. (Kabir et al., 2017a). Note: Only the cropping system P6 (rice/fish-shrimp) is practised in Uttar Kaminibaisa.

2.2. Budgeting

A sustainable cropping system must be economically viable. There are multiple economic tools available to assess the profitability of cropping systems (Dillon, 2003). In this study, representative enterprise budgets were prepared using data obtained from the case-study villages; these budgets were subjected to risk analysis. There are various ways to specify costs and returns in a farm enterprise. The approach used here follows Herdt (Herdt, 1978), emphasising the distinction between "paid-out costs" for purchased inputs and "unpaid costs" for family-supplied inputs, including family labour. Herdt (Herdt, 1978) specifies enterprise returns as "gross benefit (GB)" (the market value of products and by-products), "gross income (GI)" (gross benefit less paid-out costs) and "net income (NI)" (gross income less the imputed value of unpaid costs). Total paid-out costs (TPC) sums the cost of purchased inputs and total imputed cost (TIC) sums the costs of family-supplied inputs. These measures focus on the return to the family's resources used in farming as well as indicating the welfare of the farm family. Hence they accord well with the goals and circumstances of small farmers in the study region.

The APSIM-simulated typical seasonal yields of WS rice, DS rice, early wet-season (EWS) rice, maize, sunflower and wheat were used across the five climate and three salinity scenarios. For watermelon, pumpkin, shrimp, and fish, farmers' estimated and extrapolated typical seasonal yields were used as APSIM is incapable of modelling these crops. For the purposes of this analysis, the two case-study villages were treated as one combined setting, with suitable environments for either shrimp farming or irrigated cropping in the dry season. Similarly, only one intermediate farm size was considered (1 ha) which was close to the mean farm size in the two villages.

The projection of future prices and costs was not straightforward, given highly complex interactions involving many variables apart from climate change and salinity. Hence future prices of the modelled crops and costs of the major farm inputs (labour, fuel, and fertilizer) were estimated as well as possible through an examination of secondary sources. Farmers' estimated average input costs and output prices were used for the historical scenario. The estimation of future prices and costs is described below.

2.3. Estimation of future output prices

The International Food Policy Research Institute (IFPRI) has projected that demand for food crops is likely to increase between 70 and 100% by 2050 due to growing population and increased incomes (Nelson et al., 2010). Moreover, the increased demand for livestock feed and biofuel production will add further to the growth in demand for food crops. Use for biofuels already accounted for about 20% of sugarcane output, 9% of vegetable oil and coarse grains output, and 4% of sugar-beet output during 2007–2009 (FAO et al., 2011). Furthermore, climate change is expected to be a barrier to increased food production in many environments. Thus, prices of agricultural commodities are likely to follow an upward trend as the growth in demand outpaces the growth in supply (Nelson et al., 2010).

Price changes in agricultural markets are not intrinsically greater than in other markets but the projection of prices in the long run is fraught with difficulty and estimates vary widely (FAO et al., 2011). However, IFPRI has projected the major cereal prices in 2050 through detailed analysis of global agricultural prospects, quantitative scenarios of economic and demographic futures, and the threats posed by climate change (Nelson et al., 2010). They applied a global agricultural supply-and-demand projection model (IMPACT 2009) linked to a biophysical