Agricultural Systems 162 (2018) 107–122

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

# Bio-economic evaluation of cropping systems for saline coastal Bangladesh: I. Biophysical simulation in historical and future environments

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ARTICLE INFO

*Keywords:*
Coastal zone
Cropping system
Sustainability
Climate change
Salinization
Crop simulation

ABSTRACT

Climate change, increased climate variability, extreme weather events, and increasing salinization pose a serious challenge to the sustainability of crop production in coastal Bangladesh. This study assessed yield performance of rice and non-rice crops under farmers' current practices across five climate and three salinity scenarios in the south-western coastal zone. Representative village case studies in Khulna District were used to obtain data on current cropping practices and yields. A validated biophysical crop simulation model (APSIM) was used to simulate performance of crops within 10 cropping systems, representing both existing and potential future cropping patterns. The salinity impact on rice crops was simulated directly using an improved APSIM model, capable of simulating both soil salinity dynamics and the resulting rice crop response. The salinity impact on maize, wheat and sunflower was assessed by developing crop salinity response functions and applying these post-simulation to the crop yields simulated in the absence of salinity. The future performance of some existing crops, namely, watermelon, and pumpkin were extrapolated from data available in the literature and expert knowledge. Climate change is projected to have both positive and negative impacts on crop yields but growing salinity is projected to have substantial negative effects. Allowing for uncertainties inherent in the modelling process, the results indicate that loss of crop production would be negligible under projected 2030 conditions for climate and salinity, even with farmers' current practices. Under 2060 conditions, the adverse impacts on wet-season rice, dry-season rice, and wheat remained negligible, while sunflower experienced notable yield decline. However, the effects of 2060 conditions on early wet season rice and dry-season maize were positive. Climate change in itself does not pose a major risk to crop production and aquaculture in south-west coastal Bangladesh over the next 15–45 years but increasingly salinity will have an unambiguously negative influence.

## 1. Introduction

The coastal zone of Bangladesh covers about 32% (47,551 km$^2$) of the total area of Bangladesh (Fig. 1) (BBS, 2016). In common with the other major river deltas and food baskets of South and South East Asia, such as the Irrawaddy, Chao Praya, and Mekong systems, climate change and salinization are the two biggest environmental challenges to sustainable agriculture in the coastal zone of Bangladesh (Wassmann et al., 2009; Mainuddin et al., 2013; Brammer, 2014; Dasgupta et al., 2015; Kabir et al., 2016). Though obviously interrelated, they are partly independent phenomena; even in the absence of further climate change, salinity may go on increasing. Of the total area of cultivated land in the coastal region (1,689,000 ha), about 63% (1,056,000 ha) is affected by various degrees of salinity (SRDI, 2012). From 1973 to 2009, 223,000 ha of non-saline land became affected by salinity (SRDI, 2012). Salinity intrusion will be further elevated during the current century due to sea-level rise (Agrawala et al., 2003; WB, 2013). The coastal systems of low-lying developing countries like Bangladesh are increasingly expected to face adverse impacts including damage to infrastructure, submergence, flooding, and erosion due to sea-level rise in the 21st century and beyond (IPCC, 2014a). The sea-level rise at the Bangladesh coast is likely to be about 0.1 m by 2020 and 0.25 m by 2050 compared with the base year (2000), resulting in inundation of 4% of agricultural and non-agricultural land by 2050 (Agrawala et al., 2003). The livelihoods of about 38.5 M coastal dwellers in Bangladesh – whether engaged in cropping, livestock rearing, aquaculture, or non-

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https://doi.org/10.1016/j.agsy.2018.01.027
Received 19 February 2017; Received in revised form 24 January 2018; Accepted 30 January 2018

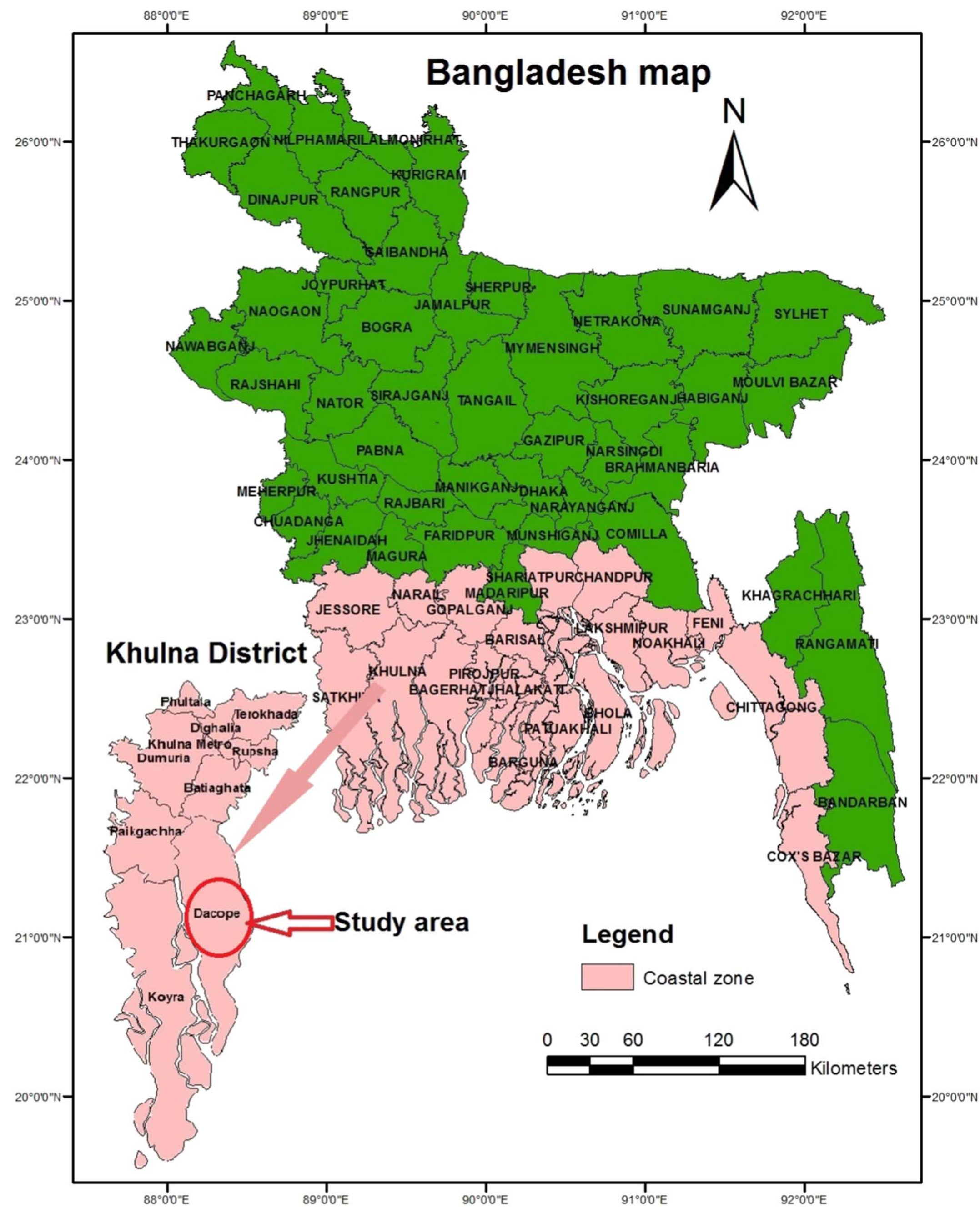


**Fig. 1.** Bangladesh and Khulna District map (study location is circled), prepared by Agricultural Statistics Division, Bangladesh Rice Research Institute.

farm activities – will be seriously affected by these projected changes in climate and environment (Agrawala et al., 2003; BBS, 2011; WB, 2013; Habiba et al., 2014).

A number of studies have been undertaken on the impacts of climate change on agriculture in Bangladesh. Previous studies have applied cropping systems models such as DSSAT (Yu et al., 2010; Alam and Ahmed, 2010; Basak et al., 2010; Hussain, 2011; Ruane et al., 2013), CROPWAT (Roy et al., 2009; Lázár et al., 2015), ORYZA (Mohandass et al., 1995; Karim et al., 2012; Timsina et al., 2016), CERES (Faisal and Parveen, 2004; Ruane et al., 2013), DCGE (Thurlow et al., 2012), regression models (Sarker et al., 2012), systematic review and meta-analysis (Wassmann et al., 2009; Challinor et al., 2014) and Aquacrop (Maniruzzaman et al., 2015; Mondal et al., 2015a) to estimate the sensitivity of rice and wheat productivity to projected temperature, precipitation, and atmospheric carbon dioxide, based on generic farming practices. A common limitation of these studies is that they tend to assess impacts on individual crops in isolation from interactions with other crops in a cropping system. They also largely fail to capture farm-specific contexts and actual farmer practice, making the modelling results insensitive to adaptation options.

The APSIM model (Holzworth et al., 2014) overcomes these limitations, and in recent years APSIM has seen more widespread use to model the impact of climate change on rice-based cropping systems in Asia (e.g. Gaydon et al., 2014b, 2017; Hochman et al., 2017a, 2017b; Poulton et al., 2016). APSIM's ability to model salinity dynamics in rice is a very new development (Radanielson et al., 2018), a feature that other models are lacking, so there are limited modelling studies on the impact of salinity on rice-based cropping systems.

In summary, there is a lack of reports that assess the combined impacts of climate and salinity change on cropping system performance from both yield and economic perspectives, under farmers' current management practices and/or with adaptive responses at the farm