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Multi-factor impact analysis of agricultural production in Bangladesh with climate change

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A B S T R A C T

Diverse vulnerabilities of Bangladesh's agricultural sector in 16 sub-regions are assessed using experiments designed to investigate climate impact factors in isolation and in combination. Climate information from a suite of global climate models (GCMs) is used to drive models assessing the agricultural impact of changes in temperature, precipitation, carbon dioxide concentrations, river floods, and sea level rise for the 2040–2069 period in comparison to a historical baseline. Using the multi-factor impacts analysis framework developed in Yu et al. (2010), this study provides new sub-regional vulnerability analyses and quantifies key uncertainties in climate and production. Rice (*aman*, *boro*, and *aus* seasons) and wheat production are simulated in each sub-region using the biophysical Crop Environment REsource Synthesis (CERES) models. These simulations are then combined with the MIKE BASIN hydrologic model for river floods in the Ganges-Brahmaputra-Meghna (GBM) Basins, and the MIKE21 Two-Dimensional Estuary Model to determine coastal inundation under conditions of higher mean sea level. The impacts of each factor depend on GCM configurations, emissions pathways, sub-regions, and particular seasons and crops. Temperature increases generally reduce production across all scenarios. Precipitation changes can have either a positive or a negative impact, with a high degree of uncertainty across GCMs. Carbon dioxide impacts on crop production are positive and depend on the emissions pathway. Increasing river flood areas reduce production in affected sub-regions. Precipitation uncertainties from different GCMs and emissions scenarios are reduced when integrated across the large GBM Basins' hydrology. Agriculture in Southern Bangladesh is severely affected by sea level rise even when cyclonic surges are not fully considered, with impacts increasing under the higher emissions scenario.

1. Introduction

Bangladesh (Fig. 1) lies on mostly flat, alluvial land at the mouth of the Ganges-Brahmaputra-Meghna (GBM) Basins that drain monsoon runoff from a large portion of South Asia, and is widely recognized as a country with high sensitivity to climate variability and change. Bangladesh uses more than 70% of its land for agricultural purposes (FAOSTAT, 2009), often with multiple cropping seasons, and nearly all of the remainder is covered by forests, settlements, roads and waterways (MPO, 1986). Bangladesh also has high population density, with a current population equivalent to half of the population of the United States living in an area the size of the state of Iowa. Long-term climate threats include a changing distribution of river floods, sea level rise in the Bay of Bengal, warming temperatures, and changing rainfall patterns, which can exacerbate current vulnerability to climate extremes and variations and pose a substantial challenge in producing enough food for a growing and developing population (Huq, 2001; Huq et al., 2003; Parry et al., 2004; Asada and

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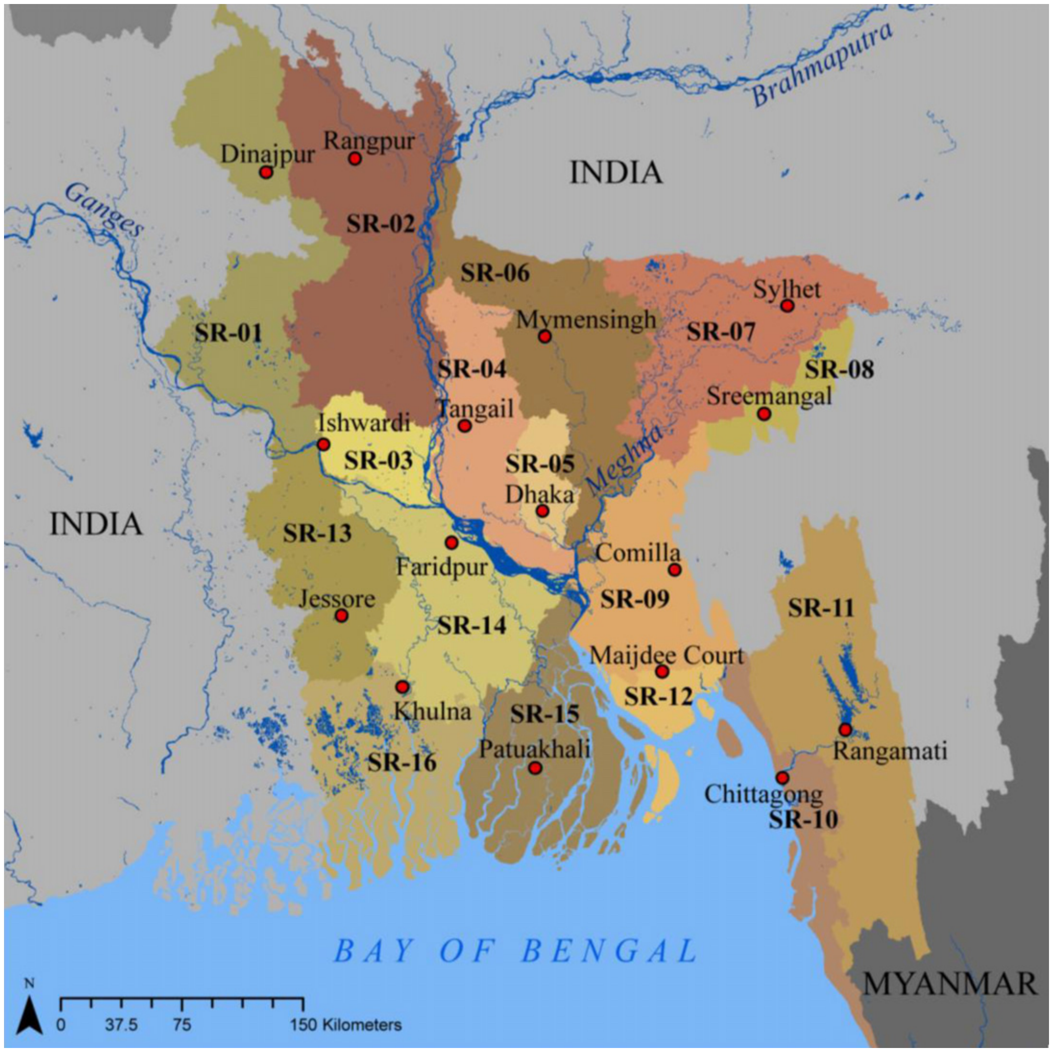

Fig. 1. Bangladesh sub-regions as defined for this study, with sentinel weather stations and major rivers.

Matsumoto, 2009). A beneficial climate impact comes from a key driver of global climate change, as elevated carbon dioxide (CO_2) concentrations enhance photosynthetic production and water efficiency in crops to a limited extent (Easterling et al., 2007; Fleischer et al., 2010; Kimball, 2010). These processes are among the complex challenges facing farmers in Bangladesh, and the experiments presented in this study elucidate the agricultural responses to projected climate conditions that are unprecedented in recent history.

Bangladesh's precarious position with respect to climate change has elevated awareness of national vulnerabilities both domestically and internationally. There have been numerous studies of climate change impacts in Bangladesh, but they have provided climate projections without quantifying agricultural impacts or tended to examine just a subset of the impact factors that are inter-compared and combined here. Rahman et al. (2009) conducted a comprehensive overview of climate change projections for temperature, rainfall, river floods, and sea level rise for various Bangladeshi sub-regions and identified adaptation strategies geared to particular impact factors and vulnerabilities from interviews and stakeholder workshops. Similar climate change impact reviews are provided by Agrawala et al. (2003), Ahmed (2006), and Tanner et al. (2007). Other studies of climate change impacts on Bangladeshi rice have focused primarily on coastal flooding impacts (Ali, 1999; Sarwar, 2005), temperature and carbon dioxide effects (Karim et al., 1994, 1998; Timsina et al., 1997; Mahmood, 1997, 1998; Timsina and Humphreys, 2006; Basak et al., 2009), or river flood impacts (Hassan et al., 2008). Much work has also been done to identify and test adaptation strategies (Huq et al., 1999; Ministry of Environment and Forests, 2005; Adger et al., 2007; Thomalla et al., 2005; Ayers and Forsyth, 2009; Rahman et al., 2009), and in 2009 the Government of Bangladesh released its Climate Change Strategy and Adaptation Plan (Ministry of Environment and Forests, 2009).

Government programs (including the construction of embankments and coastal protection), private enterprise (including the expansion of electrified pump-irrigation systems), crop breeders (developing drought, flood, or salinity resistant seeds), small farmholders (changing planting dates and/or farm management practices) and international partners (e.g. the World Bank, The Global Environmental Facility) all have roles to play to build efficient climate resilience and adaptive capacity. For a list of past and present programs on adaptation in the agricultural sector, see Table 7.1 of Yu et al. (2010). Funds are limited, however, so major adaptation programs must be carefully prioritized to maximize utility.

This study aims to identify the critical climate factors and associated uncertainties in agricultural impacts for each of 16 sub-regions in Bangladesh in order to form a basis for prioritizing adaptation measures. The impacts of changes in temperature, precipitation, CO_2 concentration, river flooding, and sea level rise on agricultural production are investigated through simulations