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Research paper

Combined deficit irrigation and soil fertility management on different soil textures to improve wheat yield in drought-prone Bangladesh

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ABSTRACT

Proper utilization of water resources is very important in agro-based and drought-prone Bangladesh. Sustainable use of water resources in agriculture requires irrigation schedules based on local environmental conditions, soil type and water availability. In this study, the water productivity model AquaCrop was used to simulate different water and fertilizer management strategies in a drought prone area of Bangladesh to obtain management recommendations. First, the Standardised Precipitation Index (SPI) and Reconnaissance Drought Index (RDI) were determined to quantify the aggregated deficit between precipitation and the evaporative demand of the atmosphere, which confirm that meteorological drought is occurring frequently in the study area. Also, the AquaCrop model was successfully calibrated and validated for wheat in the area, which was confirmed by the several statistical indicators, and could be used to design water and fertilizer management strategies. Simulations identified stem elongation (jointing) to booting and flowering stage as the most water sensitive stages for wheat. Deficit irrigation during the most water sensitive stages could increase the interannual yield stability and the grain yield compared to rainfed conditions for different soil fertility levels on loamy and sandy soils by 21–136% and 11–71%, respectively, while it could increase water productivity compared to full irrigation strategies. Deficit irrigation resulted in grain yields almost equal to yields under full irrigation and could at the same time save 121–197 mm of water per growing season. Specifically, we suggest two irrigation applications: one at the stem elongation (jointing) to booting stage and another at the flowering stage for loamy soils; and one at the end of seedling development to the beginning of crown root initiation stage and another at the flowering stage for sandy soils. Given the water scarcity in the region, instead of optimal fertility levels, moderate fertility levels are recommended that result in 60% of the potential biomass production for loamy soils and in 50% for sandy soils in combination with the suggested deficit irrigation strategies.

1. Introduction

Proper utilization of water resources is very important in agro-based Bangladesh. The fresh water sources in Bangladesh are under threat. Annual average rainfall in Bangladesh is about 2300 mm. Yet, rainfall is not uniformly distributed over the year. About 85–90% of the annual total occurs between May and October. Only 10% of the annual rainfall falls in other months (Fig. 1), with acute water scarcity problems during this dry season. Drought, which can be defined as a temporary decrease in water availability over a significant period of time, is occurring frequently in the study area. Bangladesh has faced severe droughts in more than one year out of five since its independence in 1971, causing a substantial reduction in food production (Habiba et al., 2012).

Studies have shown that global warming might result in a temperature increase (about 2–4 °C globally) and climatic changes including a shift in rainfall that may increase the frequency and/or intensity of droughts affecting the region (Solomon, 2007; Sterl et al., 2008). A recent study has shown that climate change has a negative impact on evapotranspiration, runoff and groundwater levels in Bangladesh (Kirby et al., 2016). On the other hand, the population growth rate in Bangladesh (1.37% every year) is perilous today (BBS, 2011a,b). Due to the rapid population growth, the demand for water for different sectors has increased substantially resulting in even more pressure on available water resources. As water resources in general and water resources allocated for agriculture are decreasing, it is important to increase crop water

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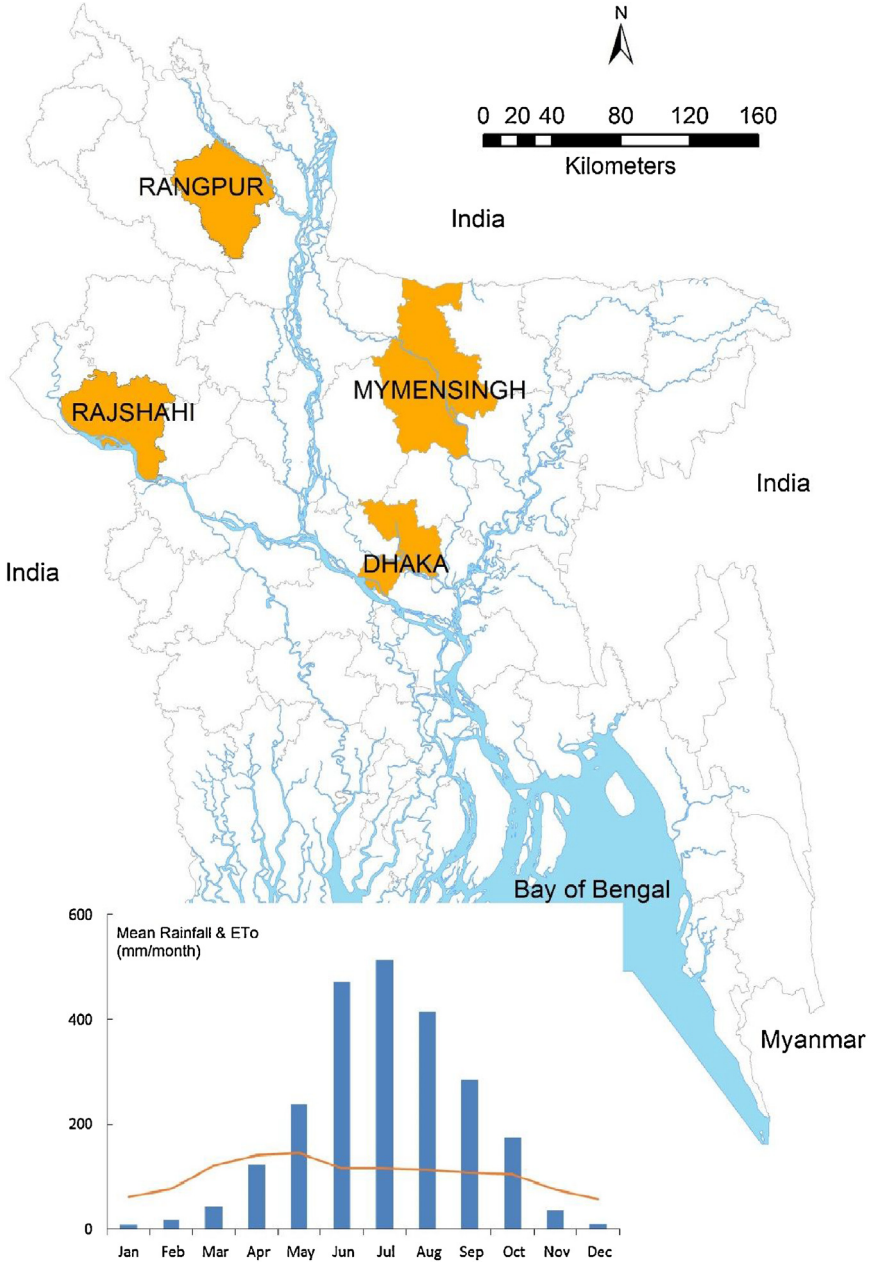

Fig. 1. Study area with indication of selected districts. Mean monthly rainfall (bars) and ET_0 (lines) of Bangladesh considering 29 climatic stations (data from FAOClim2).

productivity (i.e. the amount of yield produces per unit of water consumed) to provide food for the growing population (Kijne et al., 2003) and thus use irrigation water more efficiently.

Given that rainfall is not uniformly distributed over the year, irrigated agriculture relies strongly on groundwater in Bangladesh, particularly during the dry season. About 68.5% of irrigation water and almost 95% of drinking water comes from groundwater sources in Bangladesh (World Bank, 2000). The use of groundwater for irrigated agriculture has increased from 41% in 1982–1983 to 80% in 2009–2010 (BADC, 2010). However, overexploitation of groundwater for irrigation causes groundwater level decline in the study area (Mustafa et al., 2017; Shahid and Hazarika, 2010). Hence, efficient irrigation management is essential to reduce the growing pressure on groundwater resources and ensure sustainable water management.

Timely application of irrigation water can avoid over-and under-irrigation, hence guaranteeing more optimal growing conditions throughout the season and increasing water productivity (Raes et al., 2006; Zwart and Bastiaanssen, 2004). Irrigation schedules based on local environmental conditions, crop and soil type allow more sustainable use of water resources in agriculture. Such irrigation schedules help the farmer to apply the required amount of water to a particular crop at the appropriate time and ensure sustainable agricultural water management (Hill and Allen, 1996; Raes et al., 2000). Deficit irrigation, where water is applied below full crop-water requirements, is one of the promising irrigation strategies to achieve the goal of reducing irrigation water use while maintaining acceptable crop yield (Ali and Talukder, 2008; Behera and Panda, 2009; Fereres and Soriano, 2007; Geerts and Raes, 2009; Pereira et al., 2002).

Studies using field experiments have been conducted to identify the effect of deficit irrigation on wheat yield and water productivity in Bangladesh and have suggested different numbers of irrigation in different locations of the country (Ali et al., 2007; Hassan et al.,