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Determinants and implications of crop production loss: An empirical exploration using ordered probit analysis

Zeenatul Islam[a], Mohammad Alauddin[b,*], Md. Abdur Rashid Sarker[a]

[a] Department of Economics, University of Rajshahi, Rajshahi, 6205, Bangladesh
[b] School of Economics, The University of Queensland, Brisbane, Qld., 4072, Australia

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ABSTRACT

This study investigates farmers' perception about the severity of loss for three rice crops, identifies their determinants and explores policy implications based on findings. This research employs an ordered probit model to data collected from 1800 farm households from drought-prone and groundwater depleted areas of Bangladesh. This is the first study of its kind.

Severity of rice production loss, while differing across all three rice crops, was higher for rain-fed crops. This was broadly consistent with available independent evidence. Geophysical factors, household characteristics, institutional and market accessibility, and household adaptation strategy were key determinants of crop loss. The impact of these factors was specific to the crop and severity of loss.

This study has several policy implications involving market, R & D and institutional support based options. Strengthening support systems for institutional and market accessibility, and science driven climate change adaptation strategy including generation and wider dissemination of drought tolerant rice varieties, and enhancing farmers' capacity to change rice varieties on a regular basis, constitute key areas for policy intervention.

1. Introduction

Bangladesh launched her Seventh Five Year Plan (2016–2020)[1] in 2015 that envisioned GDP growth acceleration with environmental sustainability (GoB, 2015a,b). However, hurdles that Bangladesh confronted in the preceding decade or so include disaster preparedness and management, and adaptation measures fighting climate extreme events including droughts, floods, cyclones, sea level rise, salinity and soil erosion that hit Bangladesh with increasing severity and frequency (Majumder, 2013; Sarker et al., 2013b).

Rice, the dominant crop in Bangladesh, accounts for more than 90% of total cereal production covering 75% of Bangladesh's total cropped area (BBS, 2016; GoB, 2016). In the production year 2014–15, *boro* (winter-early summer, also known as *rabi*) rice accounted for 55%, while *aus* (summer-early monsoon, also known as *kharif 1*)rice and *aman* (monsoon-late autumn, also known as *kharif 2*) rice respectively contributed 7% and 38% of total rice production (BBS, 2016). *Aman* (mainly transplanted *aman* or T. *aman*) is a rain-fed rice crop while *boro* rice is a completely irrigated crop with an extremely high dependence on groundwater (Alauddin and Sharma, 2013; Qureshi et al., 2014). *Aus*, is both directly seeded and transplanted under rain-fed or limited irrigated conditions and grown in the very hot summer season (Rahman et al., 2009).

Insufficient rainfall leads to greater drought frequency and intensity, while increased evaporation increases the chance of complete crop failure (Liu et al., 2010; Reid et al., 2007). Of all climate change extremes, drought is not only the most widespread but also most damaging of all environmental stresses such as salinity, submergence pests and diseases. According to an IRRI (International Rice Research Institute) estimate, droughts affect 23 million hectares of rain-fed rice in South and Southeast Asia and in some Indian states, droughts can cause 40% yield loss (IRRI, 2016).

Moreover, droughts can occur at any point or for any length of time during crop production and affect a wide range of physiological, biochemical and molecular processes. These complexities and the attendant uncertainty in timing of drought occurrence, intensity and duration pose formidable challenges for the scientific community. Increased temperature, variable rainfall, stronger storms, heat and cold waves, shifting of seasons, and groundwater depletion are regular phenomena arresting expected agricultural yields, undermining food security and ensuing health complexities and casualties (Rahman and Lateh, 2016a; Dey et al., 2012; Hijioka et al., 2014; Zhang et al., 2017). Nelson et al.

* Corresponding author.
E-mail address: m.alauddin@uq.edu.au (M. Alauddin).

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(2009) predicted production losses of 14%, 44–45% and 9–19% respectively for rice, wheat and maize relative to the no-climate-change scenario in the South Asian context (see also Bandara and Cai, 2014).

Of the 13 severe droughts that hit Bangladesh in the four decades to 2010, the ones occurring since the 1990s may be linked to climate change. Furthermore, recent years have witnessed increased frequency and severity of droughts (Rahman and Lateh, 2016b). Earlier studies reported that droughts affected nearly 50% of the land area (Ahmed, 2006; Shahid and Behrawan, 2008). It is projected that by 2050, the Barind Tract[2] will be at greater risk of droughts, as a result of a potential temperature increase of 2 °C and a 10% decrease in rainfall. Temperature increase and rainfall reduction with increased variability further induce groundwater depletion with ramifications for irrigation water availability for crop production.

Climate change generally entails changes in two major climate variables: temperature and rainfall. The increase in temperature shortens the phenological phases of crops including planting, flowering and harvesting (Liu et al., 2010; Roudier et al., 2011; Teixeira et al., 2011) and affects plant growth and development. The photosynthesis rate of rice is at a maximum in the 20–32 °Ctemperature range. Even a moderate increase of 1–2 °C is likely to have an adverse impact on cereal yields (Schellnhuber et al., 2013). Fluctuations and occurrence of extreme climate events reduce rice yields significantly, particularly at critical crop growth stages (Alauddin and Hossain, 2001; Lansigan et al., 2000; Teixeira et al., 2011). Bangladesh experienced rising temperature, particularly during monsoon, over the past three decades (UNDP, 2009) and is likely to experience an increase in overall average temperature up to1 °C by 2030 and 1.4 °C by 2050 (FAO, 2006; IPCC, 2007).

Rainfall in Bangladesh has recently become highly variable and has demonstrated an increasingly uneven distribution although the total annual rainfall remains almost the same. This erratic behaviour of rainfall produces noticeable adverse impacts on rice yields. Moreover, the variability and seasonality of monsoon rainfall further affect groundwater recharge during the wet season and may lead to increased exploitation during dry season (Schellnhuber et al., 2013; Schellnhuber et al., 2013; Alauddin and Quiggin, 2008). Alauddin and Sharma (2013) found a two-way causation between mean groundwater depth and percentage of total area irrigated from groundwater sources in 10 of the 21 (greater) districts representing nearly half of Bangladesh's cropped area. Hasan et al. (2016) using long-term Bangladeshi district-level panel data found the existing high yielding varieties (HYVs) of *aman* and *boro* rice crops to have lower capacity to cope with climate variability than traditional varieties (TVs).

Empirical studies (Bradshaw et al., 2004; Reid et al., 2007) emphasize the importance of adaptation measures in combating these adverse sequels of climate change to ensure food security. A number of studies focused on the determinants of farmers' adaptation strategies and adaptive decisions to cope with climate change impacts (e.g., Abid et al., 2016; Alauddin and Sarker, 2014; Bahinipati and Venkatachalam, 2015; Chalise and Naranpanawa, 2016; Wang et al., 2015). As a prelude to the assessment of adaptation strategies, it is critically important to investigate how farmers perceive production losses and choose to adopt appropriate measures and assess their effectiveness given that rain-fed crops are most vulnerable to climate change and invariably face higher potential production losses.

Against the above background, this study investigates farmers' perception about the severity of loss for three rice crops (*aman*, *aus* and *boro*), identifies their determinants and explores policy implications. This research employs an ordered probit model to data from 1800 farm households from nine drought-prone and groundwater depleted areas from eight districts of Bangladesh. The remainder of the paper is organized as follows. Section 2 provides a review of the relevant literature. Section 3 explains materials and method while Section 4 presents and discusses empirical results. Section 5 provides conclusions and explores policy implications.

2. Review of literature

A number of studies examined the economic impact of climate change on agricultural production in the context of developing countries (Chang, 2002; Deressa and Hassan, 2009; Gbetibouo and Hassan, 2005; Haim et al., 2008; Kabubo-Mariara and Karanja, 2007; Kurukulasuriya and Ajwad, 2007; Lansigan et al., 2000; Molua, 2009; Sanghi and Mendelsohn, 2008; Wang et al., 2009). Studies on the impact of climate change on Bangladesh agriculture have focused on assessing the impact of climate variables on rice productivity or farmers' adaptation strategies to reduce crop damage.

UNDP (2007) and, UNDP and GoB (2009) reported an *aman* rice crop production loss of 20–30% from the 2006 drought in the northwestern region of Bangladesh. BBS (2015) reported a 48% loss in the agriculture sector including crops, livestock and fishery and a crop loss of 36.2% due to climate change during the 2009–2014 periods. Mottaleb et al. (2015) estimated an income decline of 9% of the shares of *aman* and *aus* rice crops in total income in the decade since 2000.

Rimi et al. (2009) analyzed trends in climate variables for the 1950–2006 period and observed that the yields of *aus*, *aman* and *boro* rice crops were adversely affected by the rise in temperature, unpredictable rainfall, flooding, drought and salinity. Basak et al. (2010) assessed the impacts on the yields of BR3 and BR14 varieties of *boro* rice in 12 districts. Their model predicted an average yield reduction of over 20% for the two rice varieties in 2050 and 50% in 2070. Yu et al. (2010) estimated an average of 7.4% reduction in long-term rice production every year during the simulation period of 2005–2050. This result showed a reduction in *aman* and *aus* rice production in all sub-regions. Paul (1998) reported that the drought occurrence of 1994–95 adversely affected 15 distinct crops. The two most important crops were *aman* and *aus* rice respectively on average by 75% and 65%. Note that these two rice crops in 1994-95 accounted for 64% of the total rice crop in the study districts of greater Rangpur and Dinajpur (BBS, 2008).

Ahmed and Chowdhury (2006) examined local people's perceptions about past and present climate change and its consequences on rural livelihoods in two drought-prone districts, CHAPAI NAWABGANJ and NAOGAON in northwest Bangladesh. However, this study did not focus on the extent of crop damage as a result of droughts. FAO (2006) reported that *aman* rice was the crop most affected by drought, with recorded production losses of up to 70%.

Sarker et al. (2012; Sarker et al. (2012; 2014) reported significant impact of climate variables on rice in three crop seasons for the period of 1972–2009. However, this study did not gather empirical evidence on rice crops based on household survey data. Farmers' responses to climate change and adaptation strategies are likely to depend on a range of factors including socio-demographic and farm characteristics as well as institutional support.

Sarker et al. (2013a) investigated production variability of rice due to climate change while Alauddin and Sarker (2014) explored the determinants of farm-level adaptation strategies in the Bangladesh context. Farmers' responses towards the appropriate selection of these adaptation measures are driven by the extent of their perception about climate change and their access to extension services (Alauddin and Sarker, 2014; Bahinipati and Venkatachalam, 2015; Wang et al., 2015). These studies identified inadequate information, poor resource endowments and limited extension services as barriers to adaptation (Alauddin and Sarker, 2014; Bryan et al., 2009; Deressa and Hassan, 2009; Deressa et al., 2009; Yesuf et al., 2008). Nevertheless, the micro-level studies in existing literature are far outnumbered by the voluminous literature on aggregate or macro-level analysis. A body of literature with a rigorous investigation of the determinants of farmers' perception about severity of production loss due to climate change is yet to

[2] A northwest upland region with hard red clay soil encompassing an area of 7770 km^2.