Adoption of conservation agriculture technology in diversified systems and impact on productivity: evidence from three districts in Bangladesh.

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JEL code: O33, Q16, C24

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Abstract

Where land is an extremely limiting factor, production is increased through intensive cultivation with two or more crops in a year. We found that 82 per cent of the operating crop land is under 2 or more crops. Soil fertility depletion is one of the main biophysical limiting factors for sustaining per capita food production for smallholder farmers in this system. The adoption of conservation agricultural practices, as a way to tackle this challenge, has become an important issue in the development policy agenda for smallholder agriculture. This paper examines the adoption decisions for conservation tillage, using recent primary data collected from 606 farming households practising diverse cropping systems in three different districts where on-farm participatory trials were being carried out. The paper employs classical tests to identify variations in adoption and yield between participatory and non-participatory farmers as well as variation between cropping patterns and locations. A double hurdle model was employed to explain the factors influencing adoption decisions by farm households. The analysis reveals that several factors contribute to probability and intensity of adoption. Diversities exist between locations, cropping systems, and seasons. Policies that target conservation as a measure of sustainable agriculture must consider diversities for wider diffusion of technology.

JEL classification: O33; Q18; C21

1. Introduction

Various projections indicated a strong rising demand for cereals due to population growth and related requirements (FAO 2006, 2007; FAPRI 2008; Rosegrant et al 2001; Rosegrant et al 2007). Rice requirements would be 520 million tons in 2050. Sustainable production is necessary to meet this rising demand. Growth in cereal production may not sustain without sustainable production strategy.

In Bangladesh agriculture still contributes more than 17 percent of GDP, its growth has stood at just over 4 per cent per year over the last few years in spite of attempts to enhance it. The fear of falling this rate of growth is gradually rising due to unsustainable chemical input intensive cropping patterns, which are degrading soil quality. According to WDI (2013) cereal production has declined in 2012 relative to 2000 in Bangladesh and India.

Poor soil fertility and the associated nutrient limitations for crop growth are highlighted as pervasive constraints in smallholder farming systems in different countries (Buresh et al., 1997; Sanchez and Swaminathan, 2005). The deep tilling of soils has increasingly been seen as problematic by those concerned with sustainable agro ecosystems and ultimately global food security. Soil disturbances due to excessive tillage and other practices have been degrading soil fertility have longer term consequences on the productivity growth and food security. The rising severe threat of climate change, such as increasing risk of drought and heat stresses in the bread baskets of developing countries caste new challenges for ensuring sustainable production and future food security.

Concerns about sustainability in the era of rapid climate change, and the social and technical shortcomings of the Green Revolution, have triggered a number of alternative crop production strategies. Examples are Rice-Maize (R-M) cropping systems, which have emerged in response to the increasing demand from population growth, income growth leading to the expansion of livestock and fish sectors (Timsina, et al. 2011). Agro ecologically, R-M systems have the potential to expand into broad climatic zones across Asia.

CIMMYT (Centro Internacional de Mejoramiento de Maíz y Trigo or International Maize and Wheat Improvement Center) and IRRI (International Rice Research Institute) scientists, in collaboration with NARES (National Argicultural Research and Extension System) partners initiated an intervention project on "Sustainable intensification of Rice-Maize (R-M) production systems in Bangladesh" in November, 2008. R-M project was jointly being implemented by CIMMYT and with local partners with funding from the Australian Center for International Agricultural Research (ACIAR). This was a 5-year project involving multiple partnerships for research and technology transfer on R-M systems in three districts (Comilla, Rajshahi, and Rangpur) of Bangladesh. The national partners were Bangladesh government organizations such as Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI), Bangladesh Academy for Rural Development (BARD) and non-government organizations such as Bangladesh Rural Advancement Committee (BRAC), and Rangpur-Dinajpur Rural Services (RDRS).

The project used participatory adaptive on-farm trials to popularise conservation agriculture (CA) technologies for adoption. In fact conservation agriculture (CA) has caught renewed attention of the practitioners of developing countries due to food price spikes in recent years. CA is considered an innovative strategy for sustainable agricultural productivity and longer term food security.

The specific objectives of the study are:

i. Identify diverse cropping systems in three project sites of CIMMYT and its partners in Bangladesh and to test whether the pattern vary between project/participatory and non-project/non-participatory farmers,
ii. To assess the adoption of conservation tillage and explain the factors affecting conservation tillage technologies including cropping systems, farmer categories (project/participatory and non-project/non-participatory, marginal, small/medium, large etc.) in the selected sites in Bangladesh,
iii. To discuss policy implications.

The results of the study would be important in designing research and policy interventions to improve the adoption and impacts of CA technologies in Bangladesh and elsewhere in similar environment.

The following section presents the concepts, econometric framework and analytical strategies. Section 3 presents study areas, sampling, data and descriptive analysis. Section 4 presents the empirical econometric model, choice of variables, results and discussion of econometric analysis. Section 5 concludes, highlighting key findings and policy implications.

2. Concepts, analytical strategies

2.1 Conservation Tillage Technology

Conservation agriculture (CA) aims to sustainable use of agricultural resources through the integrated management of soil, water and biological resources. It combines tillage and crop establishment technologies with limited external inputs in order to contribute to environmental conservation and to sustainable agricultural production by maintaining a permanent or semi-permanent organic soil cover. Thus, CA is a part of sustainable agricultural system and conservation tillage is a sub-component of CA. According to ECAF (2001), CA includes any practice that reduces, changes or eliminates soil tillage and avoids the burning of residue in order to maintain adequate surface cover throughout the year.

Under conservation tillage, soil disturbance is minimised and crop residue or stubble is allowed to remain on the ground with the accompanying benefits of better soil aeration and improved soil fertility. Minimum soil disturbance requires less traction power and less carbon emissions from the soil (Delgado et al., 2011). In our case, conservation tillage practices entail minimum or reduced tillage (only one pass) and ⁄ or zero tillage and letting the stubble lie on the plot.

Tillage technologies popularised in the R-M project are zero tillage (ZT), strip tillage (ST), and minimum tillage (MT) with a machine called power tiller operated seeder (PTOS). These new technologies are more environmentally friendly than conventional technologies. Crop establishment technologies include direct seeding with machine or manual such as DSR (direct seeding rice), unpuddled transplanting, line transplanting, random transplanting, raised bed (RB) manual, and raised bed (RB) planter. DSR and appropriate mechanization for small farmers would ease labor scarcity, which is currently an important issue in Bangladesh for wide spread international migration and work availability in apparel industries. DSR, bed-planting, and ZT/MT require less water than deep tilling that is conventionally used. Blanket recommendation of nutrients for different crops, different seasons, as well as for different agro-ecological zones results in imbalanced doses of fertilizer use. So 'nutrient management' was also included in the on-farm trials. PTOS is used for MT and direct seeding simultaneously. These new technologies are more environmentally friendly than conventional practices.

CA technology ensemble is based on the principles of minimal soil disturbances, residue retention, rational crop rotations, and controlled traffic (FAO 2012; Gupta and Sayre 2007; Harrington and Erenstein 2005). This study focuses on adoption of conservation tillage technologies in various cropping systems and to explain the factors influencing such technologies. The technology adoption would differ between cropping systems.

2.2 Modelling factors influencing conservation tillage technology adoption

There is a vast literature in the area of technology adoption. We are interested not only in probability of adoption (adopt a technology or not) but also intensity of use of the technology. Non-adopters have values of zero and conditional on adoption a farmer may use the technology in less than an acre of land or more. Alternative models can be used to investigate this, such as ordinary least squares (OLS), Tobit and double hurdle (two part) models. In fact, a large proportion of farmers have zero values for new technology adoption. Which of these three models would be appropriate in this case is an empirical question.

So far we know, there has been no general agreement on the correct approach to dealing with these zero-value observations. Researchers have used OLS (Bonke, 1992), a double hurdle model (Cawley and Liu, 2007), and Tobit (Souza-Poza, Schmid, and Widmer, 2001; Kalenkoski, Ribar, and Stratton, 2005; Kimmel and Connelly, 2007). Some authors report estimates from more than one estimation procedure (Hamermesh, 2009; Price, 2008). However, Tobit has been the predominant approach in more-recent studies. The Tobit model would seem to be a sensible approach, because it was developed specifically for situations where the dependent variable is truncated at zero or some other cutoff. The double-hurdle model closely resembles a parametric generalization of the Tobit model, in which two separate stochastic processes determine the decision to adopt and the level of adoption of the technology (Green, 2000). This is a two-tiered model, originally proposed by Cragg (1971), with a probit model for the first tier or hurdle and a truncated normal linear regression model for second tier or hurdle.

To formalise, let, equation (1) shows the conservation tillage use intensity as defined by.

$$Y = \frac{CR + CK1 + CK2}{LR + LK1 + LK2} \qquad (1)$$

where Y is the ratio of area under conservation tillage to total area under rice. rice-maize and maize based systems in three seasons; R, K1 and K2 are the symbols used for the seasons *Rabi*, *Kharif1* and *Kharif2*; C represents area under conservation tillage.

The standard Tobit model (Tobin, 1958) assumes that there is a latent variable (for example, desired area adoption) underlying the observed dependent variable (actual area adoption). The two are equal when the latent variable is greater than zero, but the observed variable is zero when the latent variable is negative. It is well known that, under these assumptions, OLS parameter estimates are downward biased and inconsistent while Tobit estimates are consistent and asymptotically normal (Amemiya, 1973).

This study intends to employ a double-hurdle model, which generalizes the Tobit model. A double hurdle model is more appropriate with the assumption that, conservation tilage adoption and optimum use intensity are two distinct or independent decisions. We postulate that the households make two sequential decisions with regard to adoption and intensity of use of conservation tillage. The first hurdle is the adoption (D) equation estimated by using a probit model as described by the reduced form adoption equation (2).

$$\left.\begin{array}{l} D = 1 \; if \; D_i^* > 0 \\ D_i = 0 \; Otherwise \\ D_i^* = \acute{\alpha} Z_i + u_i \end{array}\right\} \qquad (2)$$

where D^* is a latent variable that takes the value 1 if the farmer adopts CT and zero otherwise, Z is a vector of exogenous factors/ household characteristics, α is a vector of parameters and u_i is the error term. The intensity of adoption, Y as defined in equation (1) is given by the following reduced form adoption equation (3).

$$Y_i = \begin{cases} Y_i^* = \acute{\beta} X_i + \; v_i \; if \; Y_i^* > 0 \; and \; D_i^* > 0 \\ 0 \quad otherwise \end{cases} \qquad (3)$$

where Y_i is the observed answer to the area planted with conservation tillage (contingent on adoption), X_i is the vector of exogenous factors/ household characteristics, β is the vector of parameters to be estimated, and v_i is the error term.

The error term u has a standard normal distribution and v is distributed normally with zero mean and a constant variance.

The model helps account for the high frequency and intensity of technology adoption and allows for the explanatory variables to differ by tier (but X and Z variables could be the same). The first hurdle estimates a household's decision whether or not to adopt the technology and a second hurdle, contingent on adoption, estimates the extent of adoption (Ricker-Gilbert, et al., 2011).

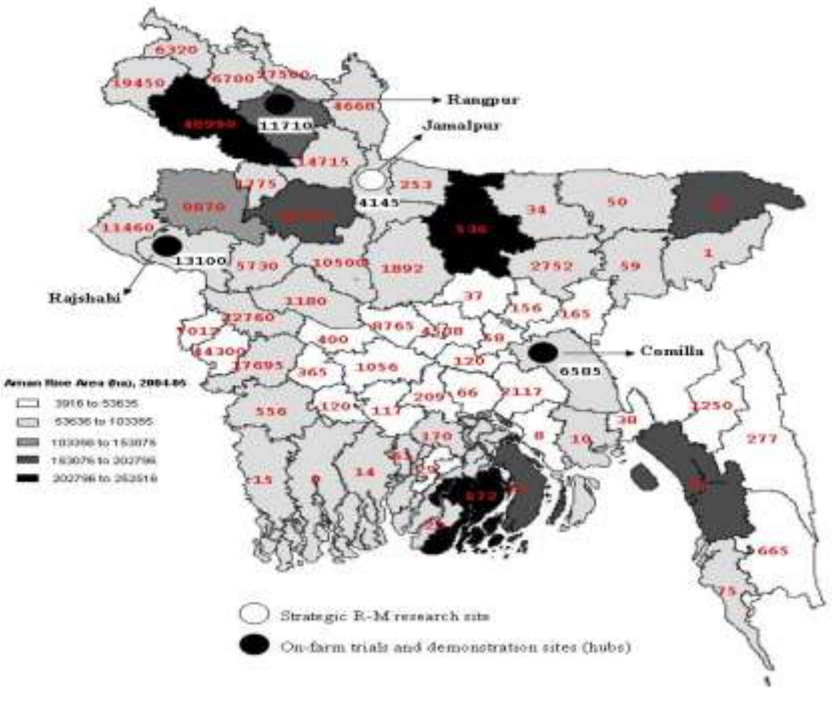
3. Survey methodology and data description

The study is based on a quantitative survey carried out in April-May 2013. The methodology used in this survey is outlined below.

3.1 Study sites

R-M project was initiated in 2008 to conduct experiment at farmers' field so that farmers adopt CA and nutrient management technologies. The project identified 3 districts purposively based on their potential for R-M systems to carry out participatory research (on-farm trial) through consultation with knowledgeable people, such as experienced extension personnel and research scientists from local partner organisations of the project. The selected districts were Rangpur, Rajshahi and Comilla (black balls in the Map in Figure 1 are study sites). From each district, two *Upazillas* were selected for intervention from the project using the same selection criteria and consultation.

Figure 1 Map of the selected study sites, Bangladesh



The characteristics of the selected sites are depicted in Box 1. In terms of R-M systems Rangpur and Rajshahi are similar. One Upazilla is near the district head quarter, the other is located far. Project and control villages within each Upazilla were nearly similar in terms of potential for R-M systems, as was found during the consultation phase of the selection of study locations. The climate of Rangpur is mild with high humidity (70%-88%). The annual rainfall ranges from 1929 to 2160 millimetres in Rangpur (BBS, 2008). The maximum rainfall is observed during the months of June and July. The average annual rainfall in Rajshahi is usually lower than Rangpur, was recorded 1371 mm in 2008. The annual rainfall in Comilla is usually higher than the other two districts.

Box 1: Summary information for sample Upazillas and villages in Rangpur, Rajshahi and Comilla districts with sample size, 2008.

Rangpur district	**Rajshahi district**	**Comilla district**
Northwestern part of Bangladesh between 25.18’ and 25.57’N latitude and 88.56’- 89.32’ E longitude A relatively long tradition of rice-maize cropping; Maize is grown in *Rabi* and *Kharif1*	Western part of Bangladesh between 24.22’ latitude and 88.6’ longitude Maize is grown in *Rabi* and *Kharif1*	About 100 kms from Dhaka in the eastern part of Bangladesh Rice-maize is an emerging system in Comilla.
Gangachara Upazila (near)	**Paba Upazilla (near)**	**Barura Upazilla (near)**
Located about 15 km to the north east of the district *sadar; loamy soil; Rabi* rice-fallow-*Aman* rice, potato-*Rabi* rice-*Aman* rice, potato-*Aus* rice-*Aman* rice and potato-maize-*Aman* rice; wheat and maize are competitive Project villages in Gangachara are: (1) Talukhabu, (2) Joydeb Bakshitari Coltrol village(1) Goalu	about 12 km to the north of the district *sadar;* soil is mostly loamy; cropping pattern: *Rabi* rice-fallow-fallow, potato-maize-*Aman* rice, potato-maize-fallow, wheat-fallow-*Aman* rice, maize-fallow-*Aman* rice, and sugarcane Project villages in Paba are: (1) Madhavpur, (2) Gosaipur Siuvipara Control village (1) Borgachi	located about 12 km south-west of Comilla town; cropping pattern: potato-maize-*Aman* rice, *Rabi rice-Aus* rice- *Aman* rice and *Rabi*-fallow-*Aman* rice Project villages in Barura are: (1) Puntala (2) Jalgaon Control village (1) Chototula Gaon
Mithapukur Upazilla far	**Durgapur Upazilla far**	**Daudkandi Upazilla far**
About 30 km to the south of the district *sadar; loamy soil with* about 80% irrigated ; yield of maize is around 6.7 t/ha Project villages in Mithapukur are: (1) Sitolgari (2) Durgapur Control village (1) Chitli Purba Para	About 30 km to the north east of the district *sadar;* drought-prone and the soil is mostly clayey loam Project villages in Durgapur are: (1) Alipur (2) Nandigram Control village (1) Shympur	30 km west from the Comilla district town; Project villages in Daudkandi are: (1) North Mohammadpur (2) Durgapur Control village (1) Biteshar

3.2 Sample farmer selection

The method of sample farmer selection for the final adoption survey is discussed below.

First we prepared the list of R-M project participating farmers (PFs) from the Excel diary sheet maintained by project scientists. We decided to interview a large number of PFs randomly to make the analysis unbiased. Until 2012, the R-M project intervenes with technologies to around 400 PFs in six select Upazillas of the project site. These farmers were drawn from different farm size groups giving higher preference to marginal/small farmers who are the resource poor groups of the society. In some *Upazillas* the maximum number of

PFs did not exceed 40, for example Mithapukur in Rangpur district and Barura in Comilla district. So we decided to interview 40 PFs from each of the 6 *Upazillas* where PFs were located; a complete survey in Upazillas where there were around 40 PFs and randomly selected 40 farmers where PFs exceeded 40.

Second, from the list of PFs we identified the farmers having trials (conservation agriculture and nutrient management plots) and extension plots in 2012 because we require technology and season specific data for the year 2012. This screening gives us a list of around 250 PFs. The final year of the R-M project was still continuing during the survey in April-May 2013. We found majority of the PFs were continuously participating in the project (2009-2012) but some farmers exited and new farmers entered into the project. Some farmers participated until 2011 then dropped and so we didn't include them because they had no information for 2012 crop seasons. According to our criteria, number of PFs was around 40 in all Upazillas except Durgapur in Rajshahi, where we got 50 PFs in the list. So we interviewed all PFs in all locations except Durgapur, and we randomly selected 40 from the list of 50 in Durgapur. In Mithapukur, Rangpur we got 37 PFs. So we interviewed 236 PFs (37 in Mithapukur, 39 in Barura and 40 in all other Upazillas)[1]. This was almost a complete survey of PFs who were with the project in 2012.

Third, the comparison groups were non-participating farmers (NFs) coming from the same project villages (PVs) and control farmers (CFs) from the control villages (CVs). NFs did not receive direct supports from the project but expected to expose with spill over effects; they might learn some CA and NM technologies from PFs or project staffs as they are located in the same villages. CFs are located in the CVs of the same *Upzillas* but far from project villages and lack well communication network with the PVs. So the chance of transmission of project information to CVs is negligible.

We planned to interview a higher number of non-participating/control farmers using proportionate random sampling. Our planned distribution of the sample was 40+30+30 (PF+NF+CF)=100 farmers from each *Upazilla* making sample size 600 from 6 *Upazillas,* which is quite large to obtain reliable results. The final sample comes from 24 villages from 6 *Upazillas* in 3 sites. We interviewed more than 30 NFs from some PVs. In total we collected information from 606 farmers.

The survey instrument was a detailed 14 pages structured survey questionnaire. The questions include household level characteristics, assets, technology adoption, production, consumption, marketing, constraints and lessons.

4. Results and key issues

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[1] In Mithapukur Upazilla, there were only 39 PFs and we managed to interview 37, the remaining 2 were not available; they were absent in the site during the survey period.

4.1 Socio-economic characteristics of the farm households

Average age of household head of the farmers interviewed was about 45 years (Table 1). Heads were slightly older in Rangpur and Comilla. About 2% of the households were female headed. There was no female headed household in Rajshahi, where family size of the farm households was also lower. Family size was the highest in Comilla and the lowest in Rajshahi. Average family size was slightly higher than 5 persons per farm household. Average literacy rate was the highest in Rajshahi followed by Rangpur and Comilla, with average of all sites of about 67%. The literacy rate was measured by the percent of 7 years and older members of household can read and write a letter in this research following household income and expenditure surveys in Bangladesh (HIES 2010). Thus Rajshahi was better in human capital education than the other two sites, but heads were younger indicating less experience in farming. The proportion of illiterate heads was the highest in Comilla followed by Rangpur and Rajshahi. Literacy rate of spouse of head was lower than the literacy rates of heads themselves in all 3 sites.

Table 1 here

4.2 Adoption of R-M systems

In Bangladesh crop seasons are classified into three major groups; *Rabi*, *Kharif1* and *Kharif2*. *Rabi* is the dry winter season dominated by *Boro* rice, *Kharif1* is pre-monsoon season dominated by *Aus* rice (late *Boro* instead of *Aus* rice in some areas, such as Rangpur) and *Kharif2* is the monsoon season dominated by *Aman* rice. In most areas farmers grow rice in more than one of these seasons. Production differs between seasons.

Nationally, *Boro* comprises the highest share of annual production; in 2010-11, 56% of total annual rice production was *Boro* according to Bangladesh Bureau of Statistics followed by *Aman* (38%) and *Aus* (6%). Cropping systems have been changing overtime with the invention and innovation of new technology. In 1982/83 about 59% of the total production was harvested in the months of mid-October to mid-December in the *Aman* season (Islam 1987; Akter 1989, Akter 1990). The remaining harvests were distributed in the months of mid-April to mid-August covering *Boro* and *Aus* seasons. There was a big gap of about 4 months between the *Aman* and *Boro* harvests, with no maize.

At present, *Boro* is the major rice and harvesting now continues from the end of March to the beginning of June. *Aus* harvesting continues from the end of July to the end of October. *Aman* harvesting continues from the mid October to the end of December. Maize is now one of the important crops, next to rice.

Maize production is increasingly rising; it is getting popular day by day. Maize is grown in *Rabi* and Kharif1 seasons. Nationally maize production was 849 thousand metric tons in 2008-09 and the production increased to 1018 thousand metric tons in 2010-11. So, annual average increase in production was more than 13% in this three years period.

Cropping system comprises a large number of crops in all three seasons with a variety of combinations. With plot specific data from 606 farmers in 3 locations (Rangpur, Rajshahi and

Comilla) and a grouping of crops into rice, maize, wheat, potato, pulses & oil seeds, vegetables & spices, jute, tobacco & betel leaf, and fallow plots, we identified around 100 combinations. Vegetable crops combined in three seasons in enormous ways. For many combinations, we identified adoption by less than 5 farmers, often only one farmer.

In terms of area allocation, the most popular pattern in Rangpur is rice-fallow-rice followed by potato-rice-rice. We found significant difference between participatory and non-participatory/control farmers with respect to potato-maize-rice pattern. Maize-Fallow-Rice is also another pattern that many farmers used but area allocation in this pattern was low. The difference between participatory and non-participatory/control farmers with respect to this potato-maize-rice pattern was not statistically significant.

Like Rangpur, rice-fallow-rice and potato-maize-rice were two extensively used patterns in Rajshahi. Rice-Fallow-Fallow was another extensively used pattern in Rajshahi, indicating that more land remains fallow in Rajshahi. Wheat, mustard and vegetables were more accepted crops in Rajshahi. In terms of area allocation, rice was more dominating in Rangpur.

Comilla is the only area where rice was grown in all three seasons, both by participatory and non-participatory farmers. Potato was not as important in Comilla as in Rangpur and Rajshahi.

To ease the analysis and as per our focus on rice-maize systems, we first categorise the rice maize systems into three groups such as 1. rice without maize, 2. rice plus maize and 3. maize without rice. Each system was further categorised into sub-categories such as 3 crops, 2 crops and 1 crop systems. So we excluded systems which have neither rice nor maize and identified 8 categories in which average area allocation are shown in Table 2. In the rice without maize systems, 2 crops patterns were the most dominating by both groups of farmers. Groups were statistically the same.

Table 2 here

4.3 Adoption of CA

Table 3 depicts a higher adoption of CA technologies in *Rabi* maize than *Rabi* rice. The project began initially with maize trials; *Boro* rice was not included. Traditionally direct seeding rice (DSR) manually was an important farmer practice of crop establishment. The method has been gradually replaced with transplanting since the green revolution in the late sixties, though direct seeding is better for soil health. Direct seeding helps maintaining crop residue on the soil surface and so builds soil organic matter that feeds soil microbial activity resulting in healthy soil and improved nutrient exchange capacity. Only around 4% of the area was under DSR manual in the *Rabi* season. Almost all farmers of *Rabi* rice used conventional tillage (intensively tilled comprising 3 or more passes) in more than 99% of their *Rabi* rice area.

Table 3 here

Rabi maize cultivation is dominated by conventional tillage (3 or more tillage, usually with machine) but direct seeding manual is a farmer practice. Overall, in more than 79% of the maize area, farmers used this method for growing maize in the *Rabi* season. ZT/MT was adopted in about 13% of *Rabi* maize area, with 9.2%, 23% and 8.4% in Rangpur, Rajshahi and Comilla respectively. The higher adoption in Rajshahi corresponds to better functioning of PTOS. Rangpur and Comilla experienced mechanical problem with the machine during the peak period.

The 'other' category includes mixed sort of tillage and crop establishment technologies. This proportion includes CA technologies along with conventional farmer practices. This is also the highest in Rajshahi followed by Rangpur followed by Comilla. This evidence indicates an incredible achievement of technology adoption in Rajshahi.

In the *Kharif1* season, DSR with conventional tillage was used by 0.4%, 2.9% and 4.3% of land in Rangpur, Rajshahi and Comilla respectively (Table 4). Only participatory farmers who were selected for CA used ZT or MT; they are in the mixed category. Here, again Rajshahi farmers are higher adopters.

Kharif1 maize cultivation is also dominated by conventional tillage as in *Rabi* maize with direct seeding manual as a farmer practice. Overall, in about 64% of the maize area, farmers used this method for growing maize in the *Kharif1* season. This proportion is lower than the *Rabi* maize, because adoption of ZT with direct seeding manual is much higher in *Kharif1* season. Indeed, ZT/MT was adopted in more than 22.3% of *Kharif1* maize area, with 28.5%, 12.9% and 28.6% respectively in Rangpur, Rajshahi and Comilla respectively. Raised bed planter was used in the highest proportion of land in Rangpur, whilst raised bed was not used by Comilla farmers. The farmers in Comilla mentioned that stormy weather causes more damage to maize if planted in raised beds. The 'other' category includes mixed sort of tillage and crop establishment technologies. Including the 'other' category, Comilla is the highest adopter of CA based technologies for *Kharif1* maize followed by Rajshahi and Rangpur.

In the *Kharif2* season, DSR was used by 1.6%, 1.2% and 7.4% of land in Rangpur, Rajshahi and Comilla respectively (Table 4). Hence Comilla farmers are the largest users of DSR. Overall, ZT/MT was used in 6.1% of land; Comilla appears the highest user of CA based technologies for *Kharif2* rice production.

Thus the adoption rate of CA technologies in rice production is the highest in Comilla in both seasons (*Kharif1* and *Kharif2*), but the adoption rate of CA technologies in maize production is the lowest in Comilla. This indicates divergence between regions, should be taken into account in popularising technologies.

4.4 Factors influencing adoption of CA

We use a dummy variable for adoption which equals one for the farm have any area under conservation tillage (ZT, ST or MT). We measure adoption intensity with area (log of decimal per household) under conservation tillage. In the following section we present the potential factors influencing adoption of conservation tillage technologies.

Choice of variables for the empirical adoption model

We follow a wide range of technology adoption studies to choose the following potential explanatory variables to be included in our regression analysis (e.g., Bandiera and Rasul 2006; Marenya and Barrett 2007; Pender and Gebremedhin 2007; Bluffstone and Köhlin 2011; Teklewold et al., 2013). The following hypotheses are also of interest as *a priori* expectations.

Household and farm characteristics

Socio-demographic characteristics relevant to the adoption decision include family size, age, gender and education level of the household head. Of the sample households, 98% have a male head. Average years of education of head ranged from 4 to 7 years across the study areas with reasonably high level of literacy rate of 82% of the household heads.

Use of farmers' education level as explanatory variable in technology adoption studies is common (e.g., Nkamleu and Adesina 2000; Adesina and Baidu-Forson 1995). The education variable was used as a surrogate for a number of factors. At the technical level, access to information as well as capacity to understand the technical aspects and profitability related to different crops may influence crop production decisions. Therefore, years of schooling was incorporated to reflect this.

Family size, a proxy to labour availability, may influence the adoption of conservation agriculture positively as its availability reduces the labour constraints faced in rice and maize production.

Age of household head may influence both the decision to adopt and extent of adoption of CA. However the direction of influence may be indeterminate. Older farmers are more risk averse and less likely to be flexible than younger farmer counterparts and thus have a lesser likelihood of adopting new technologies. Age can also be associated with loss of energy and short-planning horizons. A counter argument is that age means more exposure to production technologies and environments, and greater accumulation of physical and social capital.

We applied parsimony to select important variables from these household characteristics and finally selected family size, age (agehh) and education (eduhh) of the household head.

Resource constraints

Land is the scarcest resource in Bangladesh, and farm size largely determines the level and extent of income to be derived from farming. Land also serves as a surrogate for a large number of factors as it is a major source of wealth and influences decision to choose technology. Also, higher the farm areas more can be allocated among technologies. Hence, the average cropped area (to represent wealth) was incorporated to test its independent influence on decisions regarding technology adoption. We include cropped area which combines the cropping intensity of land.

Farmers operate a number of small plots; in our data PFs own 4.8 plots and NFs/CFs own 4.0 plots on average (Table 1A in the appendix). Higher number of plots may help farmers diversify with CA and conventional practices to distribute associated risks. So we include number of plots in household as an independent variable. We expect positive relation of this variable with CA adoption.

We include several land/soil characteristics such as area under different types of soil (sandy, loamy, clay) as self-reported by the sample farmers. Farmers may consider a specific type of soil for CA adoption.

Livestock is an important source of financial capital, draught power for cultivation is hardly used in Bangladesh. So we have used livestock unit to represent a source of financial capital. Farmers earned income from selling livestock and livestock products (egg and milk).

Farmers have other sources of financial capital and wealth. We included remittance, non-agricultural labour income and income from other sources.

Access to modern irrigation facilities is an important pre-requisite for growing high yielding rice, particularly in the dry winter season. Farmers would prefer technologies which require less irrigation where irrigation facilities constrain crop production. Dry tillage followed by formation of beds with seed and fertilizer placement would be a better option to face irrigation scarcity.

Better access to machine for conventional tillage would encourage farmers to use the usual practice rather than CA. Therefore, this access may be a constraint to CA adoption with conservation tillage.

Agricultural extension and government sources disseminate relevant agricultural production practices to farmers. Often farmers have very limited access to information from private sources. Many studies found a significant influence of extension education on adoption of agricultural technologies (e.g. Adesina and Zinnah 1993). Therefore, we also include a dummy variable called extension to account for its influence on adoption of CA.

Market access

We construct market constraint variables from framers' self-reported data and availability of transport for marketing . We have not found significant relationship of these variables with CA adoption.

Climatic factors

Bangladesh is earmarked as the country most vulnerable to climate change. We therefore include two climate related dummy variables to capture the effect of weather on the timing of crop and damage due to water logging issues. Our variables 'moisture' represents better weather in the dry season and climate3 represents harsh weather in the pre-monsoon period.

Social network

We assume that farmers who obtain help from social groups in case of crop failure or another shock, they may be willing to take risk associated with new technology. So we use a variable *helpneed* to capture this effect.

Other factors

As CA involves retention of crop residues in the field, usually weed infestation level is higher than conventional farmer practices. We include weed level variable to learn whether weed infestation affect CA adoption significantly.

We include dummy variables to capture the impact of cropping systems on CA adoption. These variables are R-M systems and only maize based systems which compare with rice based system (without maize) as the base system.

Impact of R-M project

From the descriptive analysis we got that CA adoption was higher in participating farms. So we include two variables to obtain the impact of project on CA adoption. First, we include a dummy variable for PFs (=1) to represent project support in general. Second, we include a dummy variable for the farmers who said that they got advice/information from the project staffs/scientists on agricultural practices and technologies (said yes=1). About 2.5% of the NFs said that they had received advices/information from the project. On the other hand 11% of the PFs did not receive such advices/information, though they were given physical inputs from the project.

Results of double hurdle model

Since Cragg's independent double hurdle model nests Tobit model as a special case, the standard log likelihood (LR) test applies in this case. Tobit log-likelihood is the sum of the log-likelihood of the truncated and the probit models (Green 2000). The likelihood ratio test supported Cragg's independent double hurdle model (last row of Table XX) . The results of the double hurdle model are presented in Table 4. We finally include 31 variables in the hurdle 1 (probit) and 29 variables in hurdle 2 (truncated regression). In the first hurdle probit model 16 variables were significant. We first explain significant factors. Number of plots, sandy soil, access to irrigation, income from some non-farm sources, access to machine for conventional tillage, better climatic condition, rice-maize and maize based systems and the presence and advice of R-M project were conducive to the adoption of conservation tillage. These results are conformable to our a priori expectation. The project made a highly significant and a large contribution to CA adoption.

Among the variables which negatively influenced adoption, significant were irrigation intensity (measured by proportion of land actually irrigated in 2012) and cropping intensity (measured by total cropped area in 2012, sum of area in *Rabi*, *Kharif1* and *Kharif2*.

A large proportion of land is allocated to 2/3 crops in a year. To do so farmers use soil degrading practices and it is constraining CA adoption. It is necessary to identify CA technologies that better suit 2/3 crop systems. Current practices are suitable for maize crops and so R-M system contributing to CA adoption.

The results reveal that weed infestation is not a significant constraint to CA adoption as is suggested by usual wisdom. Appropriate CA technologies can be adapted to crops other than maize production without a fear of high level of infestation.

Surprisingly, important policy variables such social network and government extension services, though contributing positively, are not contributing significantly. At the same time project contribution is highly significant and high. In the project several government organisations were involved. It is reasonable to believe that they have learned ideas on how extension services could be delivered for wider CA adoption.

Conditioned to adoption, several factors contribute to intensity of adoption. These include positive factors such as age of head, cropping intensity, and better climatic condition. The factors which affect adoption intensity negatively are clay soil type of land, non-agriculture labour activities, and the presence of project. Though probability of CA adoption increased due to project, its presence is actually a hindrance to enhance the intensity of adoption. This indicates that the project technologies used for CA adoption may be discouraging farmers to expand land areas under CA.

4.5 Does yield differ between systems and CT technologies?

Table 5 compares the yield of rice and maize between conventional and conservation tillage systems. We include *Kharif2* rice (*Aman* rice) and maize for both *Rabi* and *Kharif1*. For rice, yield in conservation tillage was significantly higher in Rangpur and Rajshahi. The difference was insignificant in Comilla.

In case of *Rabi* maize, conservation agriculture resulted in significantly higher yields in all locations consistently. In case of *Kharif1* maize the difference was not statistically significant.

Thus we find variation between geographical location and seasons. The current level of technologies could be promoted to Northern areas like Rajshahi and Rangpur for both rice and maize cultivation. In the econometric analysis we found that the probability of CA adoption is higher in Rajshahi and Rangpur than Comilla. Particularly, the probability was significantly higher in Rajshahi. So the econometric analysis and yield advantage of CA produced consistent results.

5. Conclusions and implications

Various projections in the last decade indicated necessity to sustain cereal production growth to feed the rising population. The rising severe threat of climate change, such as increasing risk of drought and heat stresses in the bread baskets of developing countries caste new challenges for ensuring sustainable production and future food security. Integrating concerns of productivity, resource conservation, quality and environment is now fundamental to sustained productivity growth.

Conservation tillage technologies reduce soil disturbances and are more environmentally friendly. In this study we applied double hurdle model to examine the probability and intensity of adoption of conservation tillage technologies promoted under participatory on-farm trials in an intervention project on "Sustainable intensification of Rice-Maize (R-M) production systems in Bangladesh". The participatory farmers extended the technologies to their own plots.

On average, ZT/MT was adopted in more than 13% of *Rabi* maize area, with 9.2%, 23% and 8.4% respectively in Rangpur, Rajshahi and Comilla. Given the maize cultivation is rising remarkably, 13% of it under CA is a high profile achievement during the project period of about 5 years beginning 2009 *Rabi* maize. The highest performance of Rajshahi was due to well functioning power tiller operated seeder (PTOS). This machine was used for direct seeding of maize in a single operation with one tillage. Farmers enjoyed the mechanism of tilling and seeding together but the operators found the machine inconvenient to handle. Sustainable intensification requires machine to be more user friendly so that private businesses come forward to invest in machine.

On average, ZT/MT was adopted in more than 22.3% of *Kharif1* maize area, with 28.5%, 12.9% and 28.6% respectively in Rangpur, Rajshahi and Comilla respectively. Raised bed planter was used in the highest proportion of land in Rangpur, whilst raised bed was not used by Comilla farmers. The farmers in Comilla mentioned that stormy weather causes more damage to maize if planted in raised beds. The 'other' category includes mixed sort of tillage and crop establishment technologies, as mentioned earlier. Including CA technologies from the 'other' category, Comilla appears the highest adopter of CA based technologies for *Kharif1* maize followed by Rajshahi and Rangpur.

The econometric analysis reveals that the probability of CA expansion is higher in land having the characteristics of sandy soil. Also farmers with more plots and have access to income from some non-farm sources are likely to adopt CA. The likelihood of adoption differs between cropping patterns, climatic conditions and irrigation access. The likelihood of adoption is constrained by rental market and intensity of adoption is constrained by soil type.

It is often argued that crop yields may fall in the initial phases of CA adoption, and will only rise above conventional tillage figures when the CA system has stabilised. In this study we have seen CA can produce equivalent or higher yields compared to conventional tillage systems, particularly in *Rabi* maize and *Kharif2* rice.

While soil health, water savings etc are important to long run societal well-being, reliable and significant increases in crop yield offer an immediate and tangible benefit to individual farmers. We conjecture that interventions that emphasize and quantify this crop yield benefit may be particularly effective at encouraging adoption. From this analysis we can conclude that any attempt to wider diffusion of CA technologies would offer an immediate benefit to individual farmer but not in all locations, not in all seasons. Diversity also exists between cropping systems which vary between regions.

The results show that the probability of adoption could be increased by using the projects like the R-M project but the project action is in fact detrimental to improve intensity of adoption. The technologies are adopted under the supervision of on-farm trials. Farmers extended some plots which are less supervised by the project scientists but still these plots were not free from complete supervision. This type of supervision is extremely limited. The machines which were introduced under the on-farm trial are not yet in a position to wider adoption. Further experiment is necessary with improved machine keeping in view that private businesses find it demanding more than the existing power tiller. Availability of existing power tiller is constraining CA adoption. PTOS is less competitive than the existing power tiller that is used for conventional tillage. Actual demand for the PTOS type of machine was much higher than the project supply. This implies that innovative method of technology diffusion is necessary to reach wider population.

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Tables

Table 1. Socio-economic characteristics of farm households surveyed in the study sites, 2012.

Characteristics	Rangpur		Rajshahi		Comilla		Total	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Age of hh head (yrs)	47.6	11.7	38.3	13.3	48.0	13.7	44.6	13.7
Female headed household (%)	3.0	17.1	0.0	0.0	2.5	15.6	1.8	13.4
Family size (no)	5.2	2.0	4.3	1.4	6.0	2.6	5.2	2.2
Household literacy rate (%)	64.7	30.6	73.1	54.9	62.2	28.2	66.7	40.0
Households have illiterate heads (%)	18.9	39.3	13.8	34.6	20.8	40.7	17.8	38.3
Literacy rate of spouse of head (%)	75.1	43.3	83.3	37.4	77.7	41.7	78.7	41.0
Sample size	201		203		202		606	

Source: Farm households survey, R-M final adoption study 2013.

2. Major rice-maize cropping systems (*Rabi-Kharif1-Kharif2*) with average area (acres per household) under the pattern

Cropping systems	Participatory			Control/Non-participatory			P value of difference
	N	Mean	Std	N	Mean	Std	
Rangpur (*Rabi-Kharif1-Kharif2*)		Acres	Acres		Acres	Acres	
Rice without maize systems							
3 crops in any season	38	0.57	0.46	55	0.67	0.51	0.35
2 crops in any 2 seasons, any 1 season remains fallow	37	0.87	1.10	79	0.79	0.85	0.70
Rice in any 1 season, 2 fallows	13	0.45	0.51	15	0.51	0.39	0.77
Rice-Maize systems							
3 crops in any season systems	56	0.40	0.42	41	0.79	0.69	0.00***
2 crops in any 2 seasons, any 1 season remains fallow	23	0.36	0.27	19	0.30	0.23	0.47
Maize without rice systems	7	0.22	0.08	9	0.29	0.15	0.27
Rajshahi (*Rabi-Kharif1-Kharif2*)							
Rice without maize systems							
3 crops in any season	37	0.43	0.32	42	0.68	0.68	0.05**
2 crops in any 2 seasons, any 1 season remains fallow	40	.53	.44	47	0.50	.047	0.74
Rice in any 1 season, 2 fallows	29	.31	.24	66	0.54	0.43	0.01***
Rice-Maize systems							
3 crops in any season systems	53	.38	.27	38	0.57	0.59	0.05**
2 crops in any 2 seasons, any 1 season remains fallow	29	.35	.28	16	0.20	0.24	0.08*
Maize without rice systems	6	.10	.04	13	0.46	0.50	0.11
Comilla (*Rabi-Kharif1-Kharif2*)							
Rice without maize systems							
3 crops in any season	37	0.73	0.60	61	0.82	0.58	0.47
2 crops in any 2 seasons, any 1 season remains fallow	16	0.59	0.42	15	0.54	0.44	0.72
Rice in any 1 season, 2 fallows	4	0.26	0.24	5	0.24	0.21	0.88
Rice-Maize systems							
3 crops in any season systems	64	0.61	0.54	62	0.62	0.42	0.91
2 crops in any 2 seasons, any 1 season remains fallow	8	0.24	0.15	2	0.83	0.74	0.04**
Maize without rice systems	7	0.19	0.20	3	0.58	0.55	0.11

Table 3 . Adoption of conservation agriculture technologies in study sites, 2012.

	Rangpur	Rajshahi	Comilla	Total
Technologies	% of rice (*Boro*) area in *Rabi* season			
Conventional tillage (CT) and direct seeding (DSR) manual	6.0	0.2	4.7	4.1
CT and line transplanting	55.0	35.8	92.7	63.1
CT and random transplanting	38.9	63.1	1.3	32.1
Other (mixed)	0.0	0.8	1.4	0.7
Total rice *Rabi* season	100.0	100.0	100.0	100.0
	% of maize area in *Rabi* season			
Zero/strip tillage (ZT/ST) and direct seeding with machine	4.5	6.6	3.8	4.5
Minimum tillage (MT) and direct seeding with machine (PTOS)	2.7	17.2	2.9	5.3
MT & raised bed planter	2.0	9.4	1.7	3.1
CT and direct seeding manual	80.1	51.1	86.9	79.3
Other (mixed)	10.6	15.7	4.6	7.7
Total maize *Rabi* season	100.0	100.0	100.0	100.0
	% of rice area in *Kharif1* season			
Technologies	Rangpur	Rajshahi	Comilla	Total
CT and DSR manual	0.4	2.9	4.3	3.1
CT and line transplanting	46.1	43.8	93.0	74.0
CT and random transplanting	52.8	47.5	0.8	20.7
Other (mixed)	0.6	5.8	1.9	2.2
Total rice *Kharif1*	100.0	100.0	100.0	100.0
	% of maize area in *Kharif1* season			
ZT and direct seeding manual	14.3	10.5	24.6	14.2
MT and direct seeding with PTOS	0.8	1.4	1.0	1.1
MT and direct seeding manual	5.7	0.1	3.0	3.1
MT & raised bed planter	7.7	0.9	0.0	3.9
CT and direct seeding manual	67.2	60.6	60.5	63.7
Other	4.3	26.5	10.9	14.0
Total maize *Kharif1*	100.0	100.0	100.0	100.0
	% of rice area in *Kharif2* season			
ZT & direct seeding manual/machine	0.1	0.4	1.7	0.7
ZT & unpuddled transplanting	0.1	0.2	0.4	0.2
MT & unpuddled transplanting	0.2	0.3	0.3	0.2
CT & direct seeding manual	1.5	0.8	5.7	2.7
CT & line transplanting	41.9	41.8	88.4	57.0
CT & random transplanting	53.3	55.6	1.0	36.9
Other	2.8	1.0	2.6	2.3
Total rice Kharif2	100.0	100.0	100.0	100.0

Source: Farm households survey, R-M final adoption study 2013.

4. Double hurdle model of factors influencing adoption and extent of adoption of conservation tillage technology, 2012.

Variables	Hurdle 1 Probability of Adopting conservation tillage		Hurdle 2 Ratio CT cropped area to total cropped area	
	Probit estimator	Robust s.e.	Trancated normal estimator	Robust s.e.
Familysize (no of persons in household)	0.012	0.038	-0.036	0.028
agehead (age of hh head)	0.003	0.006	0.012**	0.005
edhh (years of schooling of head)	-0.026	0.018	-0.006	0.014
plno (number of plots)	0.098***	0.035	-0.013	0.028
sandsoil (soil is sandy, dec/hh)	0.012***	0.003	-0.001	0.002
loamsoil (soil is loamy, dec/hh)	0.001	0.001	-0.002	0.002
claysoil (soil is clay, dec/hh)	-0.001	0.002	-0.004**	0.002
irriprop (proportion of irrigated land)	-0.565***	0.228	0.006	0.257
irrityp1 (dec/hh under electric STW irrigation)	0.005***	0.002	0.000	0.001
irritypO (dec/hh under other irrigation)	0.004**	0.002	0.001	0.001
croparea (total cropped area, dec/hh)	-0.003***	0.001	0.002***	0.001
rentlnd (Rented/lease in land, dec/hh)	-0.003*	0.002	0.000	0.001
farm_1 (marginal farm=1)	-0.141	0.208		
farm_3 (medium/large farm=1)	-0.116	0.433		
remit (international migration =1)	-0.490*	0.292	0.062	0.218
tlu (herd size, tropical livestock unit)	0.068	0.046	-0.003	0.012
q52d *10^{-3} (non-agri labour income BDT/hh)	-0.004	0.004	-0.008***	0.003
q52i*10^{-3} (Other income, BDT/hh)	0.001**	0.000	0.001	0.001
machine (scarcity of machine=1)	0.715***	0.160	0.040	0.120
transport (hh owns transport)	-0.210	0.187	0.165	0.139
helpneed (social network help=1)	0.510	0.319	0.105	0.242
project (received project services=1)	1.010***	0.255	-0.832***	0.287
govt (received govt services=1)	0.235	0.153	-0.151	0.114
Moisture (*Rabi* crop not delayed=1)	0.542**	0.267	0.455**	0.199
climate3 (water logging in *Kharif1*, dec/hh)	-0.002	0.003	0.002	0.002
weedlevel (index ranging 0-1 highest)	-0.596	0.382	-0.154	0.355
RMsys (farm has both rice and maize=1)	1.065***	0.191	-0.245	0.269
Msys (farm has maize, no rice=1)	0.654**	0.282	-0.244	0.247
Group1 (participatory farmer=1)	0.928***	0.255	-0.013	0.310
loc_2 (dummy, Rajshahi=1)	0.498*	0.272	0.073	0.222
loc_3 (dummy, Rangpur=1)	0.374	0.246	-0.112	0.203
Constant	-2.043***	0.525	3.449***	0.489
Sigma=0.7355***, log likelihood=-423.43***, LR test (tobit =double hurdle)=-49.19***				

Table 5. Yield advantage of conservation tillage, 2012

Crop	Tillage technology	Rangpur		Rajshahi		Comilla	
K2 rice	CT	4.14	1.24	4.48	1.12	3.83	1.22
	CA	4.75	1.85	5.35	1.49	3.59	0.97
	Overall	4.25	1.39	4.69	1.27	3.79	1.19
Ttest	P-value	0.00***		0.00***		0.16	
Rabi maize	CT	6.72	0.24	6.68	2.08	5.67	1.41
	CA	7.29	0.19	7.38	1.64	6.27	1.46
	Overall	6.96	0.16	7.02	1.90	5.89	1.46
Ttest	P-value	0.05**		0.04**		0.00***	
K1 maize	CT	6.27	2.26	5.32	2.11	5.90	1.15
	CA	6.21	2.35	5.36	2.52	5.25	1.50
	Overall	6.25	2.29	5.33	2.23	5.70	1.28
Ttest	P-value	0.88		0.93		0.18	

Appendix

1A. Description of variables: difference across district sites, 2012.

Variables	Rangpur N=201		Rajshahi N=203		Comilla N=202		K-Wallis chi2 test
	Mean	Std	Mean	Std	Mean	Std	P value
adop_dummy	0.4	0.5	0.3	0.5	0.3	0.5	0.34
lncaarea	1.1	1.6	1.1	1.6	0.9	1.5	0.42
Familysize (no of persons in household)	5.2	2	4.3	1.4	6	2.6	0.00***
agehead (age of hh head)	47.6	11.7	38.3	13.3	48	13.7	0.00***
edhh (years of schooling of head)	5.9	4.3	7.4	4.8	5.6	4.2	0.00***
plno (number of plots)	4.5	2.5	4.2	2.4	4.3	2.5	0.69
sandsoil (soil is sandy, dec/hh)	9.6	28.6	5.1	16.3	12.3	42.4	0.44
loamsoil (soil is loamy, dec/hh)	101.2	111.8	93.1	94.9	64.9	55.6	0.00***
claysoil (soil is clay, dec/hh)	14.6	42.7	31.9	63.9	8.9	25.8	0.00***
irriprop (proportion of irrigated land)	1	0.2	1	0.2	0.8	0.4	0.00***
irrityp1 (dec/hh under electric STW irrigation)	29.1	65.9	11.5	58.1	30.3	56.8	0.00***
irritypO (dec/hh under other irrigation)	13.3	42.4	104.4	97.1	20.2	39.7	0.00***
croparea (total cropped area, dec/hh)	258.2	230.5	192	157.4	241.2	158.7	0.00***

rentlnd (Rented/lease in land, dec/hh)	24.3	49.7	41.7	86	41.3	53.6	0.00***
farm_1 (marginal farm=1)	0.2	0.4	0.2	0.4	0.3	0.4	0.12
farm_3 (medium/large farm=1)	0.1	0.3	0.1	0.3	0	0.1	0.00***
remit (international migration =1)	0	0.1	0	0.2	0.2	0.4	0.00***
tlu (herd size, tropical livestock unit)	2.3	3	0.3	0.7	1	1.2	0.00***
q52d (non-agri labour income BDT/hh)	4492	17015	3615.8	21886	7600.5	32965	0.12
q52i(Other income, BDT/hh)	10863	48662	16861	56701	29672	231713	0.02**
machine (scarcity of machine=1)	0.4	0.5	0.1	0.3	0.3	0.5	0.00***
transport (hh owns transport)	0.8	0.4	0.8	0.4	0.3	0.5	0.00***
helpneed (social network help=1)	0	0.2	0	0.1	0.1	0.3	0.04**
project (received project services=1)	0.4	0.5	0.3	0.5	0.4	0.5	0.89
govt (received govt services=1)	0.2	0.4	0.4	0.5	0.5	0.5	0.00***
Moisture (*Rabi* crop not delayed=1)	0.1	0.2	0.1	0.2	0.1	0.4	0.00***
climate3 (water logging in *Kharif1*, dec/hh)	10.6	54.1	4.3	17.9	17.1	36.3	0.00***
weedlevel (index ranging 0-1 highest)	0.5	0.2	0.5	0.2	0.7	0.2	0.00***
RMsys (farm has both rice and maize=1)	0.6	0.5	0.6	0.5	0.6	0.5	0.68
Msys (farm has maize, no rice=1)	0.1	0.3	0.1	0.3	0	0.2	0.23