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Cereal Systems Initiative for South Asia Phase III

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Acronyms

BADC	Bangladesh Agricultural Development Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BDT	Bangladesh taka
BPL	Below poverty line
CA	Conservation agriculture
CIA	Central Intelligence Agency
CIMMYT	International Maize and Wheat Improvement Center
CSISA	Cereal System Initiative for South Asia
DAE	Department of Agricultural Extension
DSR	Direct-seeded rice
GDP	Gross Domestic Product
LCC	Leaf color chart
NW	North Western
OPV	Open pollinated varieties
PT	Power tiller
PTOS	Power tiller operated seeder
QTL	Liquid quart
RCT	Resource conserving technologies
USDA	United States Department of Agriculture
WFP	World Food Programme

Executive Summary

The present study assesses cereal production in selected areas of NW-Bangladesh, especially with respect to the biophysical and socio-economic characterization of cereal producing farm households. Three major cereal crops, namely rice, wheat, and maize dominate the cultivated land area (84%), as well as the overall agricultural economy, of Bangladesh. Positive change to the sustainability and productivity of these cereal systems are crucial to the domestic food security of both urban and rural Bangladesh, as around 2 million people are being added to the country's population annually. The land available to agriculture in this country is also under constant pressure from land degradation and transfer to alternative uses. Meeting the growing demand for food and feed by increasing food grain production has therefore become a pressing challenge for the country, and the importance of resource conservation and productivity enhancement as part of the response is increasingly recognized in the region. Against this backdrop, the empirical part of the study estimates the economics of cereal production and conventional technology diffusion with which the potential of conservation agriculture (CA) in the region can be assessed.

Primary data required for the study was collected from sampled households through personal interviews using a comprehensive and pre-tested questionnaire. The primary data collection was carried out in 18 villages of three districts in northwest Bangladesh (Dinajpur, Rajshahi and Nilphamari). The shares of cultivable area to the total land area in the study sites are 77% (Dinajpur), 74% (Nilphamari), and 63% (Rajshahi). Prior to sampling farm households, a village census was enabled to document the general village characteristics such as population, land-use, infrastructure, agricultural input-output markets and prices. A comprehensive baseline household survey (324 households) followed based upon the random selection of farm households. In order to examine the characteristics of the households more extensively, the sample was categorized into three mutually exclusive groups by landholding size: small (0.66 acres, lower 33%), medium (between 0.67 and 1.64 acres, middle 33%), and large (greater than 1.64 acres, upper 33%) farmers. Medium and smallholdings dominate the study area, with cereal producing subsistence farmers prevalent among the smallholders.

Among the sampled households, crop production is the major source of income and livelihood – contributing to 38% of total annual household income, on average. Unsurprisingly, large farmers derive a greater share of their income from cropping (55%) than small farmers (25%). On average, the large farmers cultivated land 6.3 times greater in area than do the small farmers. The average rent for the leasing of the land was BDT 14,572 per acre, while the same for leasing out was BDT 17,264 per acre. The ability of farmers in developing countries to invest in land is largely influenced by some form of credit access. About 48% of sampled farmers have taken some form of credit with an average amount of BDT 18,385, with large farmers taking more credit (BDT 28,451) than small (BDT 11,140) and medium (BDT 15,688) farmers. However, small farmers are paying a higher interest rate (26%) than the medium (24%) and large farmers (19%).

The major crop rotations followed in the region are rice–rice, rice–wheat, rice–maize and potato/maize (intercropping)–rice. Most of the cereal crops, especially during the Rabi season, are cultivated with irrigation. About 80% of the total irrigated area was covered by groundwater, with shallow tube wells being the dominant source (65% of the total area irrigated). Rice was the only crop in the Kharif (Aman) season; about 73% of cultivable land was occupied by open pollinated varieties of rice (OPVs) – with 90% of the sample farmers cultivating such varieties, while hybrid rice was cultivated only by two large farmers. During the Rabi (Boro) season, 54% of sampled households reported cultivating OPV rice, which occupies 31% of the cultivable land. Hybrid rice is more popular during this season, grown on 7% of cultivable land by 15% of the farm households. Wheat is grown on 18% of land by 45% of households, while maize occupies 8% of the cultivable land with 13% of households involved in its production.

In the case of rice, the most preferred varieties were Swarna and BR 11. The average yield (13 quintals per acre) in the study area was significant among all the farmers. The most popular wheat varieties in the study areas were Shatabdi, Prodip, and Bijoy; together these varieties accounted for about 92% of the wheat acreage. The overall average yield of wheat was approximately 11 quintals per acre and there was no significant difference across the farmer groups. Maize ranks as the third most important cereal crop after rice and wheat. Only about 8% of cultivable land (13% among crops) was occupied by Rabi maize, and 7% of cultivable land (11% of farmers cultivate) was planted to spring maize. Only hybrid maize cultivation was found in the study area; NK 40 and 900 M were the most popular varieties in both the maize seasons, and the average yield was about 30 quintals per acre across varieties.

The study area is characterized by a very insignificant presence of the government and public sector (cooperatives) agencies. The village private dealers dominate the input channels with a share of 96% of the fertilizer and pesticide markets. The sources of OPV rice seeds are also mainly private dealers (93% village, 6% district, and 1% government). An exclusive monopoly of private dealers (63% village, 37% district) was observed for the hybrid rice seed market.

Unsurprisingly, a similar domination by village private dealer in case of both wheat and maize seeds was found through which 91% of wheat seeds and 82% of hybrid maize seeds were sourced. Only about 40% (much lower among small farmers) of rice and wheat grain production was marketed. However, maize is produced mainly for markets in Rabi and spring seasons, with significant profit. The average price of rice and wheat grain was BDT 1,860 per quintal and BDT 1,784 per quintal, respectively. The market price of maize grain varies across the varieties cultivated; the highest price was obtained from M 1,873 (BDT 1,400/quintal) and a lower price for NK 40 (BDT 943/quintal).

On average, the total paid-out cost of Aman rice is BDT 11,239 per acre; the difference among the farm size groups was small. The gross revenue of Aman rice cultivation was BDT 23,594 per acre, making rice a profitable crop with cost–benefit ratio approximately 1:1.9 after imputing family labor cost. There was no significant difference in input use or profitability of rice farming among farmer groups based on the scale of operation. On average, the total paid-out cost of Boro rice was BDT 12,603 per acre. The gross revenue of Boro rice cultivation was BDT 38,782 per acre, making rice a profitable crop with a cost–benefit ratio of approximately 1:2.5, after imputing family labor cost. This net revenue is more than twice that of Aman rice, mainly due to higher crop productivity. The average paid-out cost of wheat was BDT 9,899 per acre; small farmers were observed to be more cost-effective than other groups. The gross revenue of wheat cultivation was BDT 20,036 per acre, with only small variations between the farmer groups. The cost–benefit ratio of wheat cultivation was approximately 1:1.9 after imputing family labor cost. The average total paid-out cost of maize during Rabi was BDT 11,931 per acre and BDT 8,864 per acre in spring. The cost–benefit ratio with imputed family labor is 1:2 (Rabi) and 1:2.5 (spring); spring maize has a higher ratio due to the lower cost of cultivation compared to Rabi maize.

Most farmers in the study area have adopted the use of two-wheel tractors (91%), diesel pumps (88%), and mechanical pesticide sprayers (79%), with more large farmers owning their machinery. Although awareness exists among farmers regarding technologies such as laser land levelers, seed treatment/priming, and leaf color charts (LCC), CA techniques such as turbo/ happy seeders, no-till, quality protein maize, and site-specific nutrient management are relatively unheard of. For example, only less than 2% of farmers were found adopting zero (no) tillage, direct seeded rice, and bed planting. They perceive little impact from these technologies, although 23% of non-adopters were aware of them. Understandably, given the absence of information dissemination and government encouragement, the lack of information and unavailability of the products seem to be the key constraints inhibiting wider application of CA technologies, despite the documented benefits to be gained.

In summation, the results of this study indicate a small average size of farms, a high level of inequality, lack of suitable crop variety, and the inadequate presence of government or public sector input and output market channels. The overall challenge is, therefore, to reduce the dependence of farmers on external inputs, curb the total cost of production, and achieve the goal of sustainable production of cereals through the adoption of new productivity-enhancing technologies, including CA (or individual elements thereof). To achieve this, the cereal sector in this region must overcome current unawareness among farmers about these technologies, the unsuitability of some of the technologies to be applied to small and marginal farms, and the scant involvement of the government and public sector in spreading awareness, as well as making the technology affordable. In addition, there must be sufficient provision of efficient market channels in order to encourage farmers to increase yields and profitability by adopting these technologies.

1. Introduction

Ariculture is an important economic activity in Bangladesh, contributing 19% to the national GDP (BBS 2012). Dominated by cereal production systems, the sector employs approximately 62% of the country's labor force. Out of the gross cropped agricultural land in the country, 84% is occupied by three major crops: rice, wheat, and maize.[1] Rice alone accounted for 79% of the total cultivated area in 2008 (MoA 2009) and is the most important staple food of the country, contributing (on average) over 63% of the caloric intake for urban consumers and 71% for the rural population (WFP 2008). Although wheat and maize in Bangladesh have relatively small shares with respect to the total cereal area (4% and 1%, respectively [BBS 2008a]) and production, changing dietary habits among high income groups is resulting in rising demand for processed foods of wheat and maize (USDA 2012). Nevertheless, approximately half of the population in Bangladesh remains poor (WFP 2008) – of which more than 50 million are extremely poor (BBS 2006; Quisumbing et al. 2011) – with limited availability and access to food.

Every year, almost 2 million people are being added to the total population of the country (BBS 2008b). By 2020, Bangladesh's overall cereal production should reach more than 35 million tons (DAE 2007) in order to feed a projected 167 million people.[2] The country has registered a population growth of 1.6% per annum (est. CIA World Factbook 2011) and proportionate growth in food production is crucial for ensuring the food security of millions. However, production growth rates of the two major cereals (rice and wheat) have been either stagnant or levelling off during the last decade (Ray et al. 2012; Lin and Huybers 2012). The trend is quite evident in wheat, where the rate of growth is negative for both acreage and production (-5% and -8% respectively). Except for a marginal growth rate of 1% in area and 4% in production (BBS 2007), there has been no significant change in rice productivity also during the last decade. Although the area under hybrid rice has shown positive growth, the area under local rice varieties is declining (ibid). Projected estimates of current area and production of rice show that, depending upon the prevailing supply–demand scenario and intermediate demand requirements, Bangladesh could face either a surplus or a deficit of rice in the next 20 years (Ganesh-Kumar et al. 2012).

Along with the demand for cereals for food, there is also an increasing pressure on cereals for animal feed. Maize as an input in poultry feed production in Bangladesh is growing rapidly. In 2005–2006, the country's maize area and production expanded by 24% and 37% respectively (BBS 2007). The expansion of the maize sector was further supported by investments in productive agricultural technologies (e.g. hybrid maize seeds and conservation agriculture practices) and food value chains (Ali et al. 2009; Waddington et al. 2012).

Unlike the feed demand response, however, the post-Green revolution food demand and supply shortage in Bangladesh has been dealt with by liberalizing food import policies (since 1999). As a result, the country's reliance less on national food production and more on food imports has now become a contentious policy due to the high price volatility of these imports (Dorosh and Rashid 2012). In fact, the domestic food security of both urban and rural Bangladesh is heavily dependent on the sustainability and productivity of its cereal systems. Increasing food grain production to meet the growing food, feed, and other diverse demands has therefore become a pressing challenge for Bangladesh. The present study therefore examines the cereal production status of this region, especially with respect to the economics of crop production and

[1] Computed from 2007 BBS data on agricultural crops cultivated in Bangladesh.
[2] Forecasted according to the Ministry of Health and Family Welfare (MOHFW), Bangladesh's strategic directions for the national family planning program: 1995-2000.

conventional technology diffusion, against which the potentials of conservation agriculture (CA) can be assessed.

Coming to the cropping systems, rice–rice and rice–wheat systems primarily constitute the cereal production systems in Bangladesh.[3] They still remain the cornerstones of food security, rural development, and natural resource conservation in the region (Paroda et al. 1994; Timsina and Connor 2001; Gupta et al. 2003; Ladha et al. 2003), but these systems are constantly being challenged by the problems of land degradation and shrinkage. As in many other regions of South Asia, farms in Bangladesh are undergoing continuous fragmentation of landholdings (Niroula and Thapa 2005). At the same time, Bangladesh also faces an urgent need to expand its housing, transportation infrastructure, and educational facilities, etc. in order to meet the growing demand of a rising population. In a land-scarce country, the effort to allocate land for non-agricultural purposes is naturally putting further pressure on Bangladesh's cereal production systems (Ullah 2002). Prompted mostly by the existing agricultural labor shortage and demand for land from other sectors, there is an on-going trend in the region to convert parts of cropland to alternate uses. Owing to one or many of the above reasons, the average farm size declined from 1.4 ha in 1977 to 0.86 ha in 2006 (BBS 2007). Kam et al. (2005) suggest that this trend of increasing landlessness and fragmented landholdings affect extremely poor households particularly adversely. It also reduces both productivity and efficiency of farming (Rahman and Rahman, 2009).

During the past decade, human shortage has paved the way for agricultural mechanization – the use of power tillers, in particular. The adoption of power tillers (PTs) has been advancing at an impressive pace in Bangladesh, replacing animal draught (iDE 2012). Conventional PT use involves more than two passes of heavy tillage or plowing, which results in adverse changes to soil properties such as reductions in water-holding capacity and bulk density (Monayem et al. 2009). Apart from human-induced factors such as heavy tillage and inappropriate input use, natural phenomena responsible for abiotic stresses such as land degradation, acidification, fertility and organic matter loss, also show an increasing trend in Bangladesh (Rahman 2008). In the southern part of the country in particular, significant land degradation processes occur due to plow-pan formation, soil erosion, soil salinization, continuous water logging, and riverbank erosion. Alongside such abiotic stresses, natural hazards such as sudden flash floods, tidal surges, and drought result in significant crop vulnerability to productivity changes (Rahman 2008). Furthermore, poor management practices, especially those with regard to pests and diseases, fertilizers, water and irrigation have added significant hurdles in achieving the full yield potential (Mondal 2010) of cereals production in Bangladesh. Against this backdrop, the introduction of appropriate CA-based resource conserving technologies (RCTs) offers an opportunity to enhance and sustain the productivity of limited land and other available inputs, while conserving the natural resource base of the production system.

Conventional agriculture, often involving intensive tillage as mentioned previously, is often claimed to cause soil degradation (especially so when practiced in areas of marginal productivity). The CA technology alternatives include a set of integrated soil and crop management practices that aim to minimize the negative effects of intensive farming. The RCTs recommended under the CA paradigm include direct sowing (i.e. zero tillage), minimum (or reduced) tillage, the establishment of cover crops and the retention of crop residues as mulch (both of which protect organic matter, soil moisture, and soil fertility), and the introduction of varied and appropriate crop rotations. The present study is focused on the potential of CA-based RCTs in cereal production systems in the northwest region of Bangladesh, in particular on a

[3] Rice-maize to a lesser extent also, although this system is gaining popularity.

biophysical and socioeconomic characterization of the cereal-producing households of the hub domain. Policy implications, including addressing structural causes of land fragmentation, building of infrastructure, improvements in extension services for adoption of modern production technologies, are discussed.

The rest of this document is organized as follows: Section 2 describes the study area, while Section 3 provides an explanation of the sampling and data collection procedures employed. Section 4 presents a socioeconomic characterization of the sampled households, followed by details regarding varietal adoption in Section 5. In Section 6, the economics of cereal production are analyzed and discussed. Section 7 captures the livestock productivity information, and in Section 8 the input and output market channels of cereal productions of the study area are characterized. Section 9 focuses on resource conserving technologies (RCTs), including information on adoption and familiarity, as well as explaining perceived impacts of technologies on farm profitability and reasons for their non-adoption. The final section contains the conclusions of the study.

2. Study area

This document is the outcome of work conducted under a research for development project known as the Cereal System Initiative for South Asia (CSISA). The initial phase of the CSISA project was implemented during the period 2009–2012 in four countries along the Indo-Gangetic Plains: India, Nepal, Bangladesh and Pakistan. The project follows a 'hub-based approach' in which the project identifies domain areas based on agro-ecological zones within which research and project interventions are conducted. Two hubs were established in Bangladesh (one in the northwest region, and one in the region north of Dhaka) in order to represent key intensive cereal production systems. The present study builds on the comprehensive baseline household survey of the NW Bangladesh Hub.

The study area comprises three districts in this hub: Dinajpur, Nilphamari and Rajshahi (Figure 1). They were selected purposively to capture the diverse cereal production systems of the study region. The shares of cultivable area to the total land area in the study sites are 77% (Dinajpur), 74% (Nilphamari), and 63% (Rajshahi). The study area has a tropical monsoon climate characterized by wide seasonal variations in rainfall, high temperatures, and high humidity. Three cropping seasons are commonly recognized: a hot, humid spring (March to June) known as "Kharif 1"; the monsoon period (July to October), known as "Kharif 2"; and a cool, dry winter (November to February) known as the "Rabi" season. The annual average rainfall in the study area ranges from 1,448 mm (Rajshahi District) to 2,931 mm (Nilphamari District). Approximately 80% of the rain in Bangladesh is obtained during the 4-month monsoon season. About 80% of the total irrigated area is covered by groundwater, with shallow tube wells being the dominant source (65% of the total area irrigated). The dominant cropping patterns of NW Bangladesh are rice–rice, rice–wheat, rice/fallow–maize, and potato/maize–rice (Krishna et al. 2012). The major CA-based RCTs in the research pipeline or various diffusion programs are power tiller operated seeder (PTOS), bed planting of wheat, modern improved varieties of rice and wheat, quality seed and seed treatment and crop diversification through inter-cropping and rotations (ibid).

3. Data collection and sampling procedure

Primary data collection was carried out employing three tools: (i) a village survey of 18 total villages, conducted with a group of respondents to document general village characteristics such as infrastructure and prices, as well as population and land-use details; (ii) a village census to identify all the households and collect a set of basic variables that allow for efficient household sampling; and (iii) a household survey among 324 cereal farmer households. Villages and households were selected according to a stratified random sampling method common across CSISA hubs of South Asia. Three districts within each hub domain were selected purposively to capture a wide variety of cropping patterns and the dynamics of RCT diffusion. Within each selected district, three lower administrative units (known as "unions") were purposively selected from the set of sub-districts (upazilas) in which CSISA was active. Within each selected union, one village with CSISA activities and one village without CSISA activities were randomly selected from relevant lists.

Subsequent to the selection of districts, eight union councils (UCs) were selected for the study after discussion with the hub managers and national partners: three in Dinajpur, three in Nilphamari, and two in Rajshahi (Figure 2). From most of these UCs, one CSISA intervention village and one non-CSISA village were randomly selected. In Yousufpur UC of Rajshahi district, two CSISA and two non-CSISA intervention villages were selected, as only limited project activities are planned in this area. The non-CSISA villages were selected from a complete list of villages obtained from the upazila head offices. A total of 18 villages were covered in the survey, nine in which CSISA activities had already begun (or were planned for the future) at the time of the baseline survey.

For the household survey, the sample households were randomly selected from the list of farming households drawn from the village census data. Based on land size owned by the households, the households were first sorted in ascending order of smallest to largest. This sorting was followed by systematic random sampling to select households across the landholding categories for the data collection. A total of 18 cereal (rice, wheat, and/or maize) growing households were selected from each village, making a total sample of size 324 (108 households per district). The household survey was conducted during the period of August–October 2010, with the objective to create a benchmark assessment of the cereal production systems of NW Bangladesh for further examination on the potential of CA-based production technologies. A structured questionnaire was developed for the household survey data collection in a joint effort by socioeconomists, agronomists, plant breeders, and soil scientists from different core partners of the CSISA project.[4] The questionnaire was pre-tested and modified before the actual survey was initiated. The enumerators involved in the data collection activities were familiar with the local economic conditions, and they were trained with mock interviews, and consistently monitored by CIMMYT and the hub-level socioeconomist. The collected data were periodically examined by the CIMMYT socioeconomist of South Asia, in order to avoid systematic errors in data elicitation. The study also used a significant amount of secondary data gathered from the BBS and the DAE. The primary data collected were tabulated, cleaned and subjected to statistical analysis to draw meaningful conclusions.

[4] The CSISA project is collaboration among several organizations of the Consultative Group for International Agricultural Research (CGIAR), including CIMMYT, IRRI, ILRI, and IFPRI.

4. Socioeconomic categorization of farming households

On-farm production and productivity generally depends on the extent of operations of the individual farm household. Large farmers, for example, with their extended scale of operation, often have better access to credit and markets, and are often more able to invest in improved inputs. The categorization of farmers based on the scale of operation, albeit relative, helps to understand the various factors which affect production, including farm assets, the choice of behaviors (such as the selection of crops and production technologies), market channels and, in particular, cereal cultivation patterns. For analytical purposes therefore, the farming households studied here are categorized according to the relative size of land under cultivation, into three mutually exclusive groups: small (lower 33%), medium (middle 33%), and large (upper 33%) farmers. Small farmers cultivate land less than 0.66 acres, medium farmers between 0.67 and 1.64 acres and large farmers more than 1.64 acres. The inequality between the studied farmer groups is high in terms of land under cultivation; on average, large farmers cultivate 6.3 times more area that what small farmers cultivate. The households sampled also include landless farmers, that is, farmers who do not own land, but who cultivate by leasing land or through shared cropping. About 29% and 12% of sampled farmers in the small and medium categories respectively have no land of their own (Table 1). The average area of land cultivated by the sampled households is 1.49 acres, greater than the average size of land owned (1.17 acres). This is also reflected by more households leasing in/sharing in land than leasing out/sharing out (overall averages are 31% and 12% respectively). It is interesting to note that more small and medium farmers are leasing in or sharing in land than large farmers, unlike in other parts of South Asia; this may be an indication of scarcity of off-farm employment opportunities in the study region. The average rent for leasing in land is BDT 14,572 per acre, while for leasing out it is BDT 17,264 per acre. This form of temporary transfer of cultivation rights is more popular than sharing, where both landowner and cultivator agree to share input and output costs equally.

The study area is known for a relatively diverse cropping pattern, as rice, wheat and maize are grown during different seasons of the year. Rice is the dominant crop during both Aman (cultivated by 90% of sample households) and Boro (61%) seasons (Table 1). Boro rice is more popular among large farmers. Among the sample farmers, the second most important crop is wheat, cultivated by 45% of households, followed by Rabi maize (13%) and spring (11%) maize. Interestingly, wheat cultivation is relatively more attractive to small farmers while larger farmers prefer maize cultivation. The subsistence nature of the former and non-food end-use of the latter could be associated with this difference. Alongside cropping season, the choice of cropping pattern is also influenced largely by the availability of irrigation water.

Most of the cereal crops, especially during the Rabi season, are irrigated (details of acreage under irrigation and associated costs are provided in tables 5–7). In the study area, tube wells form the most important source of irrigation, with the ratio of purchased-to-own groundwater being 2:1. Although irrigation using diesel pumps incurs a higher variable cost per crop season, the majority of farmers (79%) prefer this to electric pumps, which demand a higher fixed cost of establishment. About 48% of the total sample farmers (63% of small farmers) have to purchase water for irrigation, while 31% (57% of large farmers) use their own source of groundwater. Of the farming households, 18% have hired electric pumps for groundwater extraction. Unsurprisingly, irrigation costs more when the water is purchased than when it is extracted from the farmer's own sources (Table 7).

General socioeconomic characteristics are varied across the farmer groups as well. Only 2% of sampled households are headed by female members, nearly all of them being small farmers. While the age of household heads does not differ greatly across different farmer groups (the average being 44 years), large farmers have received considerably more schooling (6 years) than their small farmer counterparts (3 years). There also is significant variation across the surveyed households with respect to their endowment with assets and the composition of their income (Tables 2 and 3). Only 39% of the sampled households have an electricity connection, but all households have access to piped drinking water (via a hand-operated tube well). Only a few (and only small and medium) farmers have access to ration cards (4% overall), although many (54%) have below poverty line (BPL) cards. It is also not a surprise that the large farmers have greater access to BPL cards than small farmers, possibly due to their ability to bear the transaction costs needed to obtain them.

Cereal productivity and input use are closely related and farmer access to credit is often a determining factor in the adoption of improved production technology. Access to, and timely availability of, adequate low-cost credit is therefore important in cereal production – especially for small and marginal farmers. About 48% of the sampled farmers have taken out some form of credit (the average amount being BDT 18,385), with large farmers taking more credit (BDT 28,451) than small (BDT 11,140) and medium (BDT 15,688) farmers. However, small farmers are paying a higher interest rate (26%) than medium (24%) and large farmers (19%). Lack of material assets may be preventing the small farmers from obtaining institutional credit with lower rates of interest. Most of the credit taken (27%) is used for rice cultivation; 10% is used for livestock production and around 4% for wheat and maize cultivation (Table 8).

As far as other economic activities are concerned, most of the households studied are engaged in livestock production. Even among small farmers, nearly two-thirds keep large ruminants, while nearly all large (90%) farmers keep at least one cow (Table 2). However, the number of cows and bullocks kept per household is only moderately higher in large farms compared to medium and small farms. Some small ruminants are kept by about half of the households in all the farm size groups; again, a relatively higher number is kept by larger farmers.

Among the sample households, crop production is the major source of income and livelihood, making an average contribution of 38% to total annual household income (Table 3). Unsurprisingly, large farmers derive a greater share of their income from cropping (55%) than small farmers (25%). However, it is somewhat surprising to find the second most important source of income is business ventures, with an average contribution of 22%. Among both small and medium farmers, wage labor in both agricultural and non-agricultural sectors contributes significantly to income. As expected, the share of this income diminishes with farm size. Small farmers also receive a higher proportion of their income (12%) from providing services (under regular employment contracts) in comparison to the larger farmers (8%). Livelihood support from livestock is only subsidiary, with small farmers obtaining a slightly lower share of household income (5%) than their larger counterparts.

In the larger perspective, the major crop rotations in the NW Bangladesh villages are rice–rice, rice–wheat, rice–maize and potato+maize (intercropping)–rice (Krishna et al. 2012). From Table 4, it is evident that rice is the only dominant crop in the Kharif (Aman) season; about 73% of cultivable land is occupied by open pollinated varieties of rice (OPVs) which 90% of the sample farmers cultivate, while hybrid rice is cultivated by only two large farmers. During this season, approximately one-fourth of the cultivable land is kept fallow, mainly due to lack of irrigation facilities. In the Rabi season, OPV rice occupies 31% of cultivable land, with 54% households cultivating it. Hybrid rice is more popular during this season, grown on 7% of cultivable land by 15% of the farmer households. Wheat is grown on 18% of land by 45% of households, while maize occupies 8% of the cultivable land with 13% of households involved in its production. However, wheat and maize farmers were over-sampled in this study to get adequate data points for the input–output relationship; these percentage figures thus are not representative of NW Bangladesh. In fact, the cereal acreages are much less varied among the farming households.

On the other hand, non-cereal acreage in the study area is about 23% of the cultivable land, and is occupied mainly by potato, tobacco and sugarcane (Table 4). Among these, potato and sugarcane are the most popular crops, following rice and wheat. Apart from sugarcane, 100% of the recorded cereal and non-cereal crops acreage is grown under irrigation during the Rabi season. As adequate irrigation is available during this season, very little land (4%) is left fallow. In spring, maize – the only cereal cultivated during this season – occupies 7% of the cultivable land with 11% of households involved in its production. The entire spring maize crop is irrigated. The non-cereal crops grown during spring are pulses, grams and jute. Pulses and grams are grown on 12% of the cultivable land by 29% of households. These crops are most popular among small farmers, especially in Rajshahi. Jute occupies only 4% of cultivable land in the study area and is grown by 14% of households. However, most of the cultivable land (74%) is kept fallow during this season. Next, we look closely at which cereal varieties are chosen by season and by which farmer groups.

5. Varietal adoption in cereal crops

5.1 Aman rice

In Bangladesh, the Aman season is known for the cultivation of rice OPVs. Of the 324 farmers interviewed, only two farmers cultivate hybrid rice in this season. There is significant variation in varietal preference among Aman rice farmers (Table 9), the most preferred varieties being Swarna (an OPV; occupying 75% of rice acreage and 84% of farmers cultivating it) and BR 11 (an HYV, occupying 12% of rice acreage and 19% of farmers involved in cultivation). The next five popular varieties in the study area are Katari (a local aromatic rice), BR 34, Hori Dhan, BR 33 and BR 32, which together occupy 8% of the rice acreage. Among the different varieties cultivated by farmers, the highest yield is obtained for the variety BR 6 (16 quintals per acre) and the lowest yield is obtained from the variant Kalizira (a local aromatic rice yielding about 10 quintals per acre). However, less than 1% of farmers cultivate these varieties. The average yield of all the varieties in the study area is significant among all the farmer groups and yield obtained is about 13 quintals per acre.

In addition to the yield obtained, grain markets play an important role in determining the varietal adoption. There is a significant difference across the farmer groups with respect to share of grain marketed (Table 10). Unsurprisingly, this share is extremely negligible among small farmers (5%), compared to medium (31%) and large (62%) farmers; the former is thus less affected by price volatility in the grain market. The average price of rice grain is more or less similar among the groups; the overall average price is BDT 1,860 per quintal. The variety, which receives higher market prices, is Kalizira (BDT 3,258/quintal); BR 41 receives the lowest price (BDT 1,625/quintal). This variation in market price could be because of consumer preference or grain quality.

5.2 Boro rice

Rice OPVs occupy 31% of the cultivable land (and are cultivated by 54% of farmers), while hybrid rice is cultivated on 3% of cultivable land (by 15% of farmers) in this season (Table 4). The varietal preference among farmer groups is presented in Table 11. The most preferred rice varieties are BR 28 (65% of rice acreage and 65% of farmers) and BR 29 (12% of rice acreage and 16% of farmers). Other popular varieties found in the study area are Pari, Hira, ACI 1, Iraton, Lal Teer and BR 33; together they occupy 16% of the rice acreage. Among the varieties cultivated by the farmers studied, the highest yield is obtained by the variety Sonar Bangla 1 (about 30 quintals per acre) and the lowest yield is obtained from BR 33 (18 quintals per acre) (Table 12). However, these varieties are cultivated by only 3–4% of sample farmers. The average yield of all the varieties in the study area is much above the Aman rice at 23 quintals per acre. Nevertheless, as in the case of Aman rice, a significant difference exists across the farmer groups with respect to share of grain marketed, although small farmers produce more for markets in the Boro season than in Aman. The share of grain marketed is lowest among small farmers (17%), followed by medium (32%) and large (55%) farmers. The variety, which receives the highest market prices, is BR 16 (BDT 1,869/quintal) and the lowest price is for ACI 1 (BDT 1,507/quintal).

5.3 Wheat

This is the second most important crop in the study area after rice, in terms of acreage and production. Wheat varieties found here are high-yielding OPVs, most of which were developed by the Wheat Research Centre of BARI; the most popular varieties in the study the Wheat Centre of BARI; the most popular varieties in the study area are Shatabdi, Prodip and Bijoy, and together they cover about 92% of the wheat acreage (Table 13). The other wheat varieties found in the study area are Sonalika, Kanchan, Balaka, Gourab, Swarna and Protiva. Wheat yield and marketing information are shown in Table 14. The variety which obtained the highest yield was Shuchana (14 quintals per acre); the lowest yield was obtained by Protiva (8 quintals per acre), but only 2% of the large farmers cultivate each of these varieties (Table 14). The overall average yield is about 11 quintals per acre and there is no significant difference across the farmer groups. Similar to the case of rice, the market share of wheat grain is less in small (18%) farmers compared to medium (47%) and large (67%) farmers, due to the subsistence nature of wheat production by small farmers. There is a significant difference in the market price of wheat grain among farmer groups as well as in varieties. The market price is higher for Bijoy (BDT 2,085/quintal) and lowest for Kanchan (BDT 1,475/quintal). The market price obtained by small and medium farmers is 6% higher than the large farmers, and the overall price obtained from all the varieties is BDT 1,784 per quintal.

5.4 Rabi maize

Maize ranks as the third most important cereal crop after rice and wheat. However, only about 8% of cultivable land (13% of all crops) is occupied by Rabi maize and 7% of cultivable land (11% of farmers cultivates) by spring maize. The Rabi maize acreage of large farms is much higher than that of small and medium farms, by about 800% and 100% respectively. Only hybrid maize cultivation is found in the study area; NK 40 and 900 M are the most popular varieties in both the maize seasons (Table 15). In the Rabi season, NK 40 occupies about 67% of maize acreage and 65% of farmers are involved in its cultivation. Small farmers only cultivate NK 40. Hybrid 900 M occupies 17% of the total maize acreage and around 20% of farmers are involved in its cultivation. Large farmers adopt this variety widely compared to the other groups. The other notable maize varieties are 6323, Pioneer 92, M 1837 and Konak; together these contribute to 16% of maize acreage. The Rabi maize yield shows significant difference across farmer groups; a higher yield is obtained by large farmers compared to small and medium farmers (Table 16). The average yield is about 30 quintals per acre. Almost all of the Rabi maize harvest is sold. The market price of maize grain varies across the varieties cultivated and among farmer groups; the highest price is obtained for M 1873 (BDT 1,400/ quintal) and a lower price for NK 40 (BDT 943/quintal). The highest market price is obtained by small farmers, despite cultivating NK 40, the hybrid that fetches a relatively lower price compared to other varieties.

5.5 Spring maize

There is significant variation in the share of spring maize acreage across farmer groups: large farmers devote a relatively higher share of land compared to smaller (by 412%) and medium (by 239%) farmers (Table 4). Varietal adoption is similar to that of Rabi seasons: NK 40 and900 M are the most popular (Table 17). The former occupies 79% of the maize acreage (cultivated by 75% of sample farmers) and 900 M in 16% of the maize acreage (by 19% of farmers). Small farmers adopt only NK 40 and 900 M. The other popular varieties are ACI Gold, M 99, 1414 and M 1837. The marketing of spring maize grain is similar to that of the Rabi season; almost all farmers sell 100% of their grain product (Table 18). The price of spring maize grain varies among the different varieties; ACI Gold, M 99 and M 1837 fetch the highest price (BDT 1,250/quintal) and hybrid 1414 fetches the lowest (BDT 875/quintal).

6. Economics of cereal production

In this section we consider how the costs of cultivation, including the cost of irrigation, human and machine labor cost, and the share of seed, fertilizer and insecticide, are distributed according to season and cereal among the different farmer groups.

6.1 Aman rice cultivation

Details of Aman rice production, including cultivation practices and input usage, are presented in tables 19 and 20. The crop is sown in the month of June and harvested at the end of October or in the middle of November. The seed rate commonly used is 21 kg per acre and seed treatment is not followed. Direct sowing with no-till is not practiced, and on average, the farmers plough the land four times, spending BDT 469 on animal labor (4% of total paid-out cost) and BDT 1,750 on machine labor (13%) per acre. The composition of chemical fertilizers used for Aman rice comprises 29 kg of nitrogen, 25 kg of phosphorous and 17 kg of potash. A small quantity of herbicide (240 mL/acre) and fungicide (130 mL) is used per acre. In total, 45 labor days are required to cultivate an acre; 29% of total human labor is from family labor and 10% from women. All the rice farmers are harvesting manually; machine (combine) harvesters were not available in the study area during the survey.

A cost–return analysis has been carried out for the main plot (Table 21). The cost structure shows that the highest share of the cost associated with Aman rice is that of labor (one-third of the total paid-out cost), while medium and large farmers hire more human labor. Chemical fertilizer is the second highest cost incurred and accounts for 20% of the total paid-out cost. Machine and animal labor costs associated with land preparation and tillage operation are 17% of the total paid-out cost; the small farmers' share is higher than that of the larger groups. Contract labor is common in the study area and accounts for 12% of the total paid-out cost. There is a significant difference in irrigation cost, which indicates that small farmers are using purchased irrigation and large farmers are using own sources of irrigation. Seed cost incurred is more or less equal among the farmer groups and accounts for 7% of the total paid-out cost. The limited share of farmyard manure, herbicides, fungicides and insecticides is also included in the total paid-out cost. On average, the total paid-out cost is BDT 11,239 per acre; the difference among the farmer groups is small. The gross revenue of Aman rice cultivation is BDT 23,594 per acre, making rice a profitable crop with a cost–benefit ratio of approximately 1:1.9 after after imputing family labor cost. There is no significant difference in input use or profitability of rice farming among farmer groups based on the scale of operation.

6.2 Boro rice cultivation

Rice in the Boro season is grown between the last week of November and the middle of May. About 18 kg of seed is used on average per acre (Table 20). Chemical fertilizers used in Boro rice provide 35 kg of nitrogen, 17 kg of phosphorous and 19 kg of potash (Table 20). In addition, about 12 quintals of farmyard manure is applied by farmers on one acre of land, with large farmers using more manure than the others do. In total, Boro rice cultivation requires 63 human labor days, including family labor (39%) and women's labor (9%). The cost incurred in tillage operations comprises BDT 974 for animal labor and BDT 1,621 machine labor per acre.

The cost–return analysis of Boro cultivation is presented in Table 21. Cultivation is labor intensive (paid-out cost share 35%). The second highest cost item is chemical fertilizer, which accounts for 22% of the total paid-out cost. Irrigation comprises 16% of the cost, and here, a significant difference across farmer groups is observed: small and medium farmers incur 249% and 207% higher costs compared to the large farmers, as the members of the latter group depend on their own sources of irrigation. Machine and animal labor costs total BDT 12,603 per acre, and account for 14% of the total paid costs. The gross revenue of Boro rice cultivation is BDT 38,782 per acre, making rice a profitable crop with a cost–benefit ratio of approximately 1:2.5 after imputing family labor cost. The net revenue is more than twice that of Aman rice, mainly due to higher crop productivity.

6.3 Wheat cultivation

The cultivation practices of the wheat main plot are presented in Table 22. About 97% of the wheat farmers are involved in tillage operation, the average number of which is four per cropping season. Only small and medium farmers (4% each of wheat farmers) are not carrying out any tillage operation. All the large farmers are sowing seed manually, while about 96% of small and medium farmers do so, and another 4% sow using a two-wheel tractor-driven seeder. Wheat cultivation takes place from the end of November (sowing) to the end of March (harvesting); all the farmers harvest manually (machinery for harvesting was not available during the survey).

Input usage of wheat cultivation in the main plot is shown in Table 23. The seed used for one acre of land is 60 kg, more or less the same across all farmer groups. About 8 quintals of farmyard manure is used per acre; here, there is a significant difference among the groups, large farmers using more than small (180%) and medium (130%) farmers. The composition of chemical fertilizer used in the cultivation of wheat (per acre) is 30 kg nitrogen, 16 kg phosphorous, 17 kg potash, and 33 kg of agricultural lime. A limited amount of herbicides (270 mL/acre) and fungicides (50 mL/acre) are used. About 20 workdays of human labor are required per acre; this includes 59% hired labor and 15% women's labor. The costs of animal and machine labor used for tillage operations are respectively BDT 1,117 and BDT 1,790 per acre; the cost of animal draft is higher in large farmers and machine labor cost is higher among small farmers.

In addition to cropping pattern and input usage, cost components and revenues are given in Table 24. Chemical fertilizer (24%) cost and seed used (21%) cost appear to be cost-intensive; together they account for 45% of the total paid-out cost. The share of chemical fertilizer among large farmers is higher than that of the smaller groups. The different labor costs involved in cultivation are 16% machine labor, 14% hired human labor, 11% contract labor and 5% animal labor used per acre of land. About 8% of the total paid-out cost is involved in irrigation, where the cost to medium farmers is significantly higher than that for small and large farmers. Farmyard manure, herbicides, fungicides and insecticides constitute a limited share of total paid -out cost. Taking all the inputs used together, the average paid-out cost is BDT 9,899 per acre; small farmers are more cost-effective than other groups. The gross revenue obtained from wheat cultivation is BDT 20,036 per acre, with little variation between the farmer groups. The cost–benefit ratio of wheat cultivation is approximately 1:1.9 after imputing family labor cost. The net revenue with and without family labor is significantly higher in small and large (with little variation among the groups) farmers than in medium farmers. However, the managerial return is effective in the medium farmer group, possibly because the amount of family labor involved is less than that among small and large farmers.

6.4 Maize cultivation

The cultivation practices of Rabi and the spring maize main plot are compared in Table 25. The average number of tillage operations per acre of land during the Rabi season is four, and two in spring. During the Rabi season, only medium farmers (10% of the study sample) are not doing any tillage operation; about 32% of maize farmers are not doing any tillage operation in the spring season, while more medium farmers (more, that is, than the overall average) are not doing any tillage operation. A manual broadcast method is followed by all the maize farmers for sowing and no farmer is carrying out seed treatment in either season. The Rabi maize cultivation period is the end of November to mid-January (sowing) and from the last week of May to the first week of June (harvesting). Spring maize is cultivated from December to the end of January (sowing) and June to mid-July (harvesting).

Input usage in the main plot is presented in Table 26. There is little difference in input usage in the Rabi and spring seasons; the average seed rate used in both seasons is 7 kg per acre, while extra (12.5%) seed is used by small farmers for the sowing of Rabi maize and extra (12%) seed is used by medium farmers for spring maize. About 12 quintals of farmyard manure is used per acre for Rabi maize and 9.5 quintals in the spring season; small farmers do not use farmyard manure in either maize season. The composition of chemical fertilizer usage is more or less similar for both maize cultivations; the average of Rabi and spring maize is 28 kg of nitrogen, 17 kg of phosphorus, 21 kg of potash and 39.5 kg of soil pH amendments applied per acre. Herbicide is not used, with the exception of one medium farmer who used 30 mL per acre for Rabi maize; limited fungicide (225 mL/acre) is used. The average number of human labor days required for Rabi and spring maize is 49 days per acre. The share of hired labor used for Rabi maize is 64% (60% for spring maize); women's share of the labor is around 17% of the total labor involved in cultivation for each season. The cost of animal labor and machine labor varies significantly between seasons; costs are higher by 124% and 127% respectively in the Rabi season than in the spring season. The cost of animal and machine labor also varies significantly across the farmer groups (Table 26). Manual harvesting is carried out by all the farmers in the study area in both seasons, as combine (machine) harvesters were not available during the survey.

The cost–return structure of maize production given in Table 27 clearly shows that human labor is cost intensive and accounts for 31% (Rabi) and 38% (spring) of the total paid-out cost, while greater labor costs are incurred in larger farms than small and medium farms. About 20% of total paid-out cost is involved in Rabi maize (medium [435%] and large [544%] farmers' cost is higher than that of small farmers); the cost of spring chemical fertilizer is comparatively less than Rabi maize and adds 13% to the total paid-cost. In the case of Rabi (spring) maize, seed is also a major cost component, 17% (23%) of the total paid-out cost. About 12% of costs are involved in irrigation in both seasons; as with wheat and rice, significant differences arise due to more small farmers needing to purchase water while more large farmers have their own irrigation sources. Animal draught, machine labor, and contract labor costs together account for 19% (Rabi) and 13% (spring) of the total paid-out cost. Most of the maize farmers surveyed use own sources of farmyard manure (small farmers use none); herbicides are not used (excluding one medium farmer in Rabi season) in both seasons. A limited share (2%) of fungicide and insecticide costs is also included in total paid-out cost. The average total paid-out cost during Rabi is BDT 11,931 per acre and BDT 8,864 per acre in spring. The cost–benefit ratio with imputed family labor is 1:2 (Rabi) and 1:2.5 (spring), while spring maize brings a higher benefit due to the lower cost of cultivation in spring compared to Rabi maize. The managerial returns to family labor are higher for large farmers for both maize seasons; the return is more than twice that of small and medium farmers for Rabi maize. It is two (small farmers) and four (medium farmers) times higher in spring maize.

7. Livestock productivity

The Government of Bangladesh has given top priority to livestock development in recent years to meet the growing demand for milk, meat and egg production, and to create employment and generate income for the rural poor. Statistics show that about 6.5% of national GDP is covered by the livestock sector, which has an annual productivity growth rate of 9%. The majority of livestock found in NW Bangladesh are cattle, buffalo, goat, sheep and poultry. The sampled households in the study area rear crossbred and local cattle (see Table 2); crossbred cattle are less adaptable and more susceptible to parasitic infestation and disease compared to the local variety. The cattle are mostly reared as a component of traditional crop-based farming and as a source of manure. Female buffaloes are not found in the sampled households; male buffaloes (bullocks) are used as draught animals for ploughing and pulling carts. More goats and sheep are owned by farmers across all the farmer groups than large ruminants. About 20% of the population of Bangladesh earns their livelihood through work associated with raising cattle and poultry. Livestock resources also play an important role in the sustenance of landless people.

Livestock form the second most important asset and source of income for the farming households in the study area. About 6.5% of household income is from livestock activities estimated in the study area (Table 3). The ownership of large and small ruminants is common in the study area; about 78% of the households own large ruminants and 56% of the households own small ruminants. Within the household sample, livestock ownership and size of cultivated land are positively correlated. Livestock productivity information is given in Table 29; first calving marks the beginning of a cow's productive life. The age at first calving is closely related to the generation interval; the local cattle in the study area give birth first at the age of 47 months, and crossbred calves at about 56 months. Cattle in the tropics have on average lower milk yields and shorter lactations than cattle in temperate countries; this difference is caused by both genetic and non-genetic factors. In tropical cattle, milk production often ceases several months before the next calving and before the depressing effect of gestation on milk production is evident. Length of lactation is not so greatly influenced by the calving interval. The lactation length of crossbred cattle (10 months) is greater than that of local cattle (7 months) in the sampled households. The maximum milk yield of a crossbred cow is three times higher than that of a local cow (7.2 liters vs. 2.2 liters per day). The annual milk yield of local cows is 551 liters and that of the crossbred is 1,857 liters. The inter-calving period is higher in crossbred cows (17 months vs. 13 months for local cows). The aim of over-mating is to ensure that only pregnant heifers are used as replacements. The replacement rate also varies between the breeds; 8% (local) and 6% (crossbred) are replaced annually in commercial extensively farmed cattle herds in the study area.

Looking at the feed variety and cost information, we find that the most common feed for milch animals in the study area is rice straw and concentrates, with the latter costing more (Table 30 and 31). In the study area, the livestock owners feed their cattle mostly rice straw, green grasses and concentrates, while very few farmers feed small quantities of wheat straw (Table 28 and 30). The share of dry matter in the daily feed ration is estimated in Table 30, and includes 78% rice straw, 13% green grasses and 10% concentrates. Although a certain amount of cereal residue used among the surveyed households (Table 28) is for cooking fuel (24%), it is mainly used for feeding animals (42%). While small farmers use comparatively more residue as fuel (30%), large farmers utilize nearly half of their cereal residue in feeding livestock (49%), thereby creating more value and direct income opportunities. Rice straw constitutes the bulk of cereal residues fed (53% of both rice OPVs and hybrid residues are fed) while maize stover and wheat straw are mainly used as fuel (75% and 66% respectively) (Table 28). Over all residues and farm types, about 9% of residues (mostly rice straw) are left in the field. This is mainly due to the difficulty in harvesting rice straw at the end of the Rabi season. In addition, straw from hybrid rice appears to be less attractive for collection (23% is left in the field) than that from OPVs (11% left in the field). About 13% of wheat straw is used for roof-making/fencing purposes followed by 6% of OPV rice straw (especially from Aman rice).

The health and breeding costs of dairy animals is presented in Table 32; the average cost of animal health services is BDT 122 per visit, and such services are provided by government veterinary clinics, private veterinary clinics and animal health stock assistants. In the study area, breeding is carried out by artificial insemination and through improved bulls. Insemination of farm animals is very common in today's agriculture industry in developing countries, especially for breeding dairy cattle. It provides an economical means for a livestock breeder to improve their herd, using males with highly desirable traits. About 62% of livestock owners are using either means of breeding (47% improved bull and 15% artificial insemination) in the study area. The average cost of artificial insemination is BDT 218; improved bull insemination costs BDT 87 per visit.

The average milk produced in the study area is two liters per day and the price is BDT 26 per liter (Table 33). The consumption pattern is as follows: 74% of milk produced is sold, 19% is

The average milk produced in the study area is two liters per day and the price is BDT 26 per liter (Table 33). The consumption pattern is as follows: 74% of milk produced is sold, 19% is consumed, and 7% is processed into products such as curd, cheese, ghee, butter and sweets. The informal dairy market (milk vendor, shopkeeper) dominates in the study area (76%) and formal markets (dairy society, private milk collection center; 1%) are not active. Direct consumers constitute 23% of dairy markets (Table 34).

8. Market channels: cereal inputs and outputs

An understanding of agricultural input and output markets is essential for improving agricultural productivity and growth. Development of these markets is important because farmers are not encouraged to increase yields if they are unable to sell their produce. If this occurs, it defeats the objective of intensifying agricultural production, from which the majority of the population derives its livelihood. The input market will focus on seed, fertilizer and pesticide access of cereal crops, with emphasis on identifying key drivers. The vital point of the output market will be the cereal grain markets, and will include the role played by the public and private sectors.

In the study area, the government and cooperative societies play no role in the fertilizer and pesticide markets; the village private dealer has a 96% share, and district private dealers 4% (Table 35). The sources of OPV rice seed are 93% village private dealers, 6% district private dealers and 1% government supply; hybrid rice seed is purchased only from private dealers (63% village and 37% district) (Table 36). All the adopted wheat varieties are developed by BADC, with 91% obtained by farmers from village private dealers and the balance from the government and district private dealers equally. Hybrid maize seed follows the same pattern, dominated by about 82% of village private dealers, again followed by an equal supply from district private dealers and government.

When it comes to the cereal output market, a major role is played by traders at village and district levels; there is no intervention from the government and cooperative markets in the study area (Table 37). Rice grain (both OPVs and hybrid) has been marketed only to the village traders (87%) and district traders (13%). Wheat grain is also marketed mostly to the village traders (96%) followed by the district traders. Hybrid maize trades 79% to village traders, 19% to district traders and 1% each to state traders and co-operative societies.

Now that we have a comprehensive picture of the diverse, sometimes fractured, often unequal scenario of the study area, let us consider what conservation agriculture technologies can do in terms of meeting and overcoming the challenges, in order to increase productivity and income levels, as well as to make agricultural practice much more sustainable. In order to do this, CA technologies also need better dissemination and adoption; thus, we look at what is hindering this process.

9. Farmer perception and farm adoption of CA technologies

Conservation agriculture aims to achieve sustainable and profitable agriculture and subsequently aims at improved livelihoods of farmers through the application of the three CA principles: minimal soil disturbance, permanent soil cover and crop rotations. According to the FAO

(2009), conservation technologies can benefit farmers in three ways; first, the economic benefits that improve production efficiencies, second, agronomic benefits that improve soil productivity and finally, environmental and social benefits that protect the soil and make agriculture more sustainable. In this section, we give an overall representation of current technology adoption and ownership, familiarity with and adoption of CA technologies, sources and frequencies of information, perceived impacts of CA technologies on farm profitability, and reasons for non-adoption of CA technologies.

9.1 Conventional technology adoption in the study area

The current most adopted technologies in the study area are the two-wheel tractor (91%), diesel pumps (88%) and mechanical pesticide sprayers (79%), and the ownership of machinery is significantly higher among large farmers than smaller groups (Table 38). Small farmers are adopting more power threshers for wheat/rice and more own the equipment than the larger farmers. None of the farmers owns the wheat/maize de-husker, while more large farmers are adopting it than small and medium farmers. Electric submersible pumps are adopted more than twice as often by small and medium farmers than large farmers, while the large farmers have more ownership than medium farmers. About 11% of total farmers adopt knapsack sprayers; the adoption rate (16%) and ownership (50% of adopting farmers) are higher among large farmers. Only a few (8%) large farmers have adopted pedal threshers. About 25% of farmers have adopted rotavators (used with a four-wheel tractor), with the adoption rate is higher among large farmers (33%) than medium (30%) and small farmers (11%); none of the farmers in the study area owns a rotavator. Only one large farmer in the study area has adopted a PTOS. The landlessness and fragmentation of small landholdings to tiny land parcels are possibly be the primary factors discouraging farmers from adoption of agricultural innovations, leading detrimental to land conservation and economic results.

9.2 Familiarity and adoption of CA and related technologies

Familiarity with and adoption of CA-related technologies are shown in Table 39. The farmers are aware of but have not adopted laser land levelers, seed treatment/priming or LCCs. None of the farmers had heard of, or seen, turbo/*Happy Seeders*, no-till, and site-specific nutrient management. Only two farmers had heard of quality protein maize. About 27% of sampled farmers are aware of rotavators, while the adoption rate is much higher among large (37%) and medium (31%) farmers than among small (12%) farmers. Less than 2% of farmers are adopting zero (no) tillage, direct seeded rice, and/or bed planting, despite 23% of non-adopters being aware of these technologies.

9.3 Sources of information on CA

Information sources for CA technologies are presented in Table 40. The CSISA project is the principal source of information on CA technologies (such as laser land levelers, bed planting, zero tillage, and direct seeded rice), and there is little variation in the frequency of information among the farmer groups. About 84% of farmers are getting information about rotavators through other farmers. Mass media is the main source of information for relay/intercropping. Government extension officers and private dealers (with information from the CSISA project) are equally the main sources of information for quality protein maize and LCCs. Farmers are receiving more frequent information on CA technologies such as rotavators, relay/ intercropping, bed planting, zero tillage and direct seeded rice; large farmers are getting more frequent information than medium and small farmers.

9.4 Perceived impact of CA technology

The perceived impact of CA technologies on irrigation, cost, yield and profit of the adopting farmers is presented in Table 41. Rotavators are used by 27% of sampled farmers; 100% of farmers who adopted it say that it has no impact (neither more nor less) on irrigation, but that the cost of cultivation is reduced while yield and profit increased. About 13% of farmers adopt relay/intercropping (which requires less irrigation); all of the adopting farmers state it is cost effective and results in higher yield and profit. CA technologies such as bed planting, zero tillage and direct seeded rice are used by very few farmers, and mostly have no impact on irrigation. However, adopters perceived that both bed planting and zero tillage have higher profits and yield compared to direct seeded rice. All of the farmers who adopted these CA technologies, excluding medium (50%) farmers in zero tillage, and medium (100%) and large (50%) farmers in direct seeded rice, benefited in terms of farm profitability (Table 42).

9.5 Barriers to CA-technology adoption

Reasons for the non-adoption of the main CA technologies (Table 43) were recorded from farmers who had awareness (either heard of or seen) of them. The bed planting method has not been adopted due to a) lack of complete information of the technology, alongside b) scarcity of service providers in the sampled villages. Large farmers express their views more than smaller ones. In case of zero tillage, lack of information takes first place, followed by non-availability of machine services. Rotavators were not available in the study area during the survey and are expensive to adopt. Direct seeded rice is generating a weed problem, farmers lack information, and it is not available in the study area. The reason for non-adoption of laser land levelers, seed treatment/priming, quality protein maize, LCC, and relay/inter-cropping is mainly due to a lack of information, while in the case of relay/inter cropping the main crops are not matching with other crops (not shown in the table because very few farmers were aware of these CA technologies during this survey). Lack of information, and the unavailability of a given technology, thus appears to be the main obstacles to the adoption of CA technologies, despite the obvious benefits that would be derived from their application.

10. Conclusion

This study was developed from a comprehensive socioeconomic household survey, aimed to provide important baseline indicators for the CSISA project. The project aims to develop and disseminate improved cereal production technologies, which are economically sustainable, while conserving the natural resource base. Information gathered from 324 cereal-producing households from three different districts of NW Bangladesh was synthesized into 43 summary data tables. Details on general characterization of farming households in the Bangladesh hub focus on cropping patterns, varietal adoption, productivity and economics of cereal production, details on livestock production, level of adoption and perceived impact of CA and related production technologies, and existing marketing channels. There have been only a few attempts to characterize the cereal production sector of NW Bangladesh; this study thus gains special relevance, especially as findings are given separately for each farmer group (small, medium and large) in order to realize more meaningful conclusions.

The study area is dominated by small and marginal farmers, the average cultivated land size being 1.49 acres. There is significant inequality in land ownership, which includes an average 15% of landless farmers using leased/share-in land. Most of the sample farmers cultivate more than one cereal crop across seasons, and in addition produce potato, pulses and gram, jute, sugarcane, tobacco, lentil and vegetables in the area. Crop diversity varies significantly across seasons: Kharif is dominated by rice, but during the winter (Rabi) season a number of crops are cultivated across farmer groups. Rice is the most important cereal crop as almost all the farmers are engaged in its cultivation, and small farmers keep a major share of the produce for home consumption. Significant adoption of hybrid seed is observed during the Rabi season with full irrigation. The rice productivity in the sample farms is significantly higher (18.3 quintals per acre) than the national average figure (10.2 quintals). In the case of wheat, the yield of sampled farmers is 80% higher than the national average; maize yield in the farming household is 28.9 quintals per acre, while the national average is 21.5 quintals per acre. A few old varieties dominate cereal production in NW Bangladesh, and this could be one of the major hurdles in reaching higher levels of productivity.

The agriculture of the study area is dominated by subsistence farming. Only about 40% of rice and wheat grain produced is marketed, a share which is much lower among small farmers. Rice and wheat are relatively remunerative crops, generating sufficient profit for the farming community. Maize is produced mainly for markets in the Rabi and spring seasons, with significant profit and more large farmers cultivating it. One major challenge is linking cereal farms with input/output markets effectively, especially for the smallholders. In the case of inputs like seed and fertilizer, village and district level dealers are the main suppliers, and in many cases, the quality of these inputs is doubtful. Only a small share of inputs comes through the government supply channel, and in the private markets, prices of fertilizer are high, reducing the profits of cereal farmers.

Given the small size of the average farm, the high level of income inequality, the lack of access to modern crop varieties and the negligible presence of government or public sector input and output market channels, the formidable challenge are to reduce the total cost of production by curbing overarching dependence on external input resources. With this in mind, CA techniques, based on resource-conserving technologies, have been developed and are being disseminated in half of the study villages under the CSISA project in order to achieve the goal of sustainable production of cereals. A wide range of CA technologies, namely relay/ inter-cropping, rotavators, bed planting, zero tillage and direct seeded rice, were adopted in the farmers' fields. At the time of the baseline survey, the diffusion of these technologies was, unsurprisingly, marginal. The farmers were largely unaware of the technologies' impact on cost, input use or profitability; this could pose a significant challenge to CA dissemination-adoption programs. Government extension officers in collaboration with CSISA personnel and NGOs have a significant role to play in the diffusion of such RCTs over time, especially in terms of extensive and dedicated efforts to overcome the constraints of information unavailability and unsuitability of some CA-related technologies to small farms. There are evidences in the literature for profit advantage of larger farms, and this arises both from scale-dependent mechanization, and from lower capital costs and better protection from adverse income shocks (for example, Niroula and Thapa, 2005). In sum, policy focus on novel technology diffusion techniques alongside alleviation of physical constraints faced by small and marginal farmers to CA adoption will be required to enhance the cereal productivity of Bangladesh.

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Table 1: General household characterization (n=324)

	Farmer group				*p*-value
	Small	Medium	Large	Overall	
Land owned [acres]	0.33	0.72	2.42	1.17	0.00[a]
	(0.03)	(0.05)	(0.16)	(0.08)	
% of landless farmers[#]	29.25	12.04	2.73	14.51	
Cultivated land - leased in [%]	34.60	29.40	18.72	22.85	
Cultivable land - leased out [%]	15.24	5.15	7.55	7.77	
Cultivated land - shared in [%]	7.47	8.82	8.11	8.21	
Cultivable land - shared out [%]	3.80	3.10	4.48	4.13	
Land cultivated [acres]	0.46	1.06	2.91	1.49	0.00[a]
	(0.02)	(0.03)	(0.12)	(0.07)	
% of households cultivating					
Aman rice	84.91	94.44	90.91	90.12	0.14[b]
Boro rice	41.51	67.59	74.55	61.42	0.00[b]
% of households cultivating wheat	51.89	38.89	44.55	45.06	0.29[b]
% of households cultivating					
Rabi maize	1.89	13.89	21.82	12.65	0.00[b]
spring maize	3.77	10.19	19.09	11.11	0.00[b]
% of households with large ruminants*	63.21	79.63	90.91	78.09	0.00[b]
% of households with small ruminants*	44.34	57.41	66.36	56.17	0.00[b]
% of female-headed households	4.72	0.93	0.00	1.85	na
Age [year] of household-head	41.22	44.35	46.10	43.92	0.01[a]
	(1.16)	(1.11)	(1.09)	(0.65)	
Education [year schooling] of household head	3.37	4.01	6.02	4.48	0.00[a]
	(0.41)	(0.38)	(0.39)	(0.23)	

Note: Figures in parentheses show the standard error of sample mean,
[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;
[b] = *p*-value derived from c2 test with trend.
#Farm size group was categorized on the basis of operated land (leased-in or shared-in).
*Includes adult and young livestock.

Table 2: Household asset status

	Farmer groups				*p*-value
	Small	Medium	Large	Overall	
% of households with					
electricity connection	43.39	27.77	42.72	38.96	0.94[b]
piped water connection	100.00	100.00	100.00	100.00	na
ration card	8.49	3.70	0.00	4.01	na
BPL card	30.18	58.33	73.63	54.32	0.00[b]
Livestock assets [number]					
Cattle (local, adult female)	1.29	1.42	1.94	1.62	0.00[a]
	(0.08)	(0.10)	(0.12)	(0.07)	
Cattle (crossbred; adult female)	1.00	1.00	1.13	1.08	0.01[a]
	(0.00)	(0.00)	(0.09)	(0.06)	
Buffalo (adult female)	nil	nil	nil	Nil	na
Draft animal (adult male)	1.21	1.70	1.87	1.69	0.00[a]
	(0.10)	(0.22)	(0.13)	(0.09)	
Goats and sheep (adult)	2.13	2.65	2.97	2.64	0.00[a]
	(0.19)	(0.29)	(0.25)	(0.15)	
Poultry	7.31	10.42	12.61	10.47	0.00[a]
	(0.96)	(1.33)	(1.02)	(0.68)	

Note: Figures in parentheses show the standard error of sample mean;

[a] = p-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

[b] = p-value derived from c^2 test with trend;

na = not applicable.

Table 3: Income sources in households

% income from	Farmer groups				*p*-value
	Small	Medium	Large	Overall	
Crops	25.06	34.15	54.62	38.13	0.00[a]
	(1.61)	(1.13)	(2.00)	(1.16)	
Livestock	5.17	6.75	7.86	6.61	0.01[a]
	(0.64)	(0.66)	(0.75)	(0.40)	
Other farm activities	1.39	1.22	3.44	2.03	0.04[a]
	(0.47)	(0.45)	(0.73)	(0.33)	
Agricultural labor	18.21	14.39	1.14	11.14	0.00[a]
	(2.32)	(1.99)	(0.59)	(1.10)	
Non-agricultural labor	18.77	13.63	2.42	11.51	0.00[a]
	(2.27)	(1.98)	(0.74)	(1.09)	
Services	11.77	6.81	7.68	8.73	0.62[a]
	(2.44)	(1.70)	(1.62)	(1.13)	
Business	18.92	23.04	22.38	21.47	0.16[a]
	(2.56)	(2.46)	(1.88)	(1.33)	
Remittances	0.71	0.00	0.45	0.39	Na
	(0.71)	(0.00)	(0.45)	(0.28)	

Note: Figures in parentheses show the standard error of sample mean;

[a] = p-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom.

Table 4: Cropping pattern in the study area

Season	Crops	% area under cultivation				*p*-value	% farmers following				*p*-value
		Small	Medium	Large	Overall		Small	Medium	Large	Overall	
Kharif	Rice (OPVs)	71.53	75.67	71.75	72.65	0.00[a]	84.91	94.44	90.91	90.12	0.14[b]
	Rice (hybrid)	0.00	0.00	0.16	0.10	na	0.00	0.00	1.82	0.62	na
	Vegetable	0.34	1.66	0.97	1.07	0.20[a]	0.94	6.48	8.18	5.25	0.02[b]
	Pulses & grams	3.62	1.22	3.50	2.97	0.02[a]	5.66	3.70	10.00	6.48	0.19[b]
	Other crops	0.84	0.79	0.90	0.87	na	2.83	1.85	2.73	2.47	0.97[b]
	Fallow land	23.67	20.66	22.72	22.34	0.00[a]	39.62	49.07	55.45	48.15	0.02[b]
	Total	100.00	100.00	100.00	100.00		159.43	225.02	329.08	235.80	
Rabi	Maize	1.07	8.53	8.71	7.90	0.04[a]	1.89	13.89	21.82	12.65	0.00[b]
	Rice (OPVs)	24.19	33.32	31.61	31.27	0.00[a]	33.02	58.33	69.09	53.70	0.00[b]
	Rice (hybrid)	8.64	8.42	5.91	6.78	0.05[a]	10.38	14.81	20.00	15.12	0.05[b]
	Wheat	36.19	18.27	15.13	17.99	0.00[a]	51.89	38.89	44.55	45.06	0.29[b]
	Pulses & grams	0.00	0.64	0.72	0.63	na	0.00	2.78	4.55	2.47	na
	Potato	4.36	4.70	9.80	8.04	0.01[a]	9.43	13.89	30.91	18.21	0.00[b]
	Vegetable	0.00	1.42	2.10	1.73	na	0.00	7.41	16.36	8.02	na
	Spices	0.93	0.50	0.60	0.61	na	0.94	3.70	5.45	3.40	0.07[b]
	Lentil	4.73	3.87	4.23	4.19	0.00[a]	10.38	12.04	15.45	12.65	0.26[b]
	Sugarcane	12.49	5.68	5.49	6.24	0.00[a]	22.64	13.89	18.18	18.21	0.40[b]
	Tobacco	5.35	11.56	7.51	8.26	0.00[a]	8.49	23.15	19.09	16.98	0.04[b]
	Banana	0.47	0.44	0.89	0.74	na	0.94	1.85	7.27	3.40	0.01[b]
	Other crops	1.58	0.15	1.86	1.44	na	1.89	0.93	7.27	3.40	0.03[b]
	Fallow land	0.00	2.50	5.44	4.18	na	6.60	13.89	30.91	17.28	0.00[b]
	Total	100.00	100.00	100.00	100.00		156.60	213.89	296.36	223.15	

Note: Figures in parentheses show the standard error of sample mean;

[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

[b] = *p*-value derived from c^2 test with trend;

na = not applicable.

Table 4: Cropping pattern in the study area (Contd.)

Season	Crops	% area under cultivation				p-value	% farmers following				p-value
		Small	Medium	Large	Overall		Small	Medium	Large	Overall	
Spring	Maize	2.14	3.69	8.81	6.92	0.00[a]	3.77	10.19	19.09	11.11	0.00[b]
	Rice	1.36	0.00	0.00	0.14	na	1.89	0.00	0.00	0.62	0.08[b]
	Pulses & grams	30.88	12.52	8.97	12.02	0.00[a]	41.51	23.15	21.82	28.70	0.00[b]
	Jute	3.64	5.85	4.06	4.44	0.00[a]	7.55	15.74	17.27	13.58	0.04[b]
	Sesame	2.72	1.62	0.57	1.03	0.22[a]	5.66	5.56	2.73	4.63	0.30[b]
	Spices	0.00	1.04	0.00	0.25	na	0.00	2.78	0.00	0.93	na
	Sesbania	0.00	0.57	1.44	1.09	na	0.00	0.93	3.64	1.54	na
	Other crops	0.00	0.07	0.09	0.08	na	0.00	0.93	0.91	0.62	na
	Fallow land	59.26	74.64	76.06	74.03	0.00[a]	74.53	91.67	97.27	87.96	0.00[b]
	Total	100.00	100.00	100.00	100.00		134.91	150.93	162.73	149.69	

Note: Figures in parentheses show the standard error of sample mean;

[a] = p-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

[b] = p-value derived from c^2 test with trend;

na = not applicable.

Table 5: Share of irrigated crop area

Season	Crop, type	% area under cultivation				P-value
		Small	Medium	Large	Overall	
Kharif	Rice	51.50	30.36	33.69	34.63	0.20[a]
	Vegetable	0.00	92.15	89.32	87.51	na
	Pulses & grams	18.75	0.00	6.60	7.45	na
	Other crops	41.46	100.00	0.00	25.65	na
Rabi	Maize	100.00	89.80	100.00	97.38	0.02[a]
	Rice	100.00	100.00	100.00	100.00	0.00[a]
	Wheat	100.00	100.00	100.00	100.00	0.00[a]
	Pulses & grams	na	55.41	0.00	13.44	na
	Potato	96.70	100.00	100.00	99.82	0.01[a]
	Vegetable	na	100.00	96.28	97.07	na
	Spices	100.00	70.69	67.02	73.04	0.13[a]
	Lentil	13.91	14.83	34.12	27.60	0.24[a]
	Sugarcane	100.00	0.00	0.00	9.09	na
	Tobacco	100.00	100.00	100.00	100.00	0.00[a]
	Banana	100.00	100.00	100.00	100.00	na
	Other crops	0.00	0.00	33.92	29.61	na
Spring	Maize	100.00	100.00	100.00	100.00	0.00[a]
	Rice	0.00	na	na	0.00	na
	Pulses & grams	60.69	26.01	28.75	36.31	0.00[a]
	Jute	25.42	19.17	0.00	8.10	0.00[a]
	Sesame	0.00	6.99	63.54	25.65	na
	Spices	na	75.00	na	75.00	na
	Sesbania	0.00	0.00	0.00	0.00	na
	Other crops	na	0.00	100.00	78.95	na

Note: [a] = p-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom; na = not applicable.

Table 6: Sources and share of irrigation water

	Share (%) among				P-value
	Small	Medium	Large	Overall	
Electric tubewell, purchased	26.76	19.19	6.73	17.44	0.00[a]
	(4.28)	(3.67)	(2.25)	(2.06)	
Diesel tube well, purchased	62.86	50.70	31.84	48.27	0.00[a]
	(4.68)	(4.75)	(4.35)	(2.74)	
Total tube wells, purchased	89.62	69.89	38.57	65.71	0.00[a]
	(2.98)	(4.35)	(4.58)	(2.61)	
Canal	0.00	3.42	2.20	1.88	na
	(0.00)	(1.72)	(1.29)	(0.72)	
Tank	0.96	0.00	0.00	0.32	na
	(0.96)	(0.00)	(0.00)	(0.32)	
River	0.96	0.00	0.00	0.32	na
	(0.96)	(0.00)	(0.00)	(0.32)	
Electric tube well, owned	0.00	0.37	1.82	0.74	na
	(0.00)	(0.37)	(1.28)	(0.45)	
Diesel tube well, owned	8.49	26.44	57.45	31.10	0.00[a]
	(2.72)	(4.18)	(4.69)	(2.55)	
Total	100.00	100.00	100.00	100.00	

Note: Figures in parentheses show the standard error of sample mean;

[a] shows p-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

na = not applicable.

Table 7: Cost of irrigation water

	Cost per unit	Farmer group				*p*-value
		Small	Medium	Large	Overall	
Purchased tube well:						
Diesel tube well, purchased	BDT/hour	100.82	100.80	102.00	101.06	0.97[a]
		(2.24)	(3.36)	(2.58)	(1.55)	
Electri-c tube well, purchased	BDT/season/acre	3214.70	3655.67	3425.00	3447.26	0.36[a]
		(235.27)	(221.07)	(381.52)	(149.55)	
Canal	BDT/acre	na	1000	1000	1000	na
			(0.00)	(0.00)	(0.00)	
Diesel tube well, owned	BDT/hour	33.06	31.61	30.83	31.25	0.08[a]
		(1.00)	(0.84)	(0.45)	(0.38)	
Electri-c tube well, owned	BDT/season/acre	na	na	2079.00	2079.00	na
				(721.00)	(721.00)	

Note: Figures in parentheses show the standard error of sample mean;

[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

na = not applicable.

Table 8: Credit use across farmer groups

	Farmer group				P-value
	Small	Medium	Large	Overall	
% of farmers who resort to credit	47.17	51.85	46.36	48.46	0.90[b]
Total amount (BDT)	11140.00	15687.50	28450.98	18385.35	0.00[a]
	(908.92)	(2830.42)	(4560.47)	(1894.80)	
Share of farmers using credit for:					
rice	20.00	23.21	39.22	27.39	0.03[b]
wheat	6.00	0.00	3.92	3.18	na
maize	0.00	1.79	0.00	0.64	na
livestock	16.00	7.14	7.84	10.19	0.18[b]
Average interest rate	25.55	24.22	18.48	22.78	0.00[a]
	(0.46)	(0.79)	(1.16)	(0.55)	

Note: Figures in parentheses show the standard error of sample mean;

[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

[b] = *p*-value derived from c^2 test with trend.

Table 9: Varietal adoption in rice (Aman) with respect to share of acreage and household

Variety (name)	% share of households				% crop area cultivated			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall
Swarna	83.33	80.39	89.00	84.25	80.35	74.09	74.82	75.20
BR 11	14.44	20.59	20.00	18.49	14.47	17.31	8.97	11.58
Katari	0.00	0.98	11.00	4.11	0.00	0.53	3.47	2.40
BR-33	3.33	2.94	4.00	3.42	2.36	1.28	1.26	1.37
Hori Dhan	1.11	2.94	5.00	3.08	0.72	1.40	1.49	1.39
BR-6	1.11	1.96	2.00	1.71	0.14	0.43	0.33	0.33
BR-32	1.11	0.98	2.20	1.37	0.78	0.86	1.62	1.35
BR-34	0.00	0.98	3.00	1.37	0.00	0.29	2.17	1.49
Ranjit	0.00	0.98	3.00	1.37	0.00	0.35	1.52	1.08
Kalizira	0.00	0.00	3.00	1.03	0.00	0.00	0.87	0.57
BR-39	1.11	0.98	0.00	0.68	1.18	1.52	0.00	0.49
BR-41	0.00	0.00	2.00	0.68	0.00	0.00	0.79	0.51
Other varieties	0.00	3.92	11.00	5.14	0.00	1.94	2.69	2.24
Total	105.54	117.64	155.20	126.70	100.00	100.00	100.00	100.00

Table 10: Varietal adoption in rice (Aman) with respect to yield, market and prices

Variety (name)	Yield (q/acre) obtained by				% grain marketed by				Price (BDT/Q) obtained by			
	Small	Medi-	Large	Over-	Small	Medi-	Large	Overall	Small	Medium	Large	Overall
Swarna	13.34	13.35	13.96	13.57	4.32	23.46	53.01	28.35	1802.50	1821.12	1740.32	1772.19
	(0.40)	(0.38)	(0.31)	(0.21)	(1.44)	(3.06)	(3.29)	(2.07)	(44.17)	(15.90)	(27.75)	(17.74)
BR 11	13.95	14.20	14.10	14.10	6.38	48.24	65.70	44.63	1771.37	1797.71	1735.29	1766.89
	(0.65)	(0.73)	(0.64)	(0.39)	(3.69)	(7.28)	(7.70)	(5.12)	(105.62)	(26.54)	(33.15)	(21.06)
Katari	na	15.65	10.37	10.81	na	100.00	94.09	94.58	na	1600.00	2620.91	2621.25
		(0.00)	(0.57)	(0.68)		(0.00)	(4.51)	(4.15)		(0.00)	(99.26)	(90.61)
BR 33	12.55	13.16	11.37	12.26	6.67	0.00	62.00	26.80	1750.00	na	1595.67	1634.25
	(0.95)	(1.86)	(1.92)	(0.92)	(6.67)	(0.00)	(23.68)	(13.05)	(0.00)		(54.03)	(54.30)
Hori Dhan	12.00	12.35	12.41	12.35	0.00	33.33	67.80	48.78	na	1800.00	1631.25	1687.50
	(0.00)	(1.87)	(1.00)	(0.75)	(0.00)	(16.67)	(20.66)	(14.49)		(100.00)	(82.52)	(68.24)
BR 6	22.40	16.53	13.06	16.32	20.00	50.00	100.00	64.00	1964.00	1700.00	1850.00	1841.00
	(0.00)	(3.47)	(5.60)	(2.69)	(0.00)	(50.00)	(0.00)	(22.27)	(0.00)	(0.00)	(150.00)	(81.74)
BR 32	7.40	12.00	16.00	12.85	0.00	25.00	75.00	43.75	na	1625.00	1804.00	1744.33
	(0.00)	(0.00)	(0.00)	(2.05)	(0.00)	(0.00)	(25.00)	(21.35)		(0.00)	(71.00)	(72.39)
BR 34	na	11.20	10.80	10.90	na	100.00	100.00	100.00	na	3250.00	2311.00	2545.75
		(0.00)	(0.69)	(0.50)		(0.00)	(0.00)	(0.00)		(0.00)	(294.71)	(313.90)
Ranjit	na	21.33	14.50	16.21	na	100.00	56.67	67.50	na	1600.00	1900.00	1800.00
		(0.00)	(1.32)	(1.95)		(0.00)	(28.48)	(22.87)		(0.00)	(200.00)	(152.75)
Kalizira	na	na	9.65	9.65	na	Na	98.33	98.33	na	na	3258.33	3258.33
			(0.94)	(0.94)			(1.67)	(1.67)			(193.83)	(193.83)

Note: Figures in parentheses show the standard error of sample mean;

na = not applicable.

Table 10: Varietal adoption in rice (Aman) with respect to yield, market and prices (Contd.)

Variety (name)	Yield (q/acre) obtained by				% grain marketed by				Price (BDT/Q) obtained by			
	Small	Medi-um	Large	Over-all	Small	Medi-um	Large	Over-all	Small	Medium	Large	Overall
BR 39	6.60	14.40	na	10.50	100.00	0.00	na	50.00	2000.00	na	na	2000.00
	(0.00)	(0.00)		(3.90)	(0.00)	(0.00)		(50.00)	(0.00)			(0.00)
BR 41	na	na	10.20	10.20	na	Na	25.00	25.00	na	na	1625.00	1625.00
			(1.80)	(1.80)			(25.00)	(25.00)			(0.00)	(0.00)
Other varieties	na	9.65	13.26	12.23	na	25.00	71.18	58.87	na	3500.00	1791.57	2005.12
		(0.86)	(1.14)	(0.95)		(25.00	(13.83)	(12.87)		(0.00)	(144.00)	(247.30)
Total	13.35	13.46	13.38	13.40	4.71	30.63	62.01	37.18	1803.53	1866.88	1863.62	1860.42
	(0.36)	(0.32)	(0.25)	(0.17)	(1.26)	(3.06)	(2.80)	(1.99)	(36.14)	(36.76)	(36.57)	(25.27)

Note: Figures in parentheses show the standard error of sample mean;

na = not applicable.

Table 11: Varietal adoption in rice (Boro) with respect to share of acreage and household

Variety (name)	% share of households				% crop area cultivated			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall
BR 28	56.82	67.12	68.29	65.33	89.17	58.49	52.07	65.13
BR 29	22.73	10.96	17.07	16.08	4.77	8.47	18.58	12.21
Pari	2.27	8.22	9.76	7.54	0.32	6.11	7.65	5.01
Hira	4.55	2.74	7.32	5.03	0.95	2.94	2.05	1.87
ACI 1	0.00	5.48	4.88	4.02	0.00	3.73	2.21	1.80
Iraton	4.55	2.74	4.88	4.02	1.33	2.19	2.50	2.07
Lal Teer	4.55	2.74	4.88	4.02	1.33	3.59	3.83	2.99
BR 33	0.00	2.74	6.10	3.52	0.00	4.13	2.77	2.15
Sonar Bangla 1	6.82	1.37	2.44	3.02	1.14	0.94	1.50	1.28
BR 16	0.00	1.37	3.66	2.01	0.00	0.63	0.97	0.60
China	2.27	1.37	2.44	2.01	0.38	2.09	0.50	0.77
ACI 2	0.00	2.74	1.22	1.51	0.00	2.50	0.62	0.79
Hira 5	2.27	1.37	1.22	1.51	0.19	0.83	0.87	0.65
Other varieties	2.27	5.48	8.54	6.03	0.42	3.36	3.88	2.68
Total	109.10	116.44	142.70	125.65	100.00	100.00	100.00	100.00

Table 12: Varietal adoption in rice (Boro) with respect to yield, market and prices

Variety (name)	Yield (q/acre) obtained by				% grain marketed by				Price (BDT/q) obtained by			
	Small	Medi-	Large	Over-	Small	Medi-	Large	Over-	Small	Medi-	Large	Overall
BR 28	21.78	22.38	22.67	22.39	11.56	19.61	45.78	29.33	1592.86	1657.78	1628.91	1635.75
	(0.84)	(0.61)	(0.48)	(0.35)	(4.82)	(3.04)	(4.13)	(2.63)	(51.96)	(22.60)	(20.13)	(14.51)
BR 29	25.20	24.34	24.54	24.69	25.00	59.62	66.28	51.72	1615.00	1705.00	1629.85	1647.92
	(1.39)	(1.78)	(1.69)	(0.94)	(10.35)	(13.59)	(7.84)	(6.49)	(50.99)	(63.30)	(40.11)	(28.97)
Pari	24.00	25.25	22.92	23.92	0.00	35.67	63.62	48.20	na	1700.00	1525.00	1595.00
	(0.00)	(1.52)	(1.42)	(0.98)	(0.00)	(13.50)	(14.39)	(10.29)		(0.00)	(89.21)	(58.90)
Hira	25.00	25.03	26.99	26.20	30.0	43.0	79.7	62.40	1528.00	1612.50	1560.33	1568.33
	(1.67)	(1.03)	(1.66)	(1.05)	(30.00)	(7.00)	(12.86)	(11.31)	(0.00)	(12.50)	(28.20)	(28.20)
ACI 1	na	24.22	28.28	26.47	na	67.50	76.00	72.22	na	1507.00	1506.25	1506.62
		(2.33)	(0.90)	(1.28)		(11.09)	(19.39)	(11.28)		(35.34)	(32.87)	(22.34)
Iraton	20.93	30.00	20.68	23.07	22.50	65.00	50.00	46.87	1500.00	1743.50	1600.00	1637.40
	(0.40)	(3.33)	(1.43)	(1.77)	(22.50)	(15.00)	(28.87)	(15.44)	(0.00)	(56.50)	(0.00)	(50.29)
Lal Teer	24.20	21.47	25.53	24.18	60.00	50.00	93.25	74.12	1564.00	1525.00	1758.25	1651.37
	(0.86)	(1.87)	(0.91)	(0.85)	(40.00)	(0.00)	(6.75)	(11.00)	(36.00)	(25.00)	(161.84)	(85.68)
BR-33	na	16.20	18.64	17.95	na	0.00	36.80	26.28	na	na	1665.00	1665.00
		(7.80)	(2.67)	(2.55)		(0.00)	(5.50)	(7.78)			(47.17)	(47.17)
Sonar Bangla-1	29.33	26.67	31.33	29.56	16.67	40.00	100.00	48.33	1625.00	1500.00	1575.00	1568.75
	(2.66)	(0.00)	(2.00)	(1.48)	(16.67)	(0.00)	(0.00)	(18.33)	(0.00)	(0.00)	(75.00)	(40.02)

Note: Figures in the parentheses show the standard error of sample mean, na indicates not applicable.

Table 12: Varietal adoption in rice (Boro) with respect to yield, market and prices (Contd.)

Variety (name)	Yield (q/acre) obtained by				% grain marketed by				Price (BDT/q) obtained by			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall	Small	Medium	Large	Overall
BR-16	na	33.33	26.28	28.04	na	50.00	86.67	77.50	na	2100.00	1791.67	1868.75
		(0.00)	(2.42)	(2.46)		(0.00)	(13.33)	(13.15)		(0.00)	(110.24)	(109.63)
China	22.00	26.00	25.00	18.52	0.00	60.00	0.00	15.00	na	2000.00	na	2000.00
	(0.00)	(0.00)	(1.00)	(5.55)	(0.00)	(0.00)	(0.00)	(15.00)		(0.00)		(0.00)
ACI-2	na	21.00	29.33	23.77	na	83.00	45.00	70.33	na	1550.00	1500.00	1533.33
		(2.34)	(0.00)	(3.09)		(17.00)	(0.00)	(16.02)		(50.00)	(0.00)	(33.33)
Hira-5	21.33	24.00	30.40	25.24	0.00	30.00	60.00	30.00	na	1500.00	1625.00	1562.50
	(0.00)	(0.00)	(0.00)	(2.69)	(0.00)	(0.00)	(0.00)	(17.32)		(0.00)	(0.00)	(62.50)
Other varieties	10.80	20.87	23.11	21.34	0.00	31.25	46.00	37.25	na	2433.33	1525.00	1914.29
	(0.00)	(2.46)	(3.51)	(2.34)	(0.00)	(11.97)	(17.01)	(10.99)		(883.80)	(85.39)	(383.86)
Total	22.98	23.07	23.45	23.23	16.96	31.87	55.11	39.94	1588.59	1697.98	1617.83	1642.06
	(0.68)	(0.51)	(0.49)	(0.31)	(4.10)	(3.18)	(3.26)	(2.24)	(26.13)	(48.50)	(15.69)	(19.00)

Note: Figures in the parentheses show the standard error of sample mean, na indicates not applicable.

Table 13: Varietal adoption in wheat with respect to share of acreage and household

Variety (name)	% wheat farming households				% crop area cultivated			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall
Shatabdi	75.92	61.53	46.87	61.99	75.41	60.10	45.32	54.87
Pradip	18.52	23.81	30.61	24.14	19.32	29.75	38.12	32.36
Bijoy	5.56	7.14	6.12	6.21	5.27	4.43	5.27	5.07
Sonalika	0.00	4.76	6.12	3.45	0.00	2.48	2.56	2.03
Kanchan	0.00	0.00	8.16	2.76	0.00	0.00	5.12	2.86
Balaka	0.00	2.38	2.04	1.38	0.00	1.43	1.07	0.95
Gourab	0.00	2.38	0.00	0.69	0.00	1.81	0.00	0.44
Swarna	0.00	0.00	2.04	0.69	0.00	0.00	0.68	0.38
Protiva	0.00	0.00	2.04	0.69	0.00	0.00	1.86	1.04
Overall	100.00	102.00	104.00	102.00	100.00	100.00	100.00	100.00

Table 14: Varietal adoption in wheat with respect to yield, market and prices

Variety (name)	Yield (q/acre) obtained by				% grain marketed by				Price (BDT/q) obtained by			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall	Small	Medium	Large	Overall
Shatabdi	10.97	10.56	11.62	11.01	15.56	28.27	49.70	27.96	1872.92	1870.54	1772.37	1828.80
	(0.44)	(0.44)	(0.55)	(0.27)	(4.45)	(7.05)	(7.29)	(3.69)	(46.00)	(54.41)	(37.02)	(26.90)
Pradip	11.06	11.29	12.93	11.93	33.00	72.20	75.60	62.45	1697.40	1700.00	1742.31	1719.89
	(0.96)	(0.87)	(0.80)	(0..51)	(12.96)	(11.42)	(9.34)	(6.94)	(52.50)	(30.33)	(68.31)	(35.04)
Bijoy	11.49	10.32	12.89	11.57	6.66	66.66	65.00	46.11	2000.00	2398.50	1813.00	2084.60
	(1.18)	(0.95)	(1.65)	(0.75)	(6.66)	(33.33)	(32.53)	(16.79)	(0.00)	(351.50)	(187.00)	(182.87)
Sonalika	na	11.29	10.01	10.52	na	100.00	96.00	97.60	na	1600.00	1875.00	1765.00
		(3.72)	(1.89)	(1.60)		(0.00)	(4.00)	(2.40)		(100.00)	(72.17)	(84.26)
Kanchan	na	na	10.30	10.30	na	na	98.00	98.00	na	na	1475.00	1475.00
			(0.58)	(0.58)			(2.50)	(2.50)			(25.00)	(25.00)
Balaka	na	7.46	10.00	8.73	na	85.00	90.00	87.50	na	1500.00	2200.00	1850.00
		(0.00)	(0.00)	(1.27)		(0.00)	(0.00)	(2.50)		(0.00)	(0.00)	(350.00)
Gourab	na	9.50	na	9.50	na	90.00	na	90.00	na	1625.00	na	1625.00
		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)
Swarna	na	na	14.40	14.40	na	na	100.00	100.00	na	na	1600.00	1600.00
			(0.00)	(0.00)			(0.00)	(0.00)			(0.00)	(0.00)
Protiva	na	na	8.00	8.00	na	na	90.00	90.00	na	na	1600.00	1600.00
			(0.00)	(0.00)			(0.00)	(0.00)			(0.00)	(0.00)
Overall	11.01	10.65	11.83	11.19	18.29	47.25	67.25	43.58	1831.22	1837.11	1731.27	1784.19
	(0.38)	(0.37)	(0.39)	(0.22)	(4.21)	(6.50)	(5.17)	(3.45)	(39.33)	(50.80)	(30.54)	(23.52)

Note: Figures in the parentheses show the standard error of sample mean, na indicates not applicable.

Table 15: Varietal adoption in maize (Rabi) with respect to share of acreage and household

Variety (name)	% maize farmers				% crop area cultivated			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall
NK 40	100.00	66.67	62.50	65.41	100.00	77.65	63.05	67.30
900 M	0.00	13.33	25.00	19.51	0.00	6.33	20.62	16.68
6323	0.00	6.67	4.17	4.88	0.00	5.10	3.59	3.93
Pioneer 92	0.00	0.00	8.33	4.88	0.00	0.00	6.28	4.58
M 1837	0.00	13.33	0.00	4.88	0.00	10.92	0.00	2.80
Konak	0.00	0.00	4.17	2.44	0.00	0.00	6.46	4.71
Overall	100.0	100.00	104.17	102.00	100.00	100.00	100.00	100.00

Table 16: Varietal adoption in maize (Rabi) with respect to yield, market and prices

Variety (name)	Yield (q/acre) obtained by				% grain marketed by				Price (BDT/q) obtained by			
	Small	Medi-um	Large	Over-all	Small	Medi-um	Large	Over-all	Small	Medium	Large	Overall
NK 40	21.81	30.17	30.02	29.44	100.00	100.00	100.00	100.00	1156.00	913.11	933.17	943.35
	(7.00)	(2.18)	(2.10)	(1.51)	(0.00)	(0.00)	(0.00)	(0.00)	(31.00)	(28.40)	(25.28)	(21.29)
900 M	na	22.50	30.53	28.53	na	100.00	91.67	93.75	na	1000.00	927.67	945.75
		(2.50)	(1.52)	(1.79)		(0.00)	(8.33)	(6.25)		(0.00)	(42.14)	(33.04)
6323	na	32.00	32.00	32.00	na	100.00	100.00	100.00	na	1000.00	912.00	956.00
		(0.00)	(0.00)	(0.00)		(0.00)	(0.00)	(0.00)		(0.00)	(0.00)	(44.00)
Pioneer 92	na	na	52.00	52.00	na	na	100.00	100.00	na	na	1031.00	1031.00
			(12.00)	(12.00)			(0.00)	(0.00)			(31.00)	(31.00)
M 1837	na	24.47	na	24.47	na	100.00	na	100.00	na	1400.00	na	1400.00
		(5.27)		(5.27)		(0.00)		(0.00)		(100.00)		(100.00)
Konak	na	na	20.00	20.00	na	na	95.00	95.00	na	na	1250.00	1250.00
			(0.00)	(0.00)			(0.00)	(0.00)			(0.00)	(0.00)
Overall	21.81	27.92	31.58	29.81	100.00	100.00	97.80	98.69	1156.00	1009.53	951.48	981.95
	(6.99)	(1.69)	(1.95)	(1.37)	(0.00)	(0.00)	(2.00)	(1.19)	(31.00)	(47.82)	(22.41)	(22.59)

Note: Figures in parentheses show the standard error of sample mean;

na = not applicable.

Table 17: Varietal adoption in maize (spring) with respect to share of acreage and household

Variety (name)	% maize farmers				% crop area cultivated			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall
NK 40	75.00	54.55	85.71	75.00	71.2	66.98	81.22	79.10
900-M	25.00	9.09	23.81	19.44	28.8	5.66	17.36	16.23
ACI Gold	0.00	9.09	4.76	5.56	0.00	10.61	0.53	1.79
M 99	0.00	9.09	4.76	5.56	0.00	3.54	0.89	1.20
1414	0.00	9.09	0.00	2.78	0.00	6.13	0.00	0.78
M 1837	0.00	9.09	0.00	2.78	0.00	7.08	0.00	0.90
Overall	100.00	100.00	119.04	111.12	100.00	100.00	100.00	100.00

Table 18: Varietal adoption in maize (spring) with respect to yield, market and prices

Variety (name)	Yield (q/acre) obtained by				% grain marketed by				Price (BDT/q) obtained by			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall	Small	Medium	Large	Overall
NK 40	24.67	28.78	29.07	28.51	100.00	100.00	96.89	97.93	975.00	1027.00	935.94	960.52
	(4.06)	(2.27)	(1.61)	(1.25)	(0.00)	(0.00)	(2.77)	(1.85)	(52.04)	(63.24)	(21.70)	(21.30)
900 M	26.67	21.67	33.85	31.09	100.00	100.00	100.00	100.00	1250.00	1000.00	948.00	998.57
	(0.00)	(0.00)	(1.87)	(2.27)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(33.41)	(48.39)
ACI Gold	na	33.33	22.67	28.00	na	100.00	100.00	100.00	na	1150.00	1350.00	1250.00
		(0.00)	(0.00)	(5.33)		(0.00)	(0.00)	(0.00)		(0.00)	(0.00)	(100.00)
M 99	na	26.00	16.00	21.00	na	100.00	100.00	100.00	na	1150.00	1350.00	1250.00
		(0.00)	(0.00)	(5.00)		(0.00)	(0.00)	(0.00)		(0.00)	(0.00)	(100.00)
1414	na	20.00	na	20.00	na	100.00	na	100.00	na	875.00	na	875.00
		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)
M 1837	na	16.00	na	16.00	na	95.00	na	95.00	na	1250.00	na	1250.00
		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)
Overall	25.17	25.42	29.65	28.04	100.00	99.55	97.76	98.48	1043.75	1053.36	971.48	1001.23
	(2.91)	(2.14)	(1.30)	(1.07)	(0.00)	(0.45)	(2.00)	(1.25)	(77.98)	(44.33)	28.24	(23.02)

Note: Figures in parentheses show the standard error of sample mean; na = not applicable.

Table 19: Cultivation practices in rice production

Operation	Farmer group (Aman rice)				P-value	Farmer group (Boro rice)				P-value
	Small	Medi-	Large	Overall		Small	Medium	Large	Overall	
Tillage										
average number of tillage	3.85	3.96	4.10	3.96	0.35[a]	3.86	4.02	4.13	4.03	0.18[a]
operations	(0.10)	(0.09)	(0.14)	(0.06)		(0.13)	(0.11)	(0.11)	(0.07)	
% of farmers doing no till	0.00	0.00	0.00	0.00	na	0.00	0.00	0.00	0.00	na
Seeding type: % of farm-										
transplanting	100.00	100.00	100.00	100.00	na	100.00	100.00	100.00	100.00	na
seed treatment (% of farm-	0.00	0.00	0.00	0.00	na	0.00	0.00	0.00	0.00	na
Median date of sowing	17-Jun	16-Jun	08-June	16-Jun		17-Dec	15-Dec	09-Dec	15-Dec	
Mode date of sowing	24-Jun	29-May	29-May	29-May		15-Dec	29- Nov	29- Nov	15-Dec	
	(16.67)	(20.00)	(17.07)	(13.46)		(17.24)	(15.56)	(12.50)	(13.08)	
Median date of harvesting	04-Nov	08-Nov	04-Nov	04-Nov		08-May	05-May	08-May	08-May	
Mode date of harvesting	30-oct	15-nov	04-nov	30-oct		08-may	03-may	28-apr	03-may	
	(13.33)	(14.54)	(12.19)	(12.18)		(17.24)	(13.38)	(14.29)	(11.54)	
Mode of harvesting: (% of										
manual harvesting	100.00	100.00	100.00	100.00	na	100.00	100.00	100.00	100.00	na

Note: Figures in parentheses show the standard error of sample mean;

[a] = p-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

na = not applicable.

Table 20: Input use in rice cultivation

	Farmer group (Aman rice)				*p*-value	Farmer group (Boro rice)				*p*-value
	Small	Medium	Large	Over-all		Small	Medium	Large	Over-all	
Seed rate (kg/acre)	21.10	20.51	20.77	20.80	0.82[a]	17.38	17.17	19.68	18.30	0.03[a]
	(0.49)	(0.49)	(0.49)	(0.29)		(1.19)	(0.87)	(0.70)	(0.51)	
FYM and other manure use (qtl/acre)	7.09	8.11	10.66	8.58	0.01[a]	8.25	11.90	13.86	12.00	0.00[a]
	(0.99)	(0.77)	(0.82)	(0.51)		(0.89)	(0.93)	(0.94)	(0.59)	
Fertilizers (qtl/acre)										
nitrogen	0.29	0.28	0.31	0.29	0.21[a]	0.32	0.34	0.36	0.35	0.09[a]
	(0.01	(0.01)	(0.01)	(0.01)		(0.02)	(0.01)	(0.01)	(0.01)	
phosphorous	0.16	0.16	0.56	0.25	0.29[a]	0.16	0.18	0.18	0.17	0.22[a]
	(0.01)	(0.01)	(0.39)	(0.09)		(0.01)	(0.01)	(0.01)	(0.00)	
potash	0.16	0.19	0.18	0.17	0.06[a]	0.17	0.20	0.18	0.19	0.33[a]
	(0.01)	(0.01)	(0.01)	(0.01)		(0.01)	(0.01)	(0.01)	(0.01)	
Soil pH amendments	0.35	0.33	0.48	0.38	0.96[a]	0.36	0.33	0.25	0.30	0.00[a]
	(0.06)	(0.06)	(0.22)	(0.07)		(0.04)	(0.03)	(0.02)	(0.02)	
Other	na	0.02	0.02	0.02	na	0.04	0.03	0.05	0.05	0.67[a]
		(0.01)	(0.00)	(0.01)		(0.02)	(0.01)	(0.02)	(0.01)	
herbicides (liter/acre)	0.22	0.24	0.26	0.24	0.86[a]	0.20	0.16	0.25	0.22	0.30[a]
	(0.02)	(0.05)	(0.07)	(0.03)		(0.00)	(0.04)	(0.04)	(0.03)	
fungicides (liter/acre)	0.12	0.15	0.13	0.13	0.44[a]	0.15	0.17	0.12	0.14	0.31[a]
	(0.02)	(0.02)	(0.02)	(0.01)		(0.03)	(0.02)	(0.01)	(0.01)	

Note: Figures in parentheses show the standard error of sample mean;

[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

[b] = *p*-value derived from χ^2 test with trend;
na = not applicable.

Table 20: Input use in rice cultivation (Contd.)

	Farmer group (Aman rice)				*p*-value	Farmer group (Boro rice)				*p*-value
	Small	Medium	Large	Overall		Small	Medi-um	Large	Overall	
Human labor use (workdays/ acre)	42.38 (1.85)	45.93 (2.08)	46.68 (2.61)	44.76 (1.23)	0.12[a]	56.13 (1.13)	62.09 (1.72)	66.79 (1.72)	62.79 (1.04)	0.00[a]
% of hired labor to total labor	66.79	71.57	74.97	70.76	0.00[b]	63.67	61.83	59.92	61.32	0.01[b]
% of female labor to total labor	7.72	9.60	14.00	10.13	0.00[b]	11.58	9.13	8.31	9.24	0.00[b]
Animal labor use (BDT/acre)	1289.35 (162.19)	958.62 (81.02)	984.38 (160.06)	1076.86 (76.08)	0.24[a]	947.78 (116.05)	934.74 (96.97)	1047.06 (131.76)	974.44 (65.27)	0.78[a]
Machine labor use (BDT/ acre)	1814.23 (84.89)	1679.78 (101.14)	1746.86 (107.53)	1750.00 (55.71)	0.65[a]	1707.08 (99.15)	1605.85 (94.44)	1591.00 (83.00)	1620.52 (53.24)	0.44[a]

Note: Figures in parentheses show the standard error of sample mean;

[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

[b] = *p*-value derived from χ^2 test with trend; na = not applicable.

Table 21: Economics of rice cultivation

Cost component (BDT/ acre)	Farmer group (Aman rice)				*p*-value	Farmer group (Boro rice)				*p*-value
	Small	Medium	Large	Overall		Small	Medium	Large	Overall	
Seed	744.00 (16.70)	724.45 (16.43)	741.10 (16.80)	736.35 (9.67)	0.84[a]	1166.03 (173.66)	1145.24 (149.08)	1092.19 (134.28)	1127.03 (86.04)	0.67[a]
FYM and other manures	34.33 (27.13)	19.64 (14.97)	39.02 (28.13)	30.38 (13.76)	0.99[a]	62.07 (31.55)	32.73 (20.13)	0.00 (0.00)	25.18 (10.03)	na
Chemical fertilizer	2319.98 (89.81)	2333.05 (98.10)	2220.17 (138.23)	2298.36 (60.61)	0.85[a]	2412.79 (126.18)	2758.51 (89.56)	2835.54 (80.07)	2714.57 (55.74)	0.01[a]
Herbicide	14.93 (6.58)	25.05 (10.05)	51.24 (19.43)	28.04 (6.76)	0.34[a]	10.69 (7.43)	40.22 (14.13)	78.82 (17.68)	50.26 (9.45)	0.02[a]
Fungicide and insecticide	305.00 (19.96)	265.10 (24.52)	366.34 (28.98)	307.06 (14.11)	0.20[a]	271.86 (36.94)	337.39 (25.99)	337.97 (23.03)	323.02 (15.78)	0.48[a]
Animal labor cost	494.25 (102.08)	505.45 (77.69)	384.15 (97.54)	469.26 (54.12)	0.35[a]	588.28 (112.37)	394.67 (80.43)	317.86 (75.81)	404.77 (50.14)	0.04[a]
Machine custom hiring cost	1572.33 (108.83)	1404.91 (119.50)	1491.22 (133.87)	1491.99 (68.83)	0.60[a]	1412.76 (146.74)	1463.11 (110.15)	1420.54 (99.41)	1433.54 (65.53)	0.85[a]
Hired labour costs	3330.05 (219.94)	3794.00 (197.89)	3945.60 (254.40)	3655.40 (129.35)	0.06[a]	3902.55 (299.00)	4361.39 (201.32)	4682.44 (196.41)	4397.33 (129.99)	0.07[a]
Contract labour costs	1469.58 (232.52)	1172.36 (255.31)	1264.22 (337.31)	1310.82 (154.10)	0.14[a]	218.90 (153.80)	366.00 (289.64)	398.25 (143.72)	347.08 (121.99)	0.25[a]
Irrigation costs	1228.08 (207.93)	1590.03 (261.88)	602.38 (193.11)	1191.24 (135.04)	0.00[a]	2941.20 (347.64)	2449.23 (325.31)	1178.91 (227.71)	2011.76 (179.42)	0.00[a]

Note: Figures in parentheses show the standard error of sample mean; [a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom.

Table 21: Economics of rice cultivation (Contd.)

Cost component (BDT/ acre)	Farmer group (Aman rice)				*p*-value	Farmer group (Boro rice)				*p*-value
	Small	Medium	Large	Overall		Small	Medium	Large	Overall	
Cost of cultivation	11111.22	11589.55	10954.83	11238.76	0.36[a]	12709.37	13087.50	12157.51	12602.54	0.18[a]
	(314.94)	(321.81)	(399.78)	(196.31)		(498.31)	(438.28)	(360.13)	(244.61)	
Cost of cultivation+family labor	12703.91	13058.04	12274.91	12716.01	0.27[a]	14889.65	15822.12	15312.75	15394.69	0.26[a]
	(308.36)	(325.53)	(358.49)	(190.39)		(452.36)	(332.96)	(247.89)	(187.72)	
Gross revenue	23082.63	23598.71	24334.60	23593.62	0.59[a]	37198.00	40332.20	38355.78	38781.65	0.17[a]
	(784.60)	(738.97)	(816.73)	(451.69)		(1345.86)	(1313.38)	(1046.67)	(709.91)	
Net revenue (excluding family labor)	11971.41	12009.16	13379.77	12354.87	0.40[a]	24488.63	27244.70	26198.26	26179.11	0.31[a]
	(795.97)	(798.43)	(931.31)	(481.98)		(1304.57)	(1299.70)	(1058.35)	(703.96)	
Net revenue (including family labor)	10378.72	10540.67	12059.69	10877.61	0.32[a]	22308.35	24510.08	23043.03	23386.96	0.46[a]
	(802.65)	(815.94)	(904.34)	(484.57)		(1203.12)	(1314.18)	(1053.57)	(695.45)	
Price (BDT/quintal)	1804.58	1805.40	1800.17	1803.71	0.33[a]	1630.38	1719.73	1634.61	1663.13	0.41[a]
	(5.40)	(10.69)	(24.91)	(7.77)		(16.94)	(59.35)	(17.01)	(22.27)	
Cost of production (with paid-out cost alone; BDT/quintal)	932.92	937.97	860.07	915.56	0.26[a]	575.18	584.36	541.79	563.97	0.39[a]
	(41.77)	(40.38)	(51.75)	(25.39)		(30.93)	(34.22)	(24.18)	(17.17)	
Return to family labor (BDT/day)*	1383.18	1558.80	2045.59	1619.19	0.42[a]	1764.71	2275.30	1380.00	1775.73	0.12[a]
	(170.95)	(289.21)	(430.17)	(166.01)		(218.17)	(826.04)	(149.13)	(296.89)	
Wage rate existing (BDT/day)**	118.53	115.96	115.42	116.81	0.55[a]	110.43	113.49	116.22	113.98	0.20[a]
	(2.27)	(2.04)	(2.76)	(1.34)		(2.53)	(2.10)	(1.76)	(1.20)	

Note: Figures in parentheses show the standard error of sample mean;

[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom.

*Caluculated using net revenues without family labor/number of family labor days.

**Calculated using (wage of men*days worked by men+wage of women*days worked by women)/ (days worked by men+days worked by women).

Table 22: Cultivation practices in wheat production

Operation	Farmer group				*p*-value
	Small	Medium	Large	Overall	
Tillage					
average number of tillage operations	3.91	3.88	4.23	4.01	0.12[a]
	(0.12)	(0.09)	(0.14)	(0.07)	
% of farmers doing no till	3.64	4.65	0.00	2.76	na
Seeding type: % of farmers using					
manual broadcast	96.36	95.35	100.00	97.24	0.28[b]
rotoseeder	3.64	4.65	0.00	2.76	na
Seed treatment (% of farmers)	0.00	0.00	0.00	0.00	na
Median date of sowing	29-Nov	30-Nov	29-Nov	29-Nov	
Mode date of sowing	29-Nov	24-Nov 29-Nov 30-Nov 01-Dec 04-Dec	29-Nov	29-Nov	
	(23.64)	(11.63)	(31.91)	(22.76)	
Median date of harvesting	30 Mar	01 Apr	30 Mar	30 Mar	
Mode date of harvesting	24 Mar	08 Apr	29 Mar	29 Mar	
	(16.36)	(16.28)	(14.89)	(12.41)	
Mode of harvesting: (% of farmers)					
manual harvesting	100.00	100.00	100.00	100.00	na

Note: Figures in parentheses show the standard error of sample mean;

[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

[b] = *p*-value derived from c^2 test with trend;

na = not applicable.

Table 23: Input use in wheat cultivation

	Farmer group				*p*-value
	Small	Medium	Large	Overall	
Seed rate (kg/acre)	59.13	59.33	61.91	60.09	0.14[a]
	(0.54)	(1.11)	(1.01)	(0.52)	
FYM and other manure use (qtl/acre)	5.77	7.94	10.36	8.12	0.00[a]
	(0.76)	(0.87)	(0.76)	(0.49)	
fertilizer (qtl/acre)					
nitrogen	0.29	0.29	0.32	0.30	0.12[a]
	(0.01)	(0.01)	(0.01)	(0.01)	
Phosphorous	0.15	0.17	0.17	0.16	0.50[a]
	(0.01)	(0.01)	(0.01)	(0.00)	
Potash	0.17	0.18	0.18	0.17	0.40[a]
	(0.01)	(0.01)	(0.01)	(0.01)	
Soil pH amendments	Na	0.40	0.29	0.33	na
		(0.00)	(0.06)	(0.05)	
Other	0.04	0.05	0.03	0.03	0.34[a]
	(0.01)	(0.02)	(0.00)	(0.00)	
herbicides (liter/acre)	0.20	0.30	0.26	0.27	0.54[a]
	(0.00)	(0.05)	(0.02)	(0.02)	
fungicides (liter/acre)	0.04	0.04	0.06	0.05	0.56[a]
	(0.00)	(0.01)	(0.03)	(0.01)	
Human labor use (workdays/acre)	19.03	20.57	20.58	19.99	0.32[a]
	(0.70)	(1.01)	(0.90)	(0.50)	
% of hired labor to total labor	53.58	60.96	63.74	59.22	0.00[b]
% of female labor to total labor	8.36	9.45	9.21	15.16	0.53[b]
Animal labor use (BDT/acre)	979.55	992.86	1385.71	1117.19	0.09[a]
	(103.02)	(69.63)	(153.85)	(68.89)	
Machine labor use (BDT/acre)	1910.80	1665.79	1758.33	1789.92	0.21[a]
	(89.19)	(89.72)	(91.70)	(52.74)	

Note: Figures in parentheses show the standard error of sample mean;

[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

[b] = *p*-value derived from c^2 test with trend;

na = not applicable.

Table 24: Economics of wheat cultivation

Cost component (BDT/acre)	Farmer group				*p*-value
	Small	Medium	Large	Overall	
Seed	2074.25	2064.70	2146.44	2095.32	0.46[a]
	(19.02)	(39.38)	(38.71)	(18.82)	
FYM and other manures	9.43	4.76	0.00	4.93	na
	(5.77)	(4.76)	(0.00)	(2.58)	
Chemical fertilizers	2260.11	2325.95	2526.21	2367.66	0.15[a]
	(97.74)	(116.69)	(113.51)	(63.01)	
Herbicides	3.77	44.26	55.32	32.81	0.01[a]
	(3.77)	(17.99)	(16.39)	(7.91)	
Fungicides and insecticides	61.51	81.62	67.55	69.46	0.72[a]
	(21.28)	(28.99)	(19.10)	(13.21)	
Animal labor cost	355.66	496.43	619.15	484.51	0.32[a]
	(74.41)	(84.81)	(122.13)	(55.48)	
Machine custom hiring cost	1764.91	1450.00	1571.28	1607.68	0.13[a]
	(112.11)	(114.81)	(114.40)	(66.31)	
Hired labor cost	1234.16	1436.86	1460.20	1368.93	0.36[a]
	(93.35)	(91.50)	(85.00)	(52.70)	
Contract labor cost	1184.21	1027.78	1058.54	1096.35	0.43[a]
	(109.16)	(132.09)	(126.73)	(70.06)	
Irrigation cost	613.60	926.83	809.02	770.93	0.62[a]
	(78.17)	(191.09)	(160.37)	(82.94)	
Cost of cultivation	9561.62	9859.19	10313.71	9898.56	0.17[a]
	(238.77)	(310.76)	(299.01)	(162.84)	
Cost of cultivation+family labor	10572.66	10757.48	11139.29	10814.87	0.32[a]
	(229.02)	(304.86)	(289.68)	(157.11)	
Gross revenue	19989.33	19468.16	20597.26	20036.40	0.65[a]
	(715.02)	(678.24)	(756.82)	(416.18)	
Net revenue (excluding family labor)	10427.71	9608.97	10283.55	10137.83	0.73[a]
	(748.51)	(692.51)	(681.60)	(411.57)	
Net revenue (including family labor)	9416.67	8710.68	9457.97	9221.53	0.71[a]
	(737.38)	(707.14)	(681.06)	(410.75)	

Note: Figures in parentheses show the standard error of sample mean;
[a] shows p-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom.

Table 24: Economics of wheat cultivation (Contd.)

Cost component (BDT/acre)	Farmer group				*p*-value
	Small	Medium	Large	Overall	
Price (BDT/quintal)	1818.15	1836.52	1758.30	1803.77	0.01[a]
	(17.31)	(34.66)	(29.26)	(15.64)	
Cost of production (with paid-out cost alone; BDT/ quintal)	933.66	963.84	923.40	939.19	0.68[a]
	(42.98)	(41.20)	(39.84)	(23.95)	
Return to family labor (BDT/day)*	1741.65	2094.43	1614.55	1803.92	0.68[a]
	(239.55)	(416.02)	(146.02)	(159.24)	
Current wage rate (BDT/day)**	122.45	116.85	113.21	117.74	0.00[a]
	(2.47)	(2.46)	(2.46)	(1.46)	

Note: Figures in parentheses show the standard error of sample mean;

[a] shows p-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom.

*Calculated using net revenues without family labor/number of family labor days.

**Calculated using (wage of men*days worked by men+wage of women*days worked by women)/ (days worked by men+days worked by women).

Table 25: Cultivation practices in maize production

Operation	Farmer group (Rabi)				P-value	Farmer group (spring)				P-value
	Small	Medium	Large	Overall		Small	Medium	Large	Overall	
Tillage										
average number of tillage operations	3.88 (0.18)	3.72 (0.23)	3.97 (0.22)	3.88 (0.13)	0.63[a]	1.67 (0.67)	2.20 (0.49)	1.69 (0.36)	1.81 (0.26)	0.33[a]
% of farmers doing no-till	0.00	10.00	0.00	3.33	na	25.00	44.44	27.78	32.26	0.72[b]
Seeding type: % of farmers using										
manual broadcast	100.00	100.00	100.00	100.00	na	100.00	100.00	100.00	100.00	na
Seed treatment (% of farmers)	0.00	0.00	0.00	0.00	na	0.00	0.00	0.00	0.00	na
Median date of sowing	24-Nov	09-Dec	15-Dec	09-Dec		23-Jan	28-Jan	16-Jan	28-Jan	
Mode date of sowing	na	09-Dec 17-Dec 15-Jan (15.38)	29-Dec (23.53)	29-Dec (12.50)		na	14-Jan (22.22)	09-Dec 15-Dec 08-Jan (11.11)	07-Dec 03-Jan 14-Jan 28-Jan (9.68)	
Median date of harvesting	26-May	03-Jun	31-May	31-May		09-Jun	13-Jun	14-Jun	14-Jun	
Mode date of harvesting	na	03-Jun (23.08)	29-May (17.65)	03-Jun (15.62)		na	08-Jun (22.22)	04-Jul (16.67)	29-Jun (12.90)	
Mode of harvesting: (% of farmers)										
manual harvesting	100.00	100.00	100.00	100.00	na	100.00	100.00	100.00	100.00	na

Note: Figures in parentheses show the standard error of sample mean;
[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;
[b] =*p*-value derived from c^2 test with trend;
na = not applicable.

Table 26: Input use in maize production

	Farmer group (Rabi)				P-value	Farmer group (spring)				P-value
	Small	Medium	Large	Overall		Small	Medium	Large	Overall	
Seed rate (kg/acre)	8.00	6.85	7.06	7.03	0.33[a]	6.88	7.78	6.82	7.11	0.33[a]
	(0.00)	(0.30)	(0.28)	(0.19)		(0.66)	(0.22)	(0.36)	(0.24)	
FYM and other manure use (qtl/acre)	na	12.28	11.08	11.55	na	na	9.41	9.50	9.46	na
		(1.36)	(0.65)	(0.66)			(2.25)	(1.86)	(1.36)	
fertilizers (qtl/acre)										
nitrogen	0.20	0.28	0.33	0.30	0.20[a]	0.20	0.28	0.27	0.26	0.40[a]
	(0.10)	(0.02)	(0.02)	(0.02)		(0.06)	(0.03)	(0.03)	(0.02)	
Phosphorous	na	0.18	0.19	0.18	na	na	0.14	0.18	0.16	na
		(0.02)	(0.01)	(0.01)			(0.02)	(0.07)	(0.03)	
Potash	na	0.18	0.22	0.20	na	0.27	0.19	0.22	0.22	na
		(0.02)	(0.02)	(0.02)		(0.00)	(0.03)	(0.07)	(0.03)	
Soil pH amendments (Agricultural lime)	na	0.30	0.39	0.36	na	na	0.60	0.35	0.43	na
		(0.06)	(0.05)	(0.04)			(0.00)	(0.15)	(0.12)	
Other	na	na	0.05	0.05	na	na	na	0.04	0.04	na
			(0.02)	(0.02)				(0.00)	(0.00)	
herbicides (liter/acre)	na	0.03	na	0.01	na	na	na	na	na	na
		(0.00)		(0.00)						
fungicides (liter/acre)	0.80	0.19	0.20	0.23	0.26[a]	0.21	0.15	0.23	0.22	0.68[a]
	(0.00)	(0.05)	(0.04)	(0.05)		(0.09)	(0.12)	(0.05)	(0.04)	
human labor use (workdays/acre)	56.63	48.96	47.74	48.79	0.05[a]	50.63	51.78	46.48	48.55	0.58[a]
	(0.01)	(0.78)	(1.67)	(1.00)		(3.41)	(2.68)	(2.05)	(1.51)	
% of hired labor to total labor	39.29	52.63	76.62	64.13	0.00[b]	51.42	44.85	69.78	59.59	0.00[b]
% of female labor to total labor	27.37	11.78	21.44	17.93	0.06[b]	24.20	21.35	12.31	16.71	0.00[b]
Animal labor use (BDT/acre)	1100.00	935.71	960.00	967.86	0.97[a]	760.00	1600.00	533.33	782.86	na
	(700.00)	(228.01)	(240.00)	(154.74)		(160.00)	(0.00)	(66.67)	(157.08)	
Machine labor use (BDT/acre)	1050.00	1435.56	1597.33	1499.23	0.20[a]	na	1066.67	1225.00	1181.82	na
	(450.00)	(173.65)	(139.14)	(105.44)			(240.37)	(327.74)	(241.52)	

Note: Figures in parentheses show the standard error of sample mean;

[a] = p-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

[b] = p-value derived from c^2 test with trend;

na indicates not applicable.

Table 27: Economics of maize production

Cost component (BDT/acre)	Farmer group (Rabi)				*p*-value	Farmer group (spring)				*p*-value
	Small	Medium	Large	Overall		Small	Medium	Large	Overall	
Seed	2360.00	1843.65	2056.03	1988.75	0.19[a]	2010.63	2052.22	2004.44	2019.11	0.92[a]
	(0.00)	(140.76)	(81.65)	(74.67)		(193.64)	(178.53)	(105.11)	(81.25)	
FYM and other manures	na	na	Na	na	Na	na	na	55.56	32.26	na
								(55.56)	(32.26)	
Chemical fertilizer	510.00	2217.46	2775.47	2407.19	0.05[a]	804.00	1304.44	1090.06	1115.39	0.33[a]
	(270.00)	(281.31)	(199.92	(183.31)		(312.88)	(275.09)	(269.83)	(178.47)	
Herbicides	na	32.31	Na	13.13	Na	na	na	na	na	na
		(32.31)		(13.13)						
Fungicides and insecticides	200.00	127.12	251.88	197.95	0.82[a]	218.75	66.00	179.61	151.68	0.20[a]
	(200.00)	(46.25)	(110.80	(62.44)		(90.29)	(44.90)	(53.47)	(36.16)	
Animal labor cost	1100.00	503.85	282.35	423.44	0.16[a]	570.00	177.78	88.89	176.77	0.02[a]
	(700.00)	(179.25)	(127.25	(108.76)		(221.13)	(177.78)	(49.10)	(68.45)	
Machine custom hiring cost	1050.00	993.85	1409.41	1218.13	0.28[a]	na	355.56	544.44	419.35	na
	(450.00)	(224.72)	(177.48	(135.39)			(190.84)	(203.60)	(132.50)	
Hired labor cost	2195.00	3075.38	4440.66	3745.66	0.00[a]	2773.75	2684.44	3849.10	3372.22	0.18[a]
	(2195.00)	(400.75)	(165.41	(247.96)		(1059.87)	(645.26)	(332.62)	(306.03)	
Contract labor cost	675.00	534.71	534.91	543.58	0.73[a]	416.68	562.98	544.19	533.19	0.62[a]
	(125.00)	(30.67)	(40.21)	(25.69)		(142.40)	(37.61)	(46.17)	(33.79)	
Irrigation cost	4692.50	1505.31	1037.18	1455.81	0.06[a]	3342.00	1679.83	215.69	1044.16	0.01[a]
	(1332.50)	(446.63)	(374.53	(312.36)		(952.87)	(779.84)	(59.83)	(316.04)	

Note: Figures in parentheses show the standard error of sample mean,

[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

na= not applicable.

Table 27: Economics of maize production (Contd.)

Cost component (BDT/ acre)	Farmer group (Rabi)				*p*-value	Farmer group (spring)				*p*-value
	Small	Medium	Large	Overall		Small	Medium	Large	Overall	
Cost of cultivation	12782.50	10680.17	12787.89	11931.29	0.18[a]	10135.81	8883.26	8571.99	8864.14	0.34[a]
	(517.50)	(818.56)	(508.66)	(459.78)		(1117.21)	(948.29)	(538.25)	(435.50)	
Cost of cultiva-tion+family labor	16507.15	13402.66	14171.32	14005.04	0.38[a]	12553.03	12012.49	10285.60	11079.53	0.12[a]
	(2074.65)	(654.73)	(550.04)	(420.59)		(1414.21)	(960.35)	(525.81)	(467.05)	
Gross revenue	24989.74	26867.46	30505.80	28682.97	0.61[a]	26484.38	28716.58	27740.23	27861.64	0.96[a]
	(7410.27)	(1922.01)	(2500.58)	(1591.78)		(4079.02)	(2761.12)	(1465.61)	(1235.80)	
Net revenue (excluding family labor)	12207.24	16187.29	17717.91	16751.68	0.69[a]	16348.57	19833.32	19168.24	18997.50	0.63[a]
	(6892.77)	(2266.90)	(2561.22)	(1662.64)		(3859.68)	(2528.22)	(1313.17)	(1136.65)	
Net revenue (including family labor)	8482.59	13464.80	16334.48	14677.93	0.65[a]	13931.34	16704.09	17454.63	16782.11	0.78[a]
	(9484.92)	(2209.49)	(2550.88)	(1696.16)		(4478.55)	(2501.13)	(1349.09)	(1177.17)	
Price (BDT/quintal)	1156.00	1005.23	944.82	982.56	0.13[a]	1043.75	1062.44	967.61	1004.97	0.18[a]
	(31.00)	(56.93)	(21.98)	(27.13)		(77.98)	(49.19)	(30.48)	(25.24)	
Cost of production (with paid-out cost alone; BDT/quintal)	644.98	416.97	420.06	432.86	0.26[a]	420.86	339.52	307.02	331.15	0.22[a]
	(183.18)	(44.27)	(26.79)	(25.87)		(64.56)	(41.99)	(21.60)	(19.76)	
Return to family labor (BDT/day)*	834.54	812.45	1703.42	1287.16	0.01[a]	1274.06	742.54	2897.83	2062.58	0.34[a]
	(740.71)	(152.23)	(221.19)	(156.53)		(437.64)	(113.36)	(874.29)	(536.67)	
Wage rate existing (BDT/day)**	109.33	120.01	121.43	120.10	0.55[a]	108.52	116.96	119.63	117.42	0.02[a]
	(10.67)	(3.09)	(2.86)	(2.06)		(6.74)	(6.59)	(4.43)	(3.29)	

Note: Figures in parentheses show the standard error of sample mean,

[a] = *p*-value derived from Kruskal-Wallis equality

of population rank test with 2 degrees of freedom;

na= not applicable.

*Calculated using net revenues without family labor/number of family labor days.

**Calculated using (wage of men*days worked by men+wage of women*days worked by women)/ (days worked by men+days worked by women)

Table 28: Crop residue use across farmer categories (%)

[%]	Mode of harvest: manual				*p*-value
	Small	Medium	Large	Overall	
Rice (OPVs)					
left in field	10.44	10.54	11.53	10.84	0.24[a]
	(0.34)	(0.29)	(0.50)	(0.23)	
Sold	0.33	0.44	0.46	0.41	0.91[a]
	(0.25)	(0.31)	(0.34)	(0.18)	
Feeding	43.72	53.43	62.38	53.44	0.01[a]
	(3.98)	(3.18)	(2.67)	(1.94)	
Fuel	12.67	10.10	9.34	10.64	0.81[a]
	(2.17)	(1.24)	(1.30)	(0.92)	
Roofing	5.67	7.84	4.05	5.89	0.20[a]
	(1.30)	(1.27)	(0.85)	(0.67)	
Other	27.17	17.65	12.24	18.78	0.03[a]
	(3.82)	(3.12)	(2.37)	(1.83)	
Rice (hybrid)					
left in field	21.20	21.46	25.56	23.07	0.05[a]
	(1.66)	(1.17)	(1.45)	(0.83)	
Sold	0.11	1.94	0.25	0.83	0.06[a]
	(0.11)	(0.94)	(0.25)	(0.36)	
Feeding	45.33	52.78	57.16	52.84	0.31[a]
	(4.82)	(3.47)	(2.41)	(1.96)	
Fuel	17.50	12.43	10.80	12.94	0.51[a]
	(3.59)	(1.88)	(1.66)	(1.27)	
Roofing	0.87	0.42	0.25	0.45	0.80[a]
	(0.68)	(0.29)	(0.17)	(0.20)	
Other	15.00	10.97	5.99	9.87	0.27[a]
	(4.19)	(2.83)	(1.65)	(1.57)	

Note: Figures in parentheses show the standard error of sample mean;

[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

na = not applicable.

Table 28: Crop residue use across farmer categories (%) (Contd.)

[%]	Mode of harvest: manual				*p*-value
	Small	Medium	Large	Overall	
Wheat					
left in field	0.89	1.63	1.84	1.42	0.39[a]
	(0.46)	(0.57)	(0.81)	(0.36)	
Sold	13.93	16.28	12.86	14.26	0.57[a]
	(2.00)	(2.58)	(2.33)	(1.31)	
Feeding	3.93	2.09	6.53	4.26	0.23[a]
	(2.08)	(1.47)	(2.34)	(1.19)	
Fuel	73.04	64.42	58.37	65.68	0.00[a]
	(3.28)	(2.96)	(3.49)	(1.96)	
Roofing	5.89	15.58	18.37	12.84	0.01[a]
	(2.36)	(3.62)	(3.62)	(1.87)	
Other	2.32	0.00	2.04	1.55	Na
	(1.85)	(0.00)	(1.43)	(0.85)	
Maize (hybrid)					
left in field	1.43	2.59	2.33	2.34	0.63[a]
	(0.92)	(0.86)	(0.92)	(0.60)	
Sold	0.00	0.00	2.33	1.30	Na
	(0.00)	(0.00)	(2.33)	(1.30)	
Feeding	0.00	2.59	0.00	0.91	Na
	(0.00)	(2.69)	(0.00)	(0.92)	
Fuel	87.14	78.89	71.28	75.39	0.19[a]
	(8.58)	(4.01)	(4.34)	(2.93)	
Roofing	0.00	0.00	0.00	0.00	Na
Other	11.43	15.93	24.07	20.06	0.20[a]
	(8.57)	(2.71)	(3.85)	(2.50)	

Note: Figures in parentheses show the standard error of sample mean;

[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

na = not applicable.

Table 29: Details of livestock productivity

	cattle, local				*p*-value	cattle breed				*p*-value
	Small	Medi-	Large	Overall		Small	Medium	Large	Overall	
Age at 1st calving (months)	46.62	47.65	45.72	46.58	0.25[a]	58.00	57.00	55.55	56.37	0.82[a]
	(0.96)	(0.75)	(0.72)	(0.46)		(2.00)	(3.00)	(2.12)	(1.40)	
Max milk yield (liters/day)	2.65	1.89	2.15	2.18	0.00[a]	9.00	8.00	6.30	7.18	0.20[a]
	(0.24)	(0.10)	(0.12)	(0.09)		(1.00)	(1.22)	(0.87)	(0.64)	
Lactation length (months)	7.33	7.26	7.28	7.29	0.98[a]	9.50	10.25	9.82	9.84	0.76[a]
	(0.21)	(0.16)	(0.14)	(0.09)		(0.50)	(0.63)	(0.26)	(0.22)	
Inter-calving period (months)	12.95	13.38	12.87	13.06	0.28[a]	16.50	17.00	16.64	16.68	0.96[a]
	(0.19)	(0.26)	(0.12)	(0.11)		(1.26)	(1.00)	(0.83)	(0.56)	
Average annual milk yield (liters)	678.29	481.14	540.14	551.53	0.01[a]	2311.67	2098.75	1624.25	1857.21	0.29[a]
	(60.57)	(27.25)	(26.82)	(20.91)		(243.33)	(383.54)	(254.41)	(185.32)	
Replacement rate (years)*	7.74	8.09	8.04	7.99	0.11[a]	6.22	6.41	5.62	5.88	0.88[a]
	(0.12)	(0.12)	(0.11)	(0.07)		(0.26)	(0.26)	(0.72)	(0.44)	

Note: Figures in parentheses show the standard error of sample mean;

[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

na = not applicable.

*Calculated using = (1/ (expected life – age at first calving))

*100 Female buffalo not found in the sample household; 1.9% of households have male buffalo for draft use.

Table 30: Average contribution of feeds to dairy animal ration

[% DM]	Farmer group				*p*-value
	Small	Medium	Large	Overall	
Rice straw	76.55	78.18	77.79	77.65	0.25[a]
	(1.08)	(0.85)	(0.71)	(0.49)	
Green grasses	14.22	12.47	11.89	12.57	0.03[a]
	(0.71)	(0.52)	(0.40)	(0.30)	
Concentrates	9.22	9.35	10.32	9.78	0.13[a]
	(0.83)	(0.52)	(0.55)	(0.35)	
	100.00	100.00	100.00	100.00	

Note: Figures in parentheses show the standard error of sample mean;

[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom.

Table 31: Cost of various feed types

Dairy feed	Straw			Concentrates	Total
	Wheat	rice	maize		
Cost [BDT/quintal]	103.89	121.07	Na	1827.78	1973.89
	(5.32)	(8.22)		(63.04)	(70.02)

Note: Figures in parentheses show the standard error of sample mean. Source: CSISA village survey, 2010.

Table 32: Health and breeding costs

Cost [BDT/visit]	Farmer group				P-value
	Small	Medium	Large	Overall	
Dairy animals					
Artificial insemination	213.33	207.69	226.36	218.18	0.43[a]
	(15.63)	(13.16)	(11.14)	(7.45)	
Improved bull	114.44	76.12	79.69	86.87	0.01[a]
	(12.37)	(11.81)	(7.80)	(6.02)	
Animal health	129.75	111.04	128.38	122.46	0.56[a]
(veterinary service)	(13.22)	(8.27)	(9.21)	(5.69)	

Note: Figures in parentheses show the standard error of sample mean;

[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom.

Table 33: Value of milk sales and consumption

	Farmer group				*p*-value
	Small	Medium	Large	Overall	
Milk price (BDT/liter)	26.85	25.00	26.30	25.98	0.02[a]
	(0.63)	(0.19)	(0.42)	(0.25)	
Milk sold (liter/day)	1.85	1.24	1.47	1.48	0.01[a]
	(0.27)	(0.19)	(0.18)	(0.12)	
Milk consumed (liter/day)	0.26	0.33	0.49	0.39	0.00[a]
	(0.03)	(0.03)	(0.04)	(0.02)	
Milk processed for consumption (liter/day)	0.09	0.12	0.17	0.14	0.01[a]
	(0.01)	(0.01)	(0.02)	(0.01)	
Milk processed for sale (liter/day)	na	na	na	Na	na
Total (liter/day)	2.20	1.69	2.14	2.01	0.02[a]
	(0.27)	(0.21)	(0.19)	(0.13)	

Note: Figures in the parentheses show the standard error of sample mean;

[a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom;

na = not applicable.

Table 34: Milk market across farmer groups

[% of households]	Farmer groups				*p*-value
	Small	Medium	Large	Overall	
Main milk buyer					
formal	0.00	0.00	2.47	1.12	Na
informal	68.89	81.13	76.54	75.98	0.43[b]
consumer	31.11	18.87	20.99	22.91	0.25[b]

Note: [b] = *p*-value derived from c^2 test with trend.

Table 35: Market channels: fertilizers and pesticides

Source	% products from the source				*p*-value
	Small	Medium	Large	Overall	
Fertilizers					
government supply	0.00	0.00	0.00	0.00	Na
co-operative	0.00	0.00	0.00	0.00	Na
private dealer (village)	99.06	97.22	92.73	96.30	0.00[a]
private dealer (district)	0.94	2.78	7.27	3.70	Na
Pesticides					
government supply	0.00	0.00	0.00	0.00	Na
co-operative	0.00	0.00	0.00	0.00	Na
private dealer (village)	99.06	97.22	92.73	96.30	0.00[a]
private dealer (district)	0.94	2.78	7.27	3.70	Na

Note: [a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom; na = not applicable.

Table 36: Market channels: seed

Source of seed	% products purchased from the source				*p*-value
	Small	Medium	Large	Overall	
Rice (OPVs)					
government supply	1.20	2.30	0.00	1.23	Na
co-operative	0.00	0.00	0.00	0.00	Na
private dealer (village)	97.59	93.10	86.49	92.62	0.00[a]
private dealer (district)	1.20	4.60	13.51	6.15	Na
Rice (hybrids)					
government supply	0.00	0.00	0.00	0.00	Na
co-operative	0.00	0.00	0.00	0.00	Na
private dealer (village)	100.00	71.43	44.44	63.16	0.00[a]
private dealer (district)	0.00	28.57	55.56	36.84	Na
Wheat					
government supply	3.64	4.65	4.76	4.29	Na
co-operative	0.00	0.00	0.00	0.00	Na
private dealer (village)	96.36	93.02	83.33	91.43	0.00[a]
private dealer (district)	0.00	2.33	11.90	4.29	Na
Maize (hybrids)					
government supply	0.00	0.00	2.44	1.41	Na
co-operative	0.00	0.00	0.00	0.00	Na
private dealer (village)	100.00	95.83	70.73	81.69	0.00[a]
private dealer (district)	0.00	4.17	26.83	16.90	Na

Note: [a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom; na = not applicable.

Table 37: Market channels: cereal outputs

Outlet	% of output traded				*p*-value
	Small	Medium	Large	Overall	
Rice (OPVs)					
government	0.00	0.00	0.00	0.00	na
co-operative	0.00	0.00	0.00	0.00	na
trader (village)	84.62	90.32	83.95	86.54	0.00[a]
trader (district)	15.38	9.68	16.05	13.46	0.00[a]
trader (state)	0.00	0.00	0.00	0.00	na
Rice (hybrids)					
government	0.00	0.00	0.00	0.00	na
co-operative	0.00	0.00	0.00	0.00	na
trader (village)	80.00	94.12	85.92	88.32	0.00[a]
trader (district)	20.00	5.88	14.08	11.68	na
trader (state)	0.00	0.00	0.00	0.00	na
Wheat					
government	0.00	0.00	0.00	0.00	na
co-operative	0.00	0.00	0.00	0.00	na
trader (village)	100.00	100.00	92.50	96.34	0.00[a]
trader (district)	0.00	0.00	7.50	3.66	na
trader (state)	0.00	0.00	0.00	0.00	na
Maize (hybrids)					
government	0.00	0.00	0.00	0.00	na
co-operative	0.00	0.00	2.33	1.33	na
trader (village)	83.33	88.46	72.09	78.67	0.00[a]
trader (district)	0.00	11.54	25.58	18.67	na
trader (state)	16.67	0.00	0.00	1.33	na

Note: [a] = *p*-value derived from Kruskal-Wallis equality of population rank test with 2 degrees of freedom; na = not applicable.

Table 38: Current technology adoption

Technology (name)	% adoption				p-value	% ownership of equipment				p-value
	Small	Medium	Large	Overall		Small	Medium	Large	Overall	
Electric submersible pump	28.30	22.22	10.91	20.37	0.00[b]	0.00	4.17	16.67	4.55	na
Diesel pump	80.19	90.74	93.64	88.27	0.00[b]	12.94	33.67	63.11	38.11	0.00[b]
Two-wheel tractor	92.45	87.96	91.82	90.74	0.88[b]	1.02	2.13	4.95	2.73	0.09[b]
Rotavator	11.32	29.63	32.73	24.96	0.00[b]	0.00	0.00	0.00	0.00	na
PTOS	0.00	0.00	0.91	0.31	na	0.00	0.00	0.00	0.00	na
Mechanical pesticide sprayer	73.58	82.41	81.82	79.32	0.14[b]	12.82	15.73	57.78	29.52	0.00[b]
Knapsack sprayer	4.72	11.11	16.36	10.80	0.01[b]	0.00	16.67	50.00	31.43	na
Power thresher for wheat/rice	48.11	37.04	44.55	43.21	0.61[b]	3.92	0.00	2.04	2.14	na
Pedal thresher	0.94	0.00	8.18	3.09	na	0.00	0.00	66.67	60.00	na
Wheat/maize de-husker	6.60	28.70	38.18	24.69	0.00[b]	0.00	0.00	0.00	0.00	na

Note: [b] = *p*-value derived from χ^2 test with trend; na = not applicable.

Table 39: Familiarity and adoption of CA and related technologies

Technology	Familiarity (% farmers)			% adoption			
	Heard	Seen	Adopted	Small	Medium	Large	Overall
Laser land leveler	0.92	1.54	0.00	0.00	0.00	0.00	0.00
Bed planting	1.54	5.25	0.62	0.00	1.85	0.00	0.62
Zero tillage (no till)	11.45	29.10	1.55	1.89	1.85	0.91	1.54
Turbo/Happy Seeder	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rotavator	0.31	72.84	26.85	12.26	30.56	37.27	26.85
DSR	1.54	20.99	1.54	0.94	1.85	1.82	1.54
Double no till	0.00	0.00	0.00	0.00	0.00	0.00	0.00
QPM	0.62	0.00	0.00	0.00	0.00	0.00	0.00
Seed treatment/priming	5.55	0.62	0.00	0.00	0.00	0.00	0.00
LCC	0.31	3.09	0.00	0.00	0.00	0.00	0.00
SSNM	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relay cropping/intercrop	0.62	4.32	13.27	10.38	14.81	14.55	13.27

Table 40: Source of information on CA

CA (name)	N[#]	Source of information (% of farmers who are familiar with the technology)									Contact frequency (with the main source)*			
		CSISA	DAE officer	Co-op society	NGOs	Private dealers	Exhibi-tion/ mela	Mass media	Other farm-ers	Rela-tives/ family	Small	Me-dium	Large	Over-all
Laser land leveler	8	62.50	0.00	0.00	0.00	0.00	25.00	0.00	12.50	0.00	na	0.50	1.00	0.75
Bed planting	24	87.50	4.17	0.00	0.00	0.00	0.00	0.00	8.33	0.00	1.00	1.33	1.20	1.25
Zero tillage (no till)	136	64.71	8.82	0.00	2.94	1.47	1.47	0.00	20.59	0.00	1.11	1.08	1.14	1.11
Rotavator	324	0.31	0.31	0.00	0.00	14.20	0.93	0.00	83.95	0.31	2.02	2.00	2.13	2.05
DSR	78	65.38	2.56	0.00	0.00	0.00	0.00	1.28	29.49	1.28	1.04	1.07	1.04	1.05
QPM	2	0.00	50.00	0.00	0.00	50.00	0.00	0.00	0.00	0.00	1.00	na	1.00	1.00
Seed treat-ment/priming	20	5.00	25.00	0.00	5.00	0.00	0.00	0.00	50.00	15.00	0.67	0.71	1.00	0.85
LCC	11	36.36	36.36	0.00	0.00	0.00	9.09	18.18	0.00	0.00	na	1.00	1.00	1.00
Relay crop-ping/intercrop	59	13.56	0.00	0.00	0.00	0.00	0.00	86.44	0.00	0.00	1.60	1.44	1.65	1.58

Note: [#] Number of farmers who are familiar with the technology.

*Points are given for contact frequencies: 3 = weekly, 2 = monthly, 1 = quarterly, 0 = never; weighted average is carried out.

Table 41: Perceived impacts of CA technology

CA (name)	Perceived impact	Impact on:			
		Irrigation	Cost	Yield	Profit
Bed planting (N=2)	% farmers: positive	0.00	0.00	100.00	100.00
	% farmers: negative	0.00	100.00	0.00	0.00
	% farmers: no impact	100.00	0.00	0.00	0.00
Zero tillage (no till) (N=5)	% farmers: positive	0.00	0.00	80.00	80.00
	% farmers: negative	20.00	80.00	0.00	0.00
	% farmers: no impact	80.00	20.00	20.00	20.00
Rotavator (N=87)	% farmers: positive	0.00	100.00	98.85	98.85
	% farmers: negative	0.00	0.00	0.00	0.00
	% farmers: no impact	100.00	0.00	1.15	1.15
DSR (N=5)	% farmers: positive	20.00	60.00	20.00	40.00
	% farmers: negative	20.00	20.00	60.00	60.00
	% farmers: no impact	60.00	20.00	20.00	0.00
Relay cropping/intercrop (N=43)	% farmers: positive	0.00	0.00	100.00	100.00
	% farmers: negative	97.67	100.00	0.00	0.00
	% farmers: no impact	2.33	0.00	0.00	0.00

Table 42: Perceived impacts of CA on farm profitability

CA technology (name)	% of farmers with positive attitude			
	Small	Medium	Large	Overall
Bed planting (N=2)	na	100.00	na	100.00
Zero tillage (no till) (N=5)	100.00	50.00	100.00	80.00
Rotavator (N=87)	100.00	96.97	100.00	98.85
DSR (N=5)	100.00	0.00	50.00	40.00
Relay cropping/intercrop (N=43)	100.00	100.00	100.00	100.00

Table 43: Reasons for non-adoption or disadoption of major CA technologies

Reason for disadoption or non-adoption according to technology	% of farmers expressing it			
	Small	Medium	Large	Overall
Bed planting				
Reason 1 – Lack of information	5.88	35.29	58.82	43.59
Reason 2 – Unknown method	8.33	25.00	66.67	30.77
Reason 3 – Not available	0.00	100.00	0.00	12.82
Reason 4 – Other reasons	20.00	60.00	20.00	12.82
Zero tillage (no till)				
Reason 1 – Lack of information	20.43	36.56	43.01	38.59
Reason 2 – Not available	30.43	36.23	33.33	28.63
Reason 3 – Confused	0.00	0.00	100.00	17.01
Reason 4 – Lack of land	53.85	46.15	0.00	5.39
Reason 5 – Weed problem	40.00	40.00	20.00	4.15
Reason 6 – Lack of knowledge	0.00	60.00	40.00	2.07
Reason 7 – Other reasons	60.00	10.00	30.00	4.15
Rotavator				
Reason 1 – Not available	35.11	32.00	32.89	49.12
Reason 2 – Expensive	28.57	38.09	33.33	36.68
Reason 3 – Lack of land	81.97	13.11	4.92	13.32
Reason 4 – Other reasons	25.00	25.00	50.00	0.87
DSR				
Reason 1 – Weed problem	27.50	30.00	42.50	29.41
Reason 2 – Lack of information	33.33	36.36	30.30	24.26
Reason 3 – Not available	33.33	42.42	24.24	24.26
Reason 4 – Low yield	13.33	33.33	53.33	11.03
Reason 5 – Lack of land	66.67	33.33	0.00	4.41
Reason 6 – Other reasons	22.22	66.67	11.11	6.62

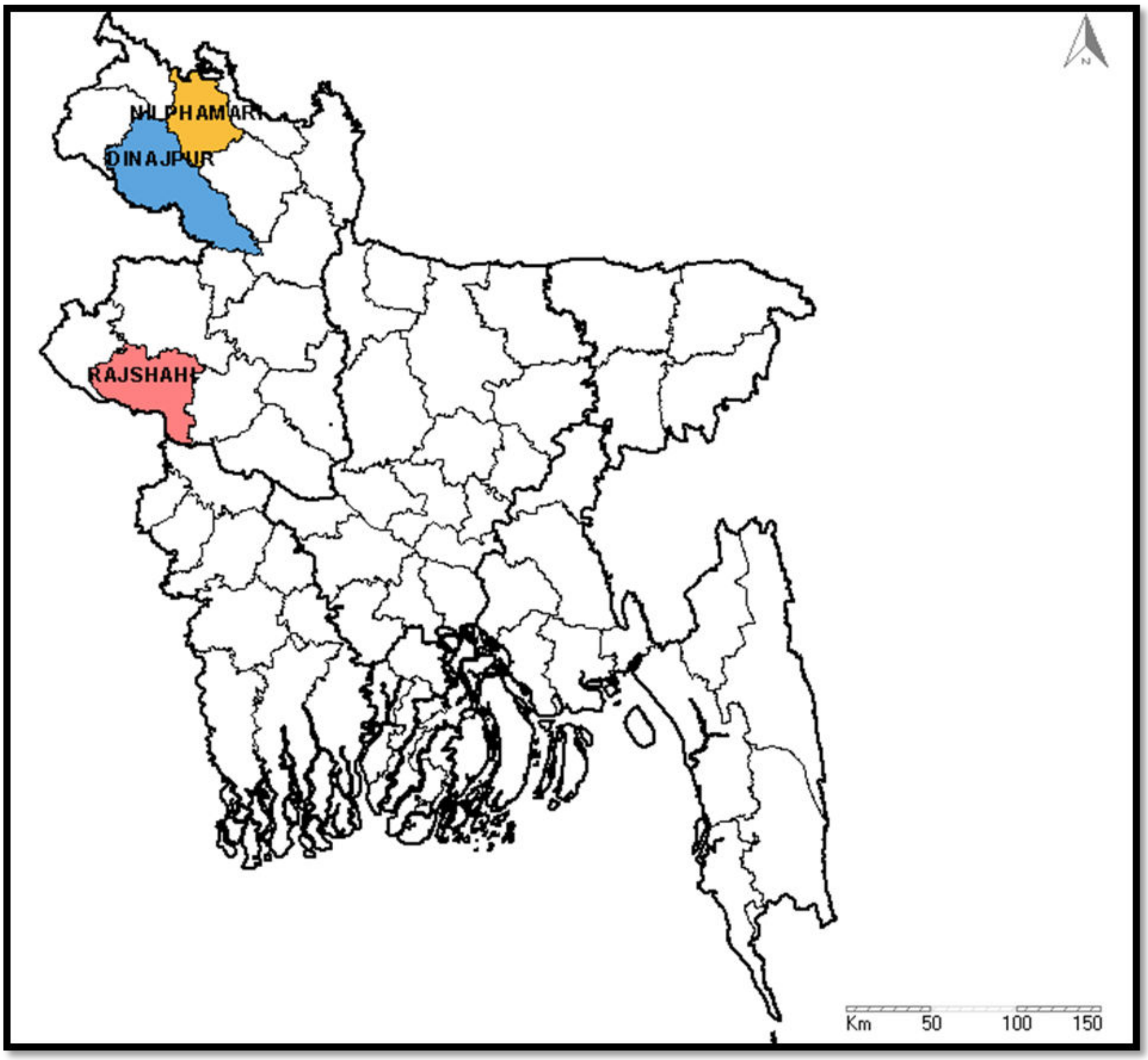

Figure 1: Map of NW Bangladesh showing the study area

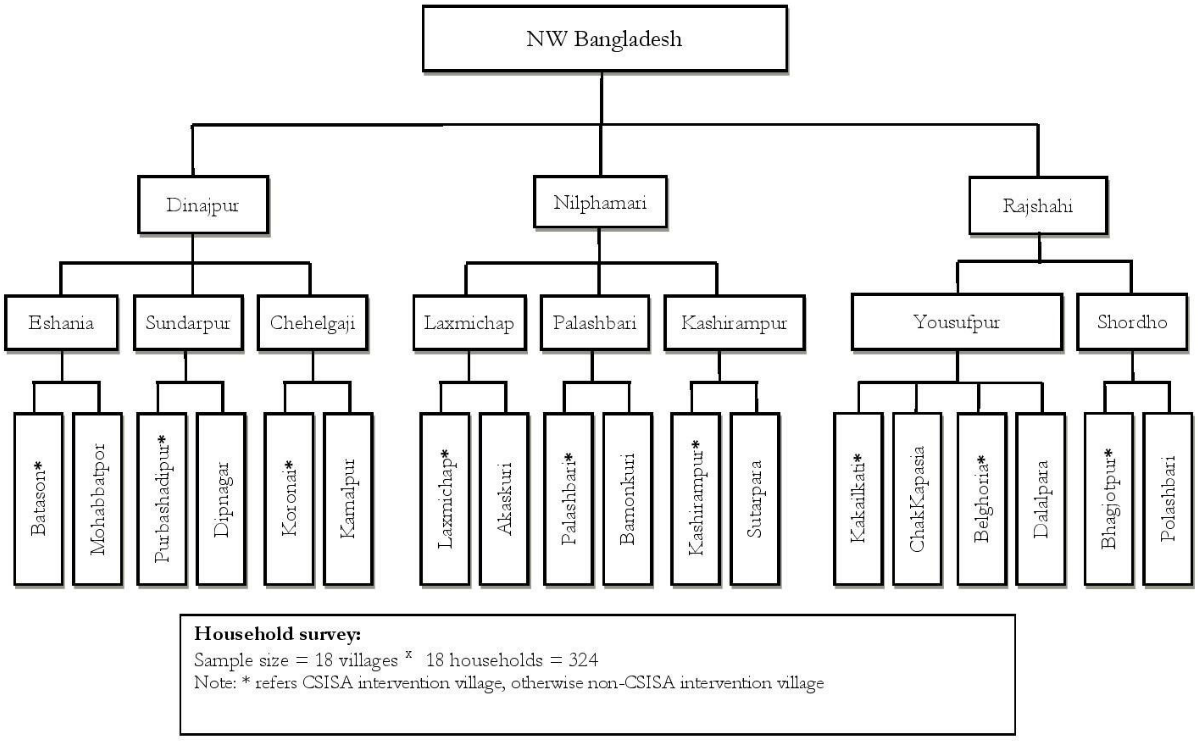

Figure 2: Sample selection within a hub domain for household surveys

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