SOCIOECONOMICS
Working Paper 7

December 2012

Farmer Access and Differential Impacts of Zero Tillage Technology in the Subsistence Wheat Farming Systems of West Bengal, India

Vijesh V. Krishna, Sreejith Aravindakshan, Apurba Chowdhury, and Bankim Rudra

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Correct Citation: Krishna, V. V., S. Aravindakshan, A. Chowdhury, and B. Rudra. 2012. *Farmer Access and Differential Impacts of Zero Tillage Technology in the Subsistence Wheat Farming Systems of West Bengal, India.* Socioeconomics Working Paper 7. Mexico, D.F.: CIMMYT.

AGROVOC Descriptors	Wheats; Varieties; Food production; Technology transfer; Farming systems; Zero tillage; Conservation tillage; Impact assessment; West Bengal; India
Additional Keywords	CIMMYT; Indo-Gangetic Plains; Malda
AGRIS Category Codes	E14 Development Economics and Policies F08 Cropping Patterns and Systems
Dewey Decimal Classif.	338.154
ISBN	978-607-8263-11-0 (On-line)

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December 2012

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Acknowledgement

The study was carried out as a sub-project, which is linked to the National Agricultural Innovation Programme (NAIP) Project titled, "Sustainable rural livelihood empowerment project for northern disadvantaged districts of West Bengal". The CIMMYT sub-project ("Resource conserving technologies and livelihoods in the northern disadvantaged districts of West Bengal") forms a part of the larger project. We acknowledge technical input from NAIP and financial support from the International Fund for Agricultural Development (IFAD).

Scientists from the lead center of the project, Uttar Bangla Krishi Viswavidyalaya (UBKV), Cooch Behar (West Bengal), have helped to carry out the field activities. Our sincere thanks are also due to Surojit Kundu (KVK, Uttar Dinajpur), Arunava Ghosh (UBKV, Coochbehar) and Kalyan Das (UBKV, Coochbehar), for providing the grassroots information and logistic support during primary data collection. The comments and suggestions on the draft version provided by Raj K. Gupta and M.L. Jat (Global Conservation Agriculture Program, CIMMYT, New Delhi) have greatly helped to explain the empirical results. We also thank Dr. Neelam Choudhury (CIMMYT/AWhere) for preparing the map of sample districts, and the five enumerators for their sincere effort during primary data collection.

Acronyms

ADA	Assistant Director of Agriculture
ATMA	Agricultural Technology Management Agency
CA	Conservation agriculture
CGIAR	Consultative Group on International Agricultural Development
CIMMYT	International Maize and Wheat Improvement Center
CSISA	Cereal System Initiative for South Asia
CT	Conventional tillage
fl	family labor
GoI	Government of India
GoWB	Government of West Bengal
HDI	Human development indices
IFAD	International Fund for Agricultural Development
ICAR	Indian Council of Agricultural Research
IGP	Indo-Gangetic Plains
IMD	India Meteorological Department
IRRI	International Rice Research Institute
KVK	Krishi Vigyan Kendra
MSP	Minimum support price
NAIP	National Agricultural Innovation Programme
NABARD	National Bank for Agriculture and Rural Development
RCTs	Resource conserving technologies
RWC	Rice-Wheat Consortium
SMS	Subject matter specialists
UBKV	Uttar Bangla Krishi Viswavidyalaya
ZT	Zero tillage

Executive Summary

The present study was carried out with the broad objective of assessing the patterns of adoption and farm profitability potentials of conservation agriculture (CA) in the three northern "disadvantaged districts" of West Bengal, namely Malda, Uttar Dinajpur and Dakshin Dinajpur. The eastern region of the Indo-Gangetic Plains (IGP) of South Asia, which encompasses the study area, is considered relatively unfavorable for wheat production. Late-sown wheat is grown here, mostly under rain-fed conditions. The per-unit cost of production of wheat in West Bengal is the second highest in India, indicating the prevalence of rather adverse farming conditions. The farmers are extremely resource-constrained and income-poor, with limited market infrastructure for inputs as well as implements. In this background, it is anticipated that the production cost- and labor-saving CA technology, such as zero-tillage (ZT) wheat, would generate significant positive livelihood impacts. Owing largely to the short history of the ZT technology diffusion in this region, its adoption and farm-level impacts are hardly examined.

The data source for the present study is a survey among 160 wheat growing households. These farmers were selected, employing a stratified random sampling procedure and household census of 10 purposively selected villages of the aforementioned districts. Both landholding size and technology adoption were employed for the household selection. The details on adoption of ZT technology and the input-output relations in wheat from the winter (rabi) crop of 2009-10 were collected during the personal interviews conducted in May-June 2010. In addition, the secondary data on wheat production and agro-climatic characteristics of the study area were assimilated to provide the necessary background.

During the rabi season, wheat occupies about 40% of the cultivated area in the sample villages. Percentage of on-farm use of drills was found ranging from 0 to 85% in the wheat acreage, with partial adoption of the technology being common. Farming was subsistence-oriented and the respondents were resource-poor. The average land-holding of the sample household was 1.05 ha. One-fourth of the respondents practiced leasing-in of land for cultivation. About one-third of farmers were indebted due to crop failure in at least one of the previous three years of survey. An equal share of respondents was also reported to have faced hunger during this period. Even in the face of such economic backwardness, the low productivity of wheat allowed them only a partial dependence on the farm produce for home consumption. Enhancement of wheat productivity through input-saving, yield-enhancing CA-based resource conserving technologies (RCTs) gained social significance in this milieu.

Despite the economic potentials of the technology, two major factors were found limiting the wider dissemination of the ZT wheat in the study area:

1. Limited availability of ZT seed drills. Only a small share of the farmers, who are willing to adopt ZT (that constitutes about 90% of the survey respondents), have actually adopted the technology. Scarcity of seed drills is one of the major reasons behind non-adoption and dis-adoption.
2. Lack of information on the working of no-till practice among farmers. About 29% of ZT drill adopters were using the drill as a mere wheat seeding equipment after ploughing the land. Such variant use or partial adoption of this "bundled technology" comes with a

significant cost increase, given the high prevailing wage rate for human labor and custom hiring charges for land preparation.

Scarcity of quality seeds of system-specific wheat varieties was another major constraint in wheat production in the study area. The major variety found in the farmers' field was PBW-343, one of the popular wheat varieties developed by Punjab Agricultural University (PAU) for the northwest plain zones for timely sown, irrigated conditions. Although this long-duration variety is not highly congenial for the late sown wheat cultivation of West Bengal, about one-third of the sample farmers were found to be adopting this. The varietal adoption is also closely related with adoption of drills. The major source of wheat seeds for the drill adopters is Krishi Vigyan Kendra (KVK; the grass-root level agricultural training and extension centers) and government extension offices, who are also promoting the wheat. These public sector agencies provide the wheat seeds at a subsidized rate to the potential users of drill as a mechanism to promote the technology. Lack of locally adaptable wheat varieties prompts these agencies to supply "older variety seeds" like PBW-343 and Sonalika. However, it should be noted that in the absence of these public sector agencies, chances of getting quality seeds for farmers would be lower.

The supply- and demand-side factors behind access and no-till adoption and the factors determining full/partial adoption of the technology are further examined, employing a multinomial logit model. The model results are summarized as follows:

- Access to information from public extension is found to be facilitating ZT drill use, but not the no-till practice *per se*. However, farmer communication networks are found not to be aiding the diffusion of no-till practice.
- Status of land tenancy, although having no impact on no-till adoption, favors ZT seed drill use against broadcasting of wheat seeds.
- Cattle ownership enhances tillage adoption, and additional animals owned reduce the chances of following ZT over conventional tillage (CT) by 33%. However, if a cattle owner prefers to use ZT drill, he may go for no-till, and not partial adoption (till + drill).
- Number of adult members in the household is found positively affecting the ZT drill adoption. However, this variable does not distinguish farmers adopting no-till with those following partial adoption.
- Education is found to have a significant and positive role in adopting both no-till as well as the drill use as seeding device.
- The aggregate community/village adoption of drills is found helpful for increasing the chances of resident farmers adopting the no-tillage practice.
- The total number of wheat farmers in a given village, which indicates competition for the limited number of drills, is found to reduce the chances of drill adoption for an individual farmer. This factor is also found to raise the probability of adopting no-till over partial adoption. Increase in the number of drills per village could overcome this constraint for rapid diffusion of the technology.

The impacts of ZT technology were studied using mean-variance analysis and kernel-density function. The no-till farmers are found to save about 12% of the paid-out cost per-acre, even when public-sector assistance/subsidy factor is accounted. There is a significant reduction in family labor use alongside ZT adoption. When the family labor cost is imputed along with the paid-out costs, the cost-savings widens to 19%. Cost of cultivation under partial adoption, using drills with tillage, is higher than that of wheat cultivation under CT, although the difference is statistically insignificant. No significant difference is found in wheat yield in ZT plots. Thus, despite having remarkable cost-saving effects, gross margin effect of ZT technology is less pronounced due to the insignificant mean yield difference. In sum, against the average farm-gate price of Rs. 9.24 (US$ 0.18)[1] for 1 kg of wheat grain, Rs. 6.13 (US$ 0.12) was the cost of wheat production under ZT and Rs. 6.00 (US$ 0.11) under CT. The cost of production is Rs. 8.46 (US$ 0.16) and Rs. 8.98 (US$ 0.17) per kg, respectively, when the family labor cost is imputed. However, cultivation of wheat variety PBW-343 is found to be critically limiting the wheat yield. Although the study is based on a single-year observation and the technology assessed is at its early phase of diffusion, it is evident that the existing limitations in the infrastructure and service/extension institutions are found to play a crucial role in defining the success of the CA Program in the subsistence cereal production system of the eastern IGP.

[1] 1 US$ = Rs. 52.64 (as of April 2012)

1. Introduction

In India, the cereal production sector has registered only sluggish productivity growth for both rice and wheat during the last two decades (GoI 2009).[2] Along with other factors, degradation of the natural resource base resulting from inappropriate land and input use is widely documented as one of the root causes of this yield stagnation (Ali and Byerlee 2000; Erenstein et al. 2008a: 254). There is an increased scientific interest in developing environmentally sustainable agricultural technologies that are resource conserving, while ensuring financial profit to the farmers. This paradigm shift is closely associated with an increased awareness about the environmental externalities of the conventional farming practices in the public and policy arena. Most prominent of such CA-based resource conserving technologies (RCTs) in the cereal system of South Asia is the zero and minimum tillage of wheat (Gupta and Sayre 2007). By minimizing the soil disturbance and providing residue soil cover, the zero tillage (ZT) or no-till practice is found to increase the soil fertility and water use efficiency, thus helping cereal farmers to sustain the crop yield over a longer term (Benites 2008: pp. 59-72; Ortiz et al. 2008).

Although ZT has never been a strange concept to farmers (it was followed by indigenous cultures, for example, Incas in the Andes), the initiation of scientific attention can be traced back to the 1970s in Brazil, where the first ZT field trials were conducted (Derpsch 2008: 9-10). At present, the ZT practice is popular in Latin America, the United States and Canada. Research on ZT for wheat also started in the 1970s in India, but was soon abandoned due to technical constraints (Ekboir 2002). However, with the involvement of the Consultative Group for International Agricultural Development (CGIAR) in the South Asian region under the Rice-Wheat Consortium (RWC) program of the Indo-Gangetic Plains (IGP), the technology gained momentum in the late 1990s in the NW Indian States.[3] Despite having a relatively short history of adoption, the technology is reported to have helped the farmers overcome the constraint of late sowing of wheat after the harvesting of late maturing basmati rice and the widespread incidence of the weed *Phalaris minor* (Mehla et al. 2000; Erenstein and Laxmi 2008).[4] At present, ZT and reduced tillage wheat occupies about 2 million ha in the IGP (Erenstein et al. 2008b). However, the overall growth rate figures often conceal the significant regional difference in adoption across the region.

Most of the zero and reduced tillage adoption is concentrated in the NW IGP. The Indian States of Haryana, Punjab and Western Uttar Pradesh account for more than 90% of the area under the technology (Erenstein and Laxmi 2008). The extent of technology diffusion diminishes towards the eastern IGP, and this pattern corresponds to the significant social and economic disparity existing across the region. An average Punjab farmer owns about 4 ha of land (>85% of which is irrigated), while his West Bengal counterpart has only 0.8 ha, largely rain-fed (Erenstein and

[2] Rice yield growth in 1980s was 3.19%, which has come down to 1.34% in 1990s and 1.92% in the next period in India. The reduction in productivity was more pronounced in case of wheat - from 3.10% growth rate of 1980s, it has declined to 1.83% and 0.58% in the succeeding decades (GoI, 2009).

[3] The RWC involved international centers, viz. CIMMYT and International Rice Research Institute (IRRI), and National Agricultural Research Systems (NARS) from Pakistan, India, Nepal and Bangladesh.

[4] Mehla et al. (2000) reported in wheat a ZT induced yield gain of 15.4% in on-farm trials which was apportioned into timeliness of planting (9.4%) and enhanced input use efficiency (6%).

Thorpe 2010). The downstream eastern Plains (Bihar, West Bengal etc.) have double the population density of the NW upstream Plains (Punjab, Haryana). The high population density in the eastern region is not only expected to make land a scarce factor of production, but also provide a greater labor force for agriculture.

However, significant seasonal labor migration is being reported from the eastern states to the south and west of India in the recent past (de Haan 2011), which possibly offsets the relative advantage of this region with respect to population density. Although the wage rate of human labor is generally less in the eastern IGP, the cereal productivity is also low in comparison to NW Plains. More importantly, the interregional wage rate difference is much below the value of productivity difference in absolute terms. Due to these factors, the livelihood impact of ZT technology could possibly be more pronounced amongst the subsistence farmers of West Bengal than in the NW region.

As shown in subsequent chapters, most of the respondents in the survey are resource poor, subsistence farmers. The agricultural technology diffusion process is expected to differ in this region as compared to the capital-intensive farming system in NW of India. The key issue in this regard are the characteristics of the technology adoption pattern in the subsistence farming system. This gains special relevance as the impact of ZT technology is more pronounced in cost reduction than in yield enhancement (Erenstein and Laxmi 2008). An adoption-impact assessment of ZT wheat was carried out under the World Bank supported National Agriculture Innovation Project (NAIP). A sub-project titled 'Resource conserving technologies and livelihoods in the northern disadvantaged districts of West Bengal,' which is a consortium-initiative led by the Uttar Bangla Krishi Vishwavidyalaya (UBKV) in collaboration with CIMMYT has been implemented with the specific objectives of assisting in livelihood analysis, its temporal and spatial dimensions, and in identifying the corresponding opportunities and threats for poverty alleviation. In this regard, comprehensive household surveys were conducted, focusing on the adoption of ZT among wheat farmers of Malda, Uttar (North) Dinajpur and Dakshin (South) Dinajpur districts. Capital-intensive, labor-saving technologies are expected to be less popular in these districts, making the case of adoption of tractor-drawn, labor-saving drill an interesting case-study.

The potential welfare gain from such a technology could be more pronounced amongst the poor farmers than their richer counterparts, owing largely to the financial inability of the former to invest. However, these poor households are also relatively laggards in the adoption of a particular technology (Rogers 2003). Empirical findings by Erenstein and Farooq (2009) reinforce this association of income poverty and adoption of CA practices. ZT adoption was found strongly linked to the wealth of the farm household, possibly due to the risk bearing ability of the households and uncertainty of technology impacts. However, if the uncertainty issue can momentarily be ignored, the ZT adoption in the study area is accompanied by the provision of subsidies (free use of seed drills and seeds) to the farmers, which could also facilitate the faster rate of initial adoption.[5] Poor farmers could be more attracted to the subsidy component than the technology *per se*, although their access to the technology becomes an issue when demand for

[5] The details of technology dissemination are provided in the next section.

machines, within a short period of the wheat sowing season, exceeds the supply. The present study, in this regard, examines the access/adoption pattern of ZT wheat, keeping the associated institutional framework in the backdrop.

This working paper is organized as follows: Section 2 details the characteristics of the study area while Section 3 includes the sampling frame of primary data collection. Subsequently, the findings of the empirical estimation are organized in Sections 4-6, which include wheat production system characteristics, adoption pattern and factors affecting the technology adoption, and farm-level impacts of the technology, in that order. Section 7 concludes the findings.

2. Methodology

2.1. Study area

The study covered the wheat growing northern disadvantaged districts of West Bengal state, situated in the eastern IGP between 21°10' and 27° 38' N latitude and 85° 50' and 89° 50' E longitude. Stretching from the Himalayas to the Bay of Bengal, the state is bordered by Bangladesh in the east, Assam and Sikkim states and Bhutan in the northeast, Orissa state in the southwest, Nepal in the northwest and the states of Jharkhand and Bihar in the west. Geographically, the NAIP project intervention districts (Malda, Uttar Dinajpur and Dakshin Dinajpur) belong to the northern Bengal Plains (Figure 1). The state has a sub-humid climate with about 75% of the annual rainfall during the monsoon season from June to September (IMD 2010).

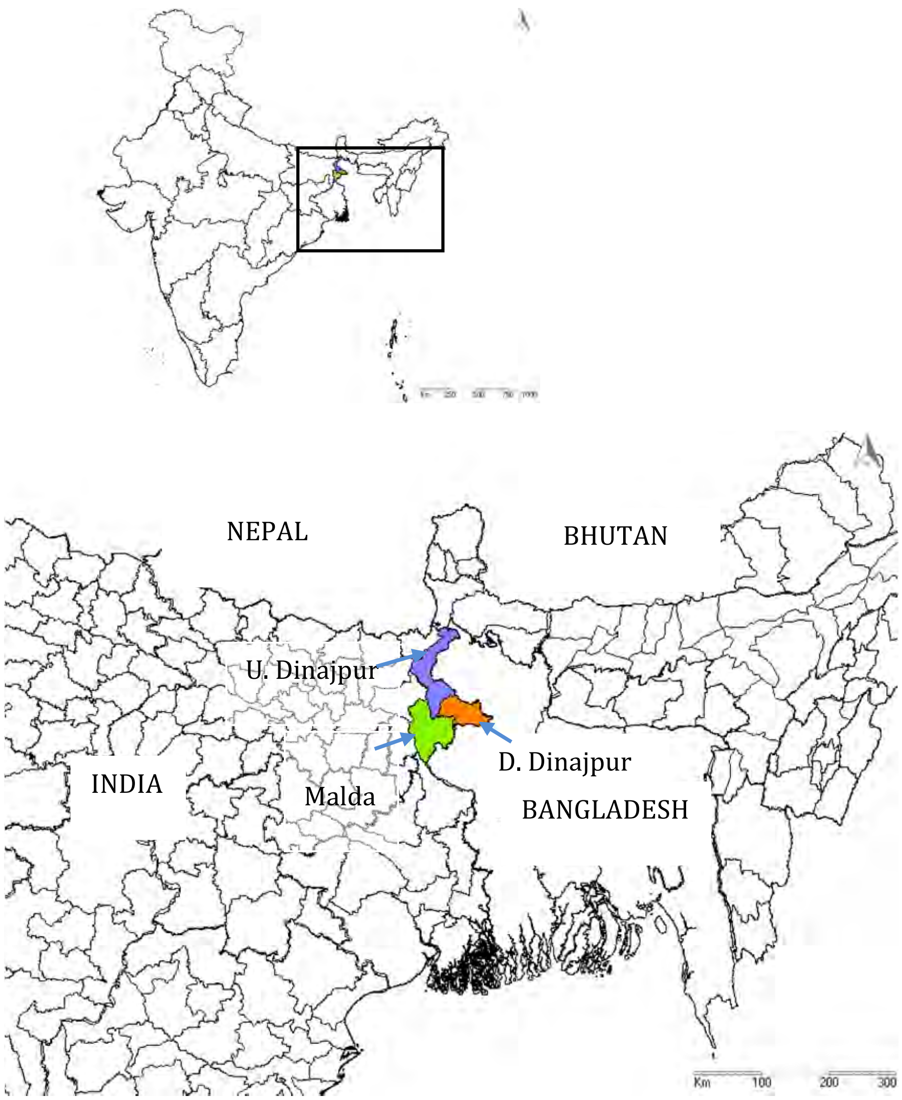

Figure 1: Map of study area
Source: Neelam Chowdhuri, AWhere/CSISA

Agriculture is the main source of income with 63% of the land area allocated to the primary sector (cf. GoWB 2004: 175). Although West Bengal occupies only 2.7% of India's land area, it supports over 7.8% of the country's population, being the most densely populated state.[6] The state has also witnessed significant internal migration from neighbouring states like Assam and also across the Indo-Bangladesh borders (GoWB 2004: 9–10) especially to urban areas like Kolkata. The high population density is often pointed out as one of the major reasons for the widespread income poverty prevailing in West Bengal.

Despite being located in the rich and fertile Indo-Gangetic region, West Bengal is one of the poorest states in terms of development indicators. Large sections of the district's rural population do not have access to basic amenities. Poverty is also gendered, with large gender disparities in literacy and low participation of women in the work force (GoWB 2004: pp. 4-5). The Gram Panchayats (the local self-governments at the village) and Rural Development Department of West Bengal figures show a higher incidence of poverty with 45% of families living below the poverty line. In the study districts, the population density is lower than the state average (881/km^2 in Malda, 778/km^2 in Uttar Dinajpur and 677/km^2 in Dakshin Dinajpur; cf. GoWB 2004: 10), but is ranked low with respect to Human Development Indices (HDI). Malda is the most "unfavored" district in West Bengal, and (undivided) Dinajpur ranks 13th out of 17 districts in accordance with the HDI. The proportion of Muslims, scheduled castes and scheduled tribes is relatively high in these districts. The three disadvantaged groups are vulnerable and suffer multiple deprivations (GoWB 2004: 5).

Rice-based cropping system is prevalent in West Bengal, which is the largest producer of rice in India. With the introduction of *boro* (dry winter) rice in the 1980s, West Bengal's rice production has increased rapidly. In 2007-8, rice was cultivated on 5.6 million ha in the state, and provided 15% of the national rice production (GoI 2009). Cropping patterns include rice–(*boro*) rice, rice–jute, rice–potato–(*boro*) rice, rice–potato–onion and rice–wheat (Varma et al. 2007). Relative to rice, wheat area is limited, with 0.34 million ha in 2007-8. The state wheat production share constitutes only 1.17% of the national figure, and again unlike rice, wheat productivity in West Bengal (0.92 quintals/acre or 0.23 tons/ha) is below the national average (1.09 quintals/acre or 0.27 tons/ha) (GoI 2009). The area under wheat shows high fluctuation, for which one of the main determinants could be the large number of competing crops. In the recent past, maize, potato and vegetables have emerged as major competing crops against wheat in the state.

In West Bengal, wheat occupies a relatively important position in the northern districts compared to the other regions. In Malda, 22% of the net sown area is under wheat. This share reduces while moving to the northern districts (Uttar Dinajpur with 13% and Dakshin Dinajpur with 5% of area) possibly due to competition from other winter crops and plantations (e.g. tea). The productivity of wheat is also high in these districts (1.19 quintals/acre in Malda, 1.09 quintals/acre in Uttar Dinajpur and 1.20 quintals/acre in Dakshin Dinajpur) compared to the state average.[7] It is also noteworthy that the wheat area trend is almost stagnant in these districts compared to the steep decline at the state-level. In other words, the shortening of the winter

[6] West Bengal is the seventh most populous sub-national entity in the world. Source: www.censusindia.net
[7] 1 acre = 0.405 ha

season in recent decades has meant that wheat cultivation is concentrated in the few northern districts of eastern IGP. However, as about 30% of the cultivable land is kept fallow during the *rabi*/winter season in the northern districts of West Bengal, there is still ample scope to enhance the wheat cultivation. UBKV is involved in the extension activities in this regard. As the famers are resource scarce with limited access to credit, they prefer low-cost wheat cultivation. This highlights the scope of ZT among the wheat farmers of this region.

ZT wheat in the study area[8]

The ZT wheat in West Bengal has a relatively short diffusion history. The technology was introduced in the 2006/07 wheat season in the state, and the subsequent year in the study villages. The CGIAR and Indian Council of Agricultural Research (ICAR) projects played key roles in popularizing the technology. For example, the drills were first introduced in the study area as part of the Rice-Wheat Consortium activities, and now through the outreach of Cereal System Initiative for South Asia (CSISA). Also within the ICAR project, entitled 'Rashtriya Krishi VikasYojana', drills and related information were disseminated to farmers. The private sector involvement is limited to the sale of herbicide chemicals. Although ZT is largely a labor-saving technology and wheat is cultivated widely using the household labor in the study area, the cost-cutting effect of the technology is found attractive for the farmers. There are a number of factors that distinguishes the ZT adoption in eastern IGP from the NW IGP:

- Land holding is significantly smaller in West Bengal. As the plot size is strongly correlated with land holding, and small plot size restricts the operation of tractor-drawn drills, there could be unique technical constraints in the adoption of ZT in the state.
- West Bengal agriculture is less capital intensive compared to NW IGP states. Number of tractors is limited. More importantly, the number of 45 HP tractors that are compatible with 11-tine drill is less popular in the state. Higher custom-hiring charges offered by the winter potato farmers are also found to induce scarcity of the tractors for wheat cultivation. The 9-tine drills, which are compatible with the locally popular 35 HP tractors, are limited in availability with the service providers.
- Unlike in Punjab and Haryana states, the drill ownership is largely public in West Bengal. The offices of Assistant Director of Agriculture (ADA) and Krishi Vigyan Kendras (KVKs) are the major service providers of the drill. However, the number of drills is limited (around five drills per KVK), compared to the potential ZT wheat area. The private sector service providers are largely absent as the diffusion process is in the early stages. In addition, during the early phases of CA technology diffusion, the state's previous political regime preferred service provision through public institutions rather than the private sector, as in NW India.
- One of the major reasons for low productivity of wheat in West Bengal is the late sowing of the crop, which again is due to the preceding long-duration rice. The popular wheat varieties like PBW-343 are meant for early sowing, and if the sowing is delayed beyond mid-November, the yield would be severely affected by terminal heat. ZT reduces the time required for field preparation, and hence potentially creates a yield advantage.

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[8] This section is developed after a brainstorming section with the scientists of UBKV and KVKs of the districts.

- Farmers' inability to purchase inputs for production due to financial constraints is more severe in the eastern IGP.

The diffusion of ZT is mainly accomplished through two different channels that consist of two different sets of institutions. One of them is directed via the State Department of Agriculture and another through the Agricultural Universities and KVKs. The degree of collaboration among these institutions is at the minimum. In the case of the State Department, the agricultural field staff (Krishi Prajukti Sahayak) help the Assistant Director identify the contact farmers and farmer groups to whom the drill with tractor will be rented out.[9] In the early stages of technology introduction (2-4 years), the farmers are provided with a significant amount of subsidy, which includes custom-hiring of drill and tractor at zero charge and free supply of wheat seed at times, to encourage their participation in the technology adoption program. Number of beneficiaries and length of the subsidy are limited by the budget availability in the public sector.

On the other hand, in the University-KVK diffusion system, the subject matter specialists (SMS) work in the "adopted" villages and provide the drills to the farmer clubs, organized by the National Bank for Agriculture and Rural Development (NABARD). Farmer clubs are grassroots level informal forums consisting of 25-40 farmer members. They are organized by the rural branches of commercial banks with the support and financial assistance from NABARD (*cf.* www.nabard.org). There are also no custom-hiring charges of drills in this mechanism, at least in the first years of technology introduction. The free supply of wheat seeds is often found to be associated with the drill adoption. Along with the provision of drills, ADA and SMS also transfer the information on aspects of wheat cultivation under ZT practice. However, it should be noted that in both the systems, only a minority of all wheat farmers could be provided with the ZT technology owing to the limited availability of funds and drills.

The supply side of ZT drills is a major issue worth mentioning at this juncture. As the existing number of drills can be hired out only by a very small share of potential adopters during the wheat sowing season, it is only self-evident that sustainability of the ZT diffusion program depends highly upon the increased provision of drills in the study area. As the farmers are extremely resource poor, availability of drills at subsidized prices to the farmer groups would be an important step in popularizing the technology. The previous government policy was to promote the public sector service provision by restricting the private sector involvement in the drill manufacturing, sale and custom hiring.

The machines marked by the government agencies are priced at Rs. 65,000 per unit (US$ 1,235), although through certain government schemes, a subsidy worth up to Rs. 30,000 (US$ 570) is provided, reducing the cost to Rs. 35,000 (US$ 665) per unit. This price is at par with the existing price in the neighboring state of Bihar and NW Indian states, where the private sector is involved in drill manufacturing and marketing. However, the availability of subsidy is limited to a certain number of machines (for example, in 2009/10, the subsidy covered only 150 machines in the entire state). In addition, manufacturing and marketing of machineries by the private sector would not be sufficient unless there is an established system for private service provision and

[9] The working of ADA confines to the block level, under whom there will be 12-15 Krishi Prajukti Sahayaks, depending on the number of villages in a block.

maintenance and repairing centers. Absence of such a system restricts the ZT machine ownership only to the government agencies and larger/richer farmers of the study area.

2.2. Sampling and data collection

The primary data was collected from 10 villages, where ZT promotion programs were active under the leadership of UBKV scientists and KVK subject matter specialists. Household interview questionnaire was developed and pre-testing done in Malda and Uttar Dinajpur villages in March 2010. The field activities included,

- Village census, which was done during April-May 2010 in the 10 villages selected from three districts (U&D Dinajpur and Malda).
- Selection of households following stratified random sampling procedure. Village census datasets were developed from all the farming and non-farming households. Basic household details, including name of household head, landholding, cereals cultivated and ZT adoption (among wheat farmers), were gathered using a short questionnaire. The wheat growing households were first grouped into ZT adopters and non-adopters during season 2009/10, and within each group, farmers were sorted based on the size of farm land owned by the households. A systematic random sampling procedure was adopted to select households from each of the groups across the landholding categories for the data collection. Care was taken to include sufficient number of both ZT and conventional tillage (CT) farmers so that the "with and without" technology impacts can be calculated. Sample size varied (9-19 households) across the study villages, depending on the number of wheat growers.
- Household level data collection was conducted during May-June 2010 after the wheat harvesting using the personal interview method. The time was selected to minimize the possible recall bias. The primary data collection was carried out by agricultural graduates and monitored by CIMMYT consultant, UBKV scientists and KVK Subject Matter Specialists.

Following data entry and preliminary analysis, the key results were presented in front of the UBKV scientists and KVK-extension fellows (July 2010). This helped to delineate the factors behind the trends observed. In addition, the brainstorming session assessed the institutional framework associated with the dissemination of ZT technology.

3. Results and discussions

3.1 Sample characteristics

Details of the ZT adoption and sampling are provided in Tables 1 and 2. The census data reveal a high variability not only with respect to the number of wheat cultivators, but also the percentage of adopters of ZT technology in the sample villages. The total number of wheat farmers per village during the 2009/10 rabi season ranged from 10 in Bansthupi, Uttar Dinajpur, to 180 in Bahirkap, Malda, (Table 1). There is also notable difference in adoption with regard to both the number of households and area under ZT technology.

Generally, the cultivation of wheat under conventional and ZT in a single farm is common. As the study deals with the livelihood impacts, a measure of percentage of farmers adopting the technology in a village would be ideal to characterize the technology acceptance than acreage share of wheat under the technology. The ZT diffusion pattern is highly village-specific: it ranges from about 6% in Bahirkap (Malda) to 85% in Lakshmidangi (Uttar Dinajpur) village. Initially, it was planned that the sample framework would include eight ZT and eight CT wheat farmers per village. However, in some villages (e.g., Bahirkap), the number of ZT farmers was less than eight, and hence more farmers were purposefully selected from those villages where ZT adoption was significantly high (e.g., Lakshmidangi and Gotlu) in order to compensate the reduction in sample size.

Table 1. Farmer use of ZT drill in the study area.

District	Village	No. of wheat farmers/village	drill use; share with respect to		Average no. of tillage by CT wheat cultivators
			no. of hhs	wheat area	
Malda	Bahirkap	180	0.06	0.01	3.40
	Bannapara	68	0.09	0.03	3.24
	Harinkole	108	0.12	0.07	3.57
U. Dinajpur	Bansthupi	10	0.10	0.06	3.00
	Sripur	36	0.14	0.16	3.13
	Lakshmidangi	41	0.85	0.88	5.33
	Gotlu	23	0.43	0.27	3.38
D. Dinajpur	Kashitara	31	0.74	0.55	3.00
	Mohukuri	36	0.33	0.20	2.03
	Sivpur	80	0.48	0.23	2.00

Source: Village census (2010).

Table 2. Sampling frame for household-level data collection.

Village, district	Project activity	Sample size	Within the sample, share of	
			drill adopters	no-till practice
Bahirkap	Only KVK	18	0.56	0.56
Bannapara	Only KVK	14	0.43	0.29
Harinkole	Only KVK	16	0.50	0.25
Malda (total)		48	0.50	0.38
Bansthupi	Only KVK	9	0.11	0.11
Sripur	+ NAIP	13	0.38	0.31
Lakshmidangi	Only KVK	16	0.63	0.31
Gotlu	+ NAIP	18	0.78	0.56
Uttar Dinajpur (total)		56	0.54	0.36
Kashitara	+ NAIP	19	0.58	0.31
Mohukuri	Only KVK	19	0.84	0.63
Sivpur	+ NAIP	18	0.44	0.44
DakshinDinajpur (total)		56	0.63	0.46
Overall		**160**	**0.56**	**0.40**

Source: Household survey (2010)

The respondents are resource poor in comparison to other parts of IGP in the country and farming is subsistence-oriented. The average land-holding of sample household is 1.05 ha. In addition, leasing-in of land for cultivation is practiced by one-fourth of the respondents. Wheat occupies 40% of the cultivated area. About one-third of farmers are indebted, owing to crop failure in the last three years. An equal share of respondents is also reported to have faced hunger.[10]

A higher share of respondents (about 50%) indicated their inability to treat one or more illnesses during the preceding three-year period due to financial constraints. Even under such economic backwardness, the low wheat productivity allows them only a partial dependence on own-production for home consumption. On average, about 40% of home consumption of wheat is purchased from the market. Enhancement of wheat productivity through cost-cutting technology gains significance in this milieu of economic backwardness. However, accessibility remains an important factor that determines the development potential of this RCT.

[10] Could only manage one meal per day sometimes during the previous year due to inability to purchase.

4. Wheat production system characteristics in the study area

Large scale wheat cultivation started expanding in West Bengal and other parts of the eastern IGP, north of the Tropic of Cancer, only in the recent decades (Erenstein 2009). The state wheat productivity has always been below the national average (by about 14% in the last decade) and there has been noticeable yield stagnation. However, during the study period (2009-10) the yield difference to national average narrowed down to about 6%. The status of wheat productivity in West Bengal, compared to the national average and to a leading producer of NW India (Punjab), is shown in Figure 2.

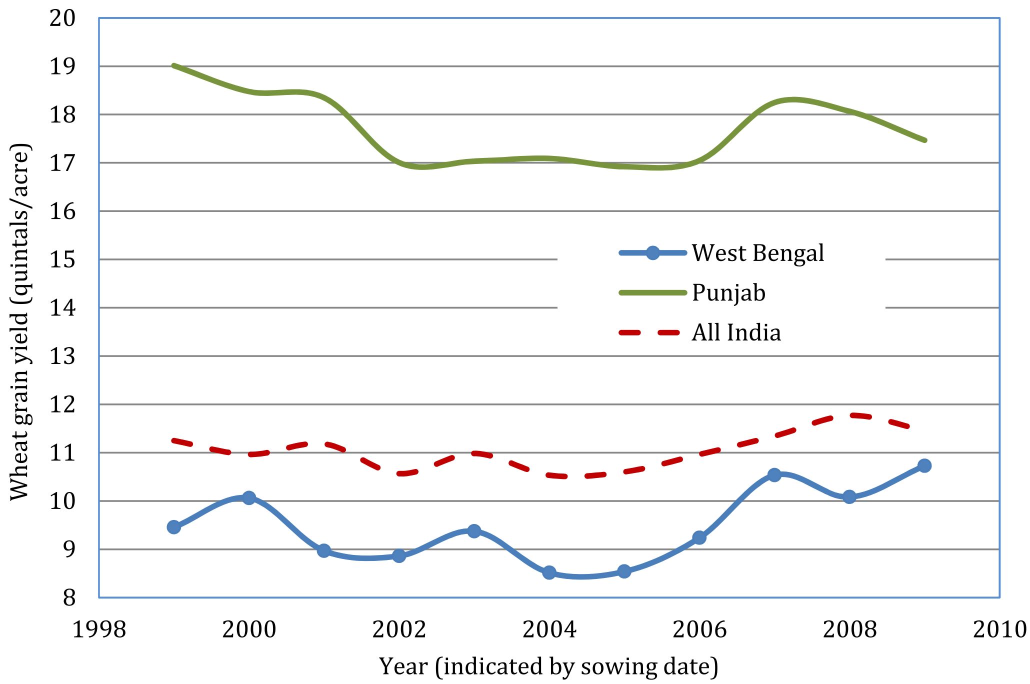

Figure 2: Wheat yield in West Bengal compared to all-India and Punjab.
Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation, GoI.
Note: 1 acre = 0.405 ha; 1 quintal = 0.1 tonne.

The wheat productivity realized in West Bengal is only 50% of what is being produced in the NW states. The yield potential of wheat in West Bengal is lower than the NW India, due to higher winter temperature and shorter wheat growing season. Further, the low-input use per hectare, largely rain-fed production process, and late sowing of crop prevents the farmers from attaining even the yield potential. The average cost of production in West Bengal is compared with that in different wheat-growing states to examine the state's status in relative terms (Figure 3). Across India, there are both low-input/low-productive states (e.g., Chhattisgarh and Jharkhand) and high-input/high-productive States (e.g., Punjab, Haryana). However, it is only in West Bengal that a higher cost of cultivation (Rs. 9.8 thousand/acre) is associated with a relatively low yield (2.5 tons/ha). Against the Minimum Support Price (MSP) announced by the

Government of India at Rs. 11/kg (rabi season of 2009/10),[11] the per-unit cost of production of wheat in the State (Rs. 9.75/kg in 2008-09) is the second highest in India after Jharkhand, indicating the prevalence of rather adverse farming conditions and low profitability potential of the crop. The reasons behind this inferior cost-yield relationship and the relevance of CA-based RCTs are discussed in the next sections.

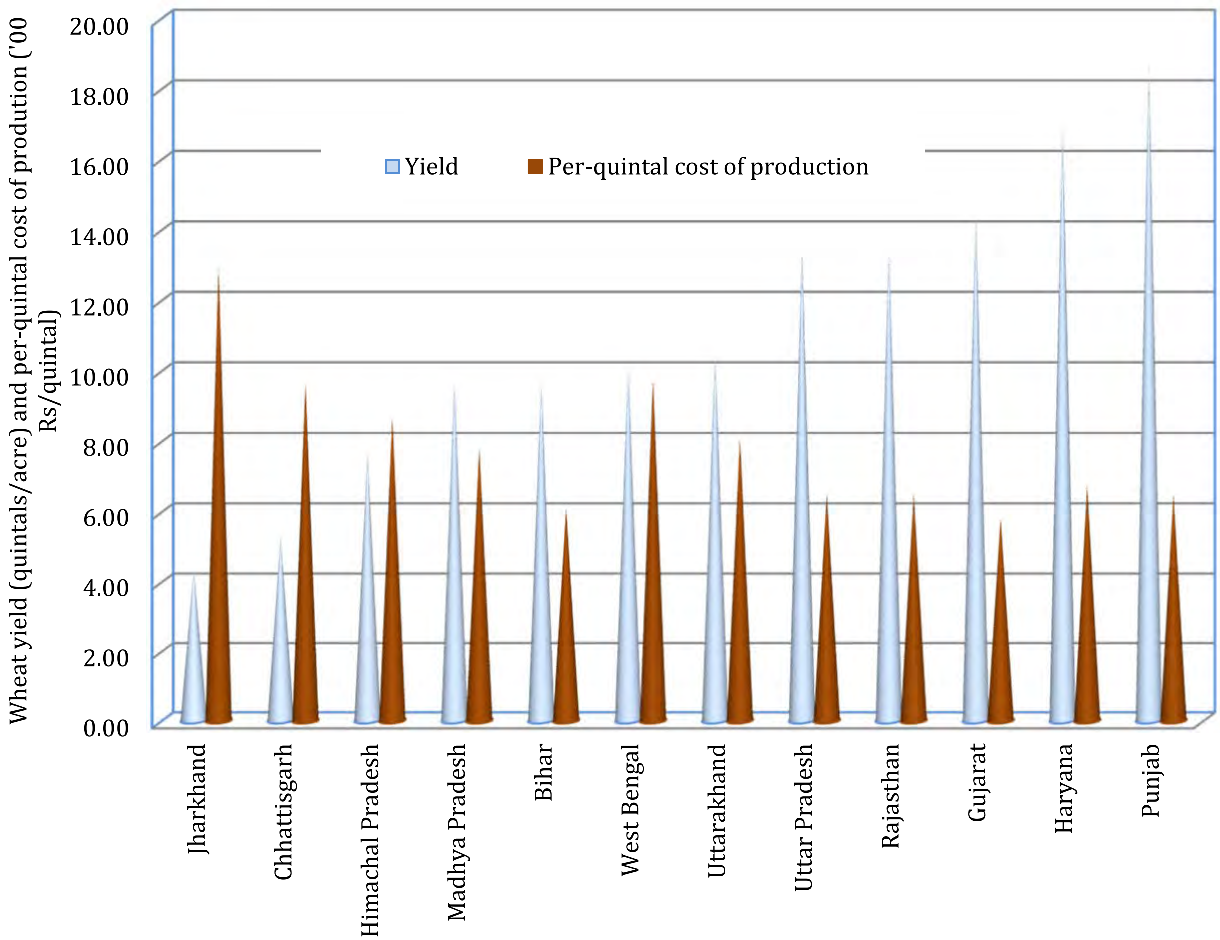

Figure 3: Wheat yield and per-unit cost of production in India in 2008-09.
Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Government of India.
Note: 1 acre = 0.405 ha; 1 US$ = Rs. 52.64 (as on April 2012); 1 quintal = 0.1 tonne.

At the time of sampling, in West Bengal, as in the case of wheat in general, the ZT technology had only a relatively short history of diffusion. This is one reason why the adoption pattern and potential technology impacts of ZT wheat in the eastern IGP are infrequently studied. It can well be expected that in a region like eastern IGP where late sowing of wheat is prevalent, ZT could be associated with a significant yield benefit by ensuring timely sowing of the crop. However, as

[11] The government procurement system in the eastern IGP is not as strong as in the NW states. Hence many farmers obtain grain market prices lower than the MSP announced for that season.

the cereal production system in West Bengal is labor-abundant as compared to most of the other wheat growing areas and ZT wheat being a labor-saving technology, its impact may be of unique economic dimensions. Keeping the inter-regional variations across the IGP in the backdrop, wheat production system of the study area is being examined here with respect to cropping patterns, credit and information availability, and varietal- and labor-use in general. The details of use pattern of other inputs with respect to ZT adoption are included in Section 6, which discusses the production impacts of the technology.

At this juncture, an issue highly pertinent to the ZT adoption is that only a small share of potential adopters have so far actually adopted the technology due to the limited availability of the drills. Majority of wheat farmers (about 90%), as observed during the household survey, are interested in adopting the technology, partly due to the net revenue increase associated with it and partly due to the coupled subsidy availability. However, the constrained supply of drills leads only to a limited number of beneficiaries, and the selection is done by the contact farmer or the farmer group. In other words, farmer self-selection does not happen largely with respect to the technology adoption, although tillage (with or without drill) adoption is still largely a farmer-dependent decision.

As the development agencies and farmer clubs choose an interested farmer as adopter of drill, it is highly relevant from the equity point of view to assess the resource status of users (who access the technology) against the non-users (majority are willing to adopt the technology, but cannot access it). It is found that the larger and higher educated farmers have a greater chance to be the beneficiaries of the program (Table 3). In addition, larger household size increases their "approachability" to the agencies that provide ZT technology. These farmers could possibly be the early adopters of the technology in the initial stage of its introduction (during rabi seasons of 2007/08 and 2008/09) as being less risk-averse, and might have continued as perpetual beneficiaries of the program thereafter. However, appreciating the high willingness of a farming community to adopt the ZT technology in wheat, it is only imperative in an egalitarian perspective to take up necessary measures to ensure its reach to the smaller and less educated farmers.

Another important consideration rests with the distinction between no-till adoption and drill use. Many farmers, who were recognized as ZT adopters during the village census, were found to be the adopters of ZT drill only, and not the "'no-till practice as they use the ZT drill as a seeding machine after removing the crop residues and ploughing the field (Table 2). For example, although eight farmers in the Harinkole village (Malda) had adopted the drill, four had ploughed the land and used the drill afterwards for sowing.

Further, only some farmers were aware of the difference between drill adoption and no-till practices, making farmer categorization and the data analysis more complicated. Although the ZT drill users were 51% of the total sample, only 40% were adopting no-till practice. Such partial adoption of technology could occur due to a number of factors and often the practice even undermines the efficiency of the technology by modification. This deviated use pattern was unexpected during the study formulation. However, the analysis later developed in such a way that the factors and effects of "defective reinvention" can be evaluated along with that of the typical no-till practice. Since use of ZT seed drill after ploughing the land goes against the CA principles and reduces or nullifies the associated financial and environmental benefits, factors that lead to this "deviant practice" deserve greater research and extension attention. We postulate that there are both supply and demand factors that lead to the reinvention of "drill + till", which will be addressed in forthcoming sections.

Table 3. Socio-economic characteristics of users and non-users of ZT seed drill

	NAIP villages [N =68]	Non-NAIP villages [N = 92]	Sig.	NAIP villages: drill user [N = 38]	NAIP villages: non-user [N = 30]	Sig	Non-NAIP villages: drill user [N =51]	Non-NAIP villages: non-user [N = 41]	Sig
No. of adults in the household	3.50 (0.91)	4.24 (1.49)	***	3.71 (1.11)	3.23 (0.43)	**	4.49 (1.45)	3.93 (1.49)	*
Cultivable land (acre) owned by household	2.66 (3.12)	2.54 (2.68)	ns	3.03 (3.84)	2.18 (1.82)	ns	3.02 (2.81)	1.95 (2.41)	*
The highest level of education (years of schooling) obtained by a household member	7.04 (5.01)	7.87 (4.84)	ns	8.21 (4.93)	5.57 (4.78)	**	9.06 (4.27)	6.39 (5.13)	***
Household experience in wheat cultivation	9.50 (7.39)	12.64 (8.11)	***	10.24 (7.97)	8.57 (6.58)	**	11.08 (7.57)	14.59 (8.43)	**

Source: Household survey (2010).

Notes:

(i) Figures in parentheses show standard deviation to mean values.

(ii) 1 acre = 0.405 ha

(iii) *, **, ***: Significant difference exists between categories at 0.10, 0.05 and 0.01 levels; [ns]: no significant difference at 0.10 level.

The cropping systems in the eastern IGP are mainly rice-based. However, in the study area wheat is popular during the winter season as a subsistence crop. About 60% of the farm produce is used for home consumption and 30% of farmers are dependent on wheat cultivation entirely for this purpose. Depending on the irrigation water availability, jute is being taken up after the winter crop. About 81% of the wheat cultivation takes place in one of the three cropping systems:

1. Rice-Wheat-Jute (high cropping intensity; 31% of wheat area)
2. Rice-Wheat-Fallow (medium cropping intensity; 33% of wheat area)
3. Fallow-Wheat-Fallow (low cropping intensity; 17% of wheat area)

Further expansion of wheat cultivation is attainable as about 50% of the non-wheat systems are kept fallow during the winter season. Boro rice, mustard and tea pose a certain degree of competition for land, but accounts only for 20% of the cropped area during this season. Financial capital and input (e.g., quality wheat seed) scarcity are found to be the two major factors limiting wheat cultivation. To promote the wheat program, the microfinance institutions and commercial banks may come up with crop-specific credit programs for shorter durations of time, preferably coupled with a crop insurance scheme. Under the prevailing scenario, about 32% of farm households were indebted in the last three years due to crop failure and were forced to limit even food consumption due to lack of resources (Table 4). The financial constraints and reduced farm investments further contribute to the reduced productivity of cereal crops. On the one hand, services of the public sector financial institutions do not have a wide reach across all the needy farmers as only <7% sample households could obtain farm credit from commercial banks and cooperatives (Table 5). On the other hand, dependence on the village money lenders, the major private credit source in Indian agriculture—is also not observed.

Even though the private input dealers are the prominent source of credit for wheat farming, only about 17% of farmers utilize this source. The interest rate charged by the dealers (9%) is the highest among all categories of credit sources. The informal source of credit (friends, relatives and neighbors), is also used by the sample farmers to generate low-interest credit. But its reach is rather limited, possibly due to the prevalence of poverty in the study area. Financial bottlenecks are thus found to be severely affecting the prospects of intensifying production in the rice-wheat system here, limiting the generation of additional farm income from existing land resources.

Table 4. Poverty indicators among sample farmers.

	drill user [N = 89]	non-user [N = 71]	sig.
Indebted due to crop failure during 2007-2009 (dummy)	0.30	0.34	ns
Dependency on leased-in land: leased-in land area as share (0-1)of cultivated land	0.16 (0.29)	0.14 (0.31)	ns
Could only manage one meal/day during 2007-2009 due to inability to purchase (at least occasionally; dummy)	0.28	0.34	ns
Inability to treat for illness during 2007-2009 due to financial constraint (at least occasionally; dummy)	0.58	0.39	**

Source: Household survey (2010).
Notes:
(i) Figures in parentheses show standard deviation to mean values.
(ii) **: Significant difference exists between categories at 0.05 level; ns: no significant difference at 0.10 level.

Table 5. Sources of credit for agriculture and allied activities.

	farmers depending on the source (%)	rate of interest (%)
Commercial banks / Co-operatives	6.88	7.54
Input dealers	16.88	9.11
Private money lenders	0.00	--
Friends, neighbours and relatives	11.88	2.63

Source: Household survey (2010).

Another major production constraint commonly found in the cereal systems of eastern IGP is the inability of farmers to access quality farm information. The sample farmers also identify lack of information as one of the major constraints in wheat production. However, the pattern of information supply is possibly different in the study villages compared to the rest of the state as the survey has been conducted where the ZT wheat was actively propagated by the state KVKs. Public extension network is found prominent in disseminating farm information and KVKs and agricultural universities are found to be the most prominent information source (Table 6).

Table 6. Sources of information on wheat cultivation.

	frequency of contact	perceived relevance	source of information on no-till practice#
Govt. Extension (incl. KVK)	High	High	100
Private input dealers	Very low	Very low	0
NGOs	Nil	--	0
Mass media	Low	Very low	2
Other farmers	High	High	45

Source: Household survey (2010).
Note: # The figures show % of adopters (N = 64).

Both the frequency of contact with the extension agents and the perceived utility of information thus obtained are indicated as high, irrespective of their technology accessibility. Without exception, all the adopters indicate government extension agents as the source of information on the ZT technology. A significant share of farmers also gained knowledge on ZT from other farmers, and this informal information network is found to be disseminating information on the technology. Nevertheless, whether the information so passed actually helps ZT dissemination is an issue that deserves in-depth examination. Further, it is found that the role of private dealers was insignificant for this purpose, as was that of NGOs and the mass media.

Availability of quality seeds of suitable wheat varieties is observed to be another major constraint for wheat production in eastern IGP. The few existing late-sown, rain-fed varieties suitable for the region (Gomti, HDR-77 etc.) are found to be poorly disseminated. The wheat seed supply system is highly disorganized in India, but its magnitude is most critical in the eastern IGP. The major wheat variety found in the farmers' field is PBW-343, developed by Punjab Agricultural University (Ludhiana) in 1994 for the NW Plain zone for timely-sown, irrigated wheat. Although this long-duration variety is not congenial for the late sown wheat cultivation of West Bengal, about one-third of the sample farmers adopted it (Table 7). Another commonly found variety, Sonalika (also known as S-308), was released in 1967 for all zones in India for late sown irrigated conditions. The only variety released in the recent past (2001) that is widely adopted in the location is HD-2733. It was developed for the NE plain zone for timely sown, irrigated conditions (Sharma et al. 2004). In addition, some varieties with unrecognized or mixed lineage are also found to be cultivated in the area.

Table 7. Varietal use in wheat.

Variety name	adoption (share) in 2009/10 rabi season#	share of variety adopters based their selection on						
		higher yield	location adaptability	pest resistance	market price	ideal harvest time	consumption preference	others
PBW 343	0.35	0.74	neg.	0.21	0.16	0.13	0.40	0.44
Sonalika	0.27	0.95	neg.	neg.	0.13	0.10	0.28	neg.
Local variety	0.21	0.97	0.22	0.19	neg.	neg.	0.22	neg.
Local-HD mix	0.11	0.90	0.14	neg.	0.19	0.19	0.48	neg.
HD 2733	0.03	0.88	0.75	1.00	0.38	neg.	0.25	0.13

Source: Household survey (2010).
Note: # 90% of farmers cultivate single variety (rest 2 varieties) in their farm; neg.: negligible

The reasons behind varietal adoption from the farmers' perspective are also provided (Table 7). Compared to others, less percentage of farmers indicated high yield as the criterion of selection of PBW-343, for its (lack of) location adaptability. However, a few local varieties and HD-2773 are found to be popular due to local adaptability. Cultivation of PBW-343 and HD-2773 is closely related with the use of ZT drills (Table 8). The major source of wheat seeds for the drill adopters is KVK/ government extension offices (81% of adopters depend on this source; *cf.* Table 9). About 46% of the ZT farmers get some subsidy on seed purchase from the public extension offices. The lack of availability of locally adaptable wheat varieties with these agencies, prompt them to supply available seeds that may not be congenial for the local agricultural system. However, it should also be noted that in the absence of these agencies, chances of getting quality seeds for farmers is further minimized. For example, the supply of the HD-2773 variety, which is preferred by farmers for yield and local adaptability, is confined to the public sector.

Line sowing using seed drills reduces seed requirement per acre and it is, therefore, quite unsurprising to find that the seed demand by non-users of drills (following broadcasting) over drill users is higher by 9% (Table 9). Majority of the non-users of ZT drills (65%) depend on private dealers for obtaining wheat seed. The extent of use of farm-saved seeds is also high amongst the farmers of this category.

Table 8. Varietal use with respect to tillage practice.[#]

Variety name	share of varietal use among drill		sig. of difference
	user	non-user	
PBW 343	0.65	0.17	***
HD 2733	0.08	0.00	***
Sonalika	0.22	0.28	ns
Local variety	0.12	0.30	***
Local-HD mix	0.06	0.23	***

Source: Household survey (2010).
Notes:
(i) # Varietal adoption is measured in terms of households adopting particular variety (and not by area under cultivation). Since 10% of farmers cultivate two varieties, the sum of % can be more than 1.00.
(ii) ***: Significant difference exists between categories at 0.01 level; ns: no significant difference at 0.10 level.
(iii) *, **, ***: Significant difference exists between adopters and non-adopters at 0.10, 0.05 and 0.01 levels; ns: no significant difference at 0.10 level.

Table 9. Seed rate, sources of seeds and availability of subsidy.

	drill adopter	non-adopters	sig.
Seed rate (kg/acre)	49.28 (16.12)	53.91 (17.25)	*
Main source of seed (share of farmers)			
Govt. Extension/ KVK/ Universities	0.81	0.11	***
Private dealers	0.13	0.65	***
Other farmers	0.02	0.06	ns
Farm-saved	0.03	0.18	***
Share of farmers who obtain subsidy for seed purchase	0.46	0.27	**

Source: Household survey (2010).
Notes: Figures in parentheses show standard deviation to mean values. 1 acre = 0.405 ha.

The wheat system characterization, with respect to adoption of CA practices, demands an examination of human labor availability pattern. Although labor is conventionally assumed to be a factor relatively abundant in the East compared to the North-West of IGP (Erenstein 2009), our survey found that the peak wage rate in Malda and Uttar and Dakshin Dinajpur districts are high even when compared to Punjab and Haryana. The prevailing wage rates during the survey were Rs. 165 (US$ 3.13) and Rs. 125 (US$ 2.40) per day for male and female laborers respectively, which is 11-18% higher compared to the normal wage rate existing in the above mentioned NW Indian states.[12] Two possible reasons for increased wage rate are:

- Labor migration to cities (e.g., Kolkata) and other parts of India (e.g. South India) for non-agricultural occupation (e.g., construction) and
- Inter-crop competition for labor. (Proliferation of tea plantations in the study area absorbs majority of the available local labor for tea-plucking, which is more remunerative and less-seasonal in demand.)

Due to the scarcity of labor (both human and machine) and high wage rates, wheat farmers in the study area were found to be largely using family labor for cultivation. Priced at the existing wage rate, family labor accounts for 66% of the labor cost in conventional wheat cultivation. The major activities that demand labor are harvesting (which is done manually, unlike in most parts of NW India), land preparation (for conventional wheat) and irrigation. Manual weeding is not found to be commonly practiced among the sample farmers. The weed menace is relatively low since the period of survey was a drought year. However, weed infestation is generally a major constraint that limits wheat production and unavailability of chemical measures, coupled with scarcity of labor and/or high wage rate, worsens its adverse yield impact (Table 10).

Table 10. Constraints in wheat production: farmer perspective.

Rank	Constraint	relevancy score (1-4)
1	Unavailability of drills and machineries	2.74
2	Lack of information on crop production	2.61
3	Lack of quality wheat seeds	2.59
4	Labor scarcity	2.49
5	Weed infestation	2.35
6	Credit availability	2.09
7	Adverse soil conditions	2.03

Source: Household survey (2010).

[12] Source of wage rate in Punjab and Haryana are obtained from the village survey conducted, under the CSISA project, which was carried out during the same time of the household level data collection for the present study.

5. Access to drills and adoption of no-till practice

Adoption studies, in which the technology in question involves employment of a bundle of innovations rather than a single element of yield-enhancing or input-saving attributes, poses special challenges (Becerril and Abdullai 2010). In the case of ZT, the innovation involves use of drills, minimum soil disturbance, weed management, residue retention etc. Such package-nature of CA-based RCTs makes the examination of their adoption and evaluation of associated farm-level impacts rather challenging. Nevertheless, across the sample farmers, not much inter-farm differences were evident in terms of weed management and residue retention. However, this is not the case with tillage or soil disturbance. The defective reinvention of the ZT technology, where the drills are used in the field after tillage for line sowing, is being followed by a significant share of sample farmers. Although the frequency of adoption of drill use seems to decline slightly with the number of tillage operations in the study area (Figure 4), there is no significant difference in the average number of tillage operations followed by the reinventing and non-adopting farmers (Table 11). Such defective reinvention comes with a significant cost increase, given the prevailing high wage rate for human labor and custom hiring charges of animal and machine labor. The average hiring charge of a pair of bullocks is Rs. 388/acre per operation (US$ 7.40), whereas that of a tractor is Rs. 586/acre (US$ 11.13). A multiple of this cost, depending on the number of tillage operations being performed before adoption of ZT, is saved with the technology adoption.

Residue retention in ZT plots is found to be mostly partial (Table 11). In the eastern IGP, rice straw forms the major fodder for cattle and buffalos and hence full retention of the crop residue for ZT as mulch may not be practical and/or economically feasible. This is an additional constraint to CA diffusion in the eastern plains in contrast to the NW IGP, where mostly wheat straw is used as fodder. However, most of the no-till adopters (87%) retain partial residue (about 25%), and residue burning is not practiced. Again, in contrast to the situation in NW IGP, late sowing is generally practiced in West Bengal for conventional tillage wheat. The extent to which ZT helped farmers sow the crop early was not estimated due to the limitation of primary data collected.

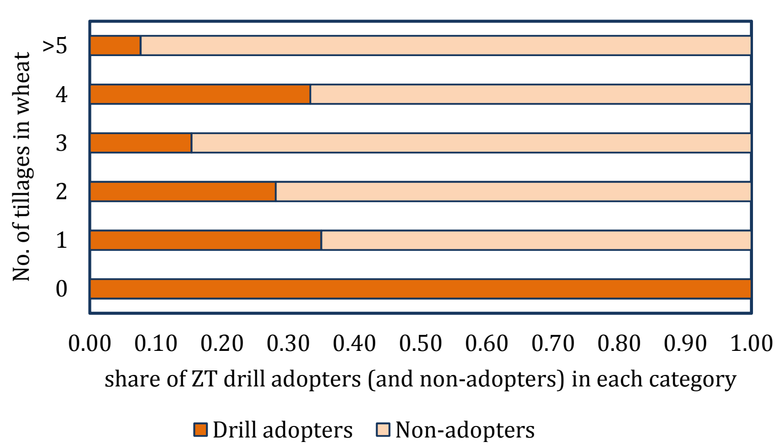

Figure 4: Tillage and seed-drill use in wheat.

Source: Household survey (2010).

Table 11. Tillage and residue retention.

		Mean (std.dev)
Number of tillage among:	Partial-adopters (drill + tillage use)	2.44 (1.36)
	Non-adopters	3.07 (1.86)
Tillage type (share of farmers using) among non-adopters of	Animal traction	0.70
	Tractor	0.83
Custom hiring charge (Rs/acre/tillage)	Animal traction	388.25 (131.32)
	Tractor	585.86*** (220.50)
Farmer (share) practice on residue retention in ZT plots	Full retention	0.09
	Partial retention	0.87
	No retention	0.04

Source: Household survey (2010).
Notes:
i. ***: Significant difference exists between mean values of sub-rows at 0.01 level
ii. 1 acre = 0.405 ha; 1 US$ = Rs. 52.64 (as on April 2012)

The survey has shown that within the two years of its introduction in the sample villages, ZT technology has gained huge popularity among the wheat farmers (Table 12). About 90% of the sample farmers are seen to have expressed willingness to adopt the technology in the next wheat season (2010/11). However, availability of drills is conceived as a major challenge. Again, many of those farmers, who had shown dis- and non-adoption behavior, indicated the difficulty of getting drills at the required time as one of the major reasons. An overwhelming share of farmers (89%) indicated the difficulty of obtaining drills as medium to high, amongst the constraints to follow ZT wheat. The absence of active private sector service providers, unlike in Punjab and Haryana, and high cost of drills are the two major factors that restrict the diffusion of ZT technology in West Bengal. Hence, should the institutional environment be congenial for provision of machineries, the CA-based RCTs will spread rapidly even in the most disadvantaged regions of eastern IGP. The supply- and demand-side factors are further examined using the econometric tools detailed in the next sub-section.

Table 12. Farmers' willingness to follow ZT practice in the forthcoming season.

		Share of farmers
Willing to follow ZT in next year among:	2009-10 adopters	0.88
	2009-10 non-adopters	0.90
Farmers indicated no willingness [N = 23] to use ZT next year due to:	(i) Low yield	0.61
	(ii) Difficulty in getting seed drill on time	0.52
	(iii) Others	0.22
	(iv) No stated reason	0.13

Source: Household survey (2010).

5.1. Review of literature and model specification

Knowler and Bradshaw (2007), through a meta-analysis of 23 studies in countries viz. Nigeria, Rwanda, Canada, US, Panama, Peru, Honduras and Burkina Faso, attempted to delineate the factors (farmer and farm household, biophysical, and financial/management characteristics and exogenous factors) affecting the adoption of CA practices.

The study reveals only a few, if any, universally significant explanatory variables. For example, although some commonly included explanatory variables, such as education of the household head and farm size owned, show convergence towards a significant and positive influence, the incidences of insignificance and negative association were also quite frequent. In addition, the number of studies on ZT adoption in South Asia is rather limited, in the best knowledge of authors, with only Farooq et al. (2007) and Erenstein et al. (2007) examining the factors influencing ZT adoption in the irrigated rice-wheat systems of Punjab (Pakistan) and Haryana (India)respectively.

In the literature, factors affecting technology adoption are traced through a number of econometric tools, including ordinary least squares (OLS), probit/logit, tobit, duration, and selection models. Most of these models were also employed to study the adoption pattern of CA techniques (Knowler and Bradshaw 2007). For example, Erenstein et al. (2007) have studied the factors affecting zero tillage adoption in the irrigated tract of Haryana using logit analysis. However, when partial adoption of the technology occurs through selective adoption of certain elements from a bundle of innovations, conventional adoption models are found inadequate in estimation. The method that is employed in this paper to capture the occurrence of reinvention is similar to that of de Herrera and Sain (1999) to study the elements of ZT adoption. In our study context, the farmers can be classified into three groups, as adopters of:

- CT and broadcasting (*c*);
- partial adoption or CT and seeding using drill (*r*); and
- no-till and seeding using drill (*z*).

Accordingly, we formulated the econometric model of multinomial logit model (Greene 2008: 843-845), where the outcomes recorded unordered in y, and vector of explanatory variables, X. Here, we estimate a set of coefficients $\beta^{(c)}$, $\beta^{(r)}$ and $\beta^{(z)}$ corresponding to each outcome category.

$$\Pr(y=c)=\frac{e^{X.\beta^{(c)}}}{e^{X.\beta^{(c)}}+e^{X.\beta^{(r)}}+e^{X.\beta^{(z)}}}$$

$$\Pr(y=r)=\frac{e^{X.\beta^{(r)}}}{e^{X.\beta^{(c)}}+e^{X.\beta^{(r)}}+e^{X.\beta^{(z)}}}$$

$$\Pr(y=z)=\frac{e^{X.\beta^{(z)}}}{e^{X.\beta^{(c)}}+e^{X.\beta^{(r)}}+e^{X.\beta^{(z)}}}$$

The model, however, is unidentified with more than one solution to $\beta^{(c)}$, $\beta^{(r)}$ and $\beta^{(z)}$, which lead to the same probabilities for $(y=c)$, $(y=r)$, and $(y=z)$. To identify the model, one of the β-values is arbitrarily set to zero. For the estimation, we have first run the model keeping $\beta^{(c)} = 0$ to obtain coefficients $\beta^{(r)}$ and $\beta^{(z)}$ that will measure the change relative to the group $y = c$. Equally important is to measure the relative probability of $(y = z)$ to the category $(y = r)$, which is estimated by re-running the model with $(y = r)$ as base category. The exponential value of a coefficient is the 'relative risk ratio' (rrr) for unit change in the corresponding variable.

The dependent variable in the aforementioned adoption model is qualitative in nature as it classifies a sample farmer into one of the three categories. The sample was collected randomly after stratifying the farmers based on drill adoption. The sample contained about 56% of adopters of drill in the rabi season of 2009/10, but 25 of these households (16% of total sample) have used the drill only for seeding, after ploughing the soil (defective reinvention of the drill technology). Hence, the percentage composition of c (44%), r (11%) and z (40%) groups, and the dummy variables representing these groups form the dependent variable in the multinomial logit model.

The explanatory variables used in the model can be grouped into four categories:

- Information variables (N = 2). They indicate the relevance of information from public sources (KVK, agricultural university, government extension etc.) and farmer-to-farmer networks. Each of these variables is measured on a scale of 0-9, which is constructed by multiplying the frequency of contact (0-3) and perceived relevance of the information obtained (0-3). In the sub-scales a 0-value indicates no relevance or infrequent contact, while 3 stands for high relevance or very frequent contact with the particular information source. Farmer proximity to the government extension agents is hypothesized to have a positive impact on adoption, while the impact of farmer networks is rather ambiguous.
- Asset variables (N = 3). The set includes variables viz. land owned by the household (measured in acres), number of large ruminants (cow, buffalo and bullock) in the farm, and share of leased-in to cultivated acreage. These variables represent the household's resource/wealth status. Tenancy is hypothesized to limit the CA technology adoption, as tenant farmers may not be interested in improving the soil quality over longer periods through technology adoption. The other variables, which stand as proxy to the wealth of the household and hence the risk bearing capacity, could be facilitating the technology adoption.
- Household characteristics (N = 3). Assuming that the decisions are taken jointly by the adult members of the household, the models were estimated with household characteristics, instead of individual characteristics of the household head. Number of adult members in the household, experience in wheat cultivation (years) and the highest education obtained by a household adult (measured in years of schooling) were included in the model. These factors are expected to have positive impact on adoption decision.
- Village attributes (N = 4). The technology adoption status in the village represented by the share of wheat farmers adopting ZT technology and number of wheat farmers in the village are included in the model to provide insights into the aggregate demand for drills.

In addition, the location variables (district dummies) were included. Given that the number of drills with the service providers like KVKs is limited, village level adoption and number of wheat farmers would raise the intra-village competition for the equipment.

As the nature of reinvention in agriculture is not widely studied, the hypotheses on factors that distinguish categories, namely $(y = z)$ and $(y = r)$, are not developed. The summary statistics of these variables are provided in Table 13. The model estimation results are detailed in the next sub-section.

Table 13. Descriptive statistics.

variable	description (unit)	statistics		
		mean	**(std. dvn)**	**range (min-max)**
C	Farmers following CT; with no drill use (dummy)	0.44		0&1
Z	Farmers adopting no-tillage (dummy)	0.40		0&1
R	Partial adopters of , that is, those who adopting of drill with tillage (dummy)	0.16		0&1
Public info.	Perceived relevance of information from public extension networks (scale of 0-9)	6.04	(3.54)	0-9
Farmer info.	Perceived relevance of information from farmer networks (scale of 0-9)	3.99	(2.89)	0-9
Land Owned	Area of land owned by the household (acre)	2.59	(2.87)	0-17
Lease-in land	Land area under lease-in arrangement out of total cultivated land (share)	0.15	(0.30)	0-1
Animal owned	Cows, buffalos and bullocks owned by the household (number)	2.54	(1.71)	0-8
Adult members	Adult household members (number)	3.93	(1.32)	3-9
Experience	Years of experience in wheat farming (number)	11.31	(7.94)	1-40
High education	Maximum years of experience obtained by a household member (number)	7.52	(4.91)	0-18
Village adoption	Number of drill adopters out of total wheat farmers in village (share)	0.36	(0.27)	0.06-0.85
Wheat farmers	Wheat farmers in village (number)	64.13	(49.45)	10-180
U. Dinajpur	Farmers from Uttar Dinajpur district (dummy)	0.35		0 & 1
D. Dinajpur	Farmers from DakshinDinajpur district (dummy)	0.35		0 & 1

Source: Household survey (2010).
Note: 1 acre = 0.405 ha

5.2. Estimation findings

The estimation results of the access (to drill) and adoption (no-till practice) model are shown in Table 14 and the associated rrr values in Appendix I. The multivariate model used was found to be highly significant with a χ^2 value of 75.55 at 24 degrees of freedom. The decision to use drill [$(y = z)$ and $(y = r)$] against broadcasting [$(y = c)$], and the decision to follow no-till practice$[(y = z)]$ are found to be significantly influenced by information, asset, household and location-specific variables.

As expected *a priori*, the information variables are found influential in determining the tillage option selected by the wheat farmers. It is proven that the general positive link between provision of information and technology adoption also holds the case for CA (de Herrera and Sain 1999; Erenstein et al. 2007). However, the source of information matters equally or more, as indicated by the model estimates. The (perceived relevance of) information from the public extension is found facilitating the drill adoption, but not the no-till practice. Although unit increase in the "scale of relevance" raises the relative probability of adoption of ZT over CT (z/c) by 67%, the variable is also associated with a diminished chance of adopting no-till over the option of reinvention (z/r).

The ZT technology has a relatively short history of diffusion in the study area, and the information on benefits of no-till practice might not have yet percolated into the farming community as that of the drill adoption (including subsidy availability). However, the strength of farmer communication networks is found to be negatively affecting drill adoption, both for the no-till adoption and the drill access (as the seeding device). This is somewhat surprising given the technology's popularity in the study area. But the farmer networks might have helped faster diffusion of information on subsidy availability with ZT adoption than that on farming impacts of the technology. Many of the economic benefits of CA practices are realized only over a longer period of time, and hence they may not be recommended by the farmers at the early stages of diffusion. As a strategic behavior, the perceived scarcity of drills could also be preventing the farmers from spreading the positive information on ZT across the farming community. In sum, although the farmer networks are effective in general by introducing the technology across the farming community during the early stage of technology diffusion, it may also cause undesirable implications by withholding crucial technical information regarding the technology impact.

Table 14. Determinants of drill access and no-till adoption in wheat: Multinomial logit model.

	$\frac{\Pr(y=z)}{\Pr(y=c)}$			$\frac{\Pr(y=r)}{\Pr(y=c)}$			$\frac{\Pr(y=z)}{\Pr(y=r)}$		
	coef.	**(std. dev)**	**p value**	**coef.**	**(std. dev)**	**p value**	**coef.**	**(std. dev)**	**p value**
Public info.	0.215	(0.064)	0.00	0.515	(0.131)	0.00	-0.300	(0.129)	0.02
Farmer info.	-0.185	(0.073)	0.01	0.104	(0.115)	0.37	-0.289	(0.114)	0.01
Land owned	0.053	(0.098)	0.59	0.055	(0.141)	0.70	-0.001	(0.124)	0.99
Lease-in land	1.630	(0.756)	0.03	1.435	(1.026)	0.16	0.196	(0.943)	0.84
Animal owned	-0.066	(0.134)	0.62	-0.405	(0.204)	0.05	0.339	(0.197)	0.09
Adult members	0.484	(0.201)	0.02	0.624	(0.292)	0.03	-0.140	(0.271)	0.60
Experience	-0.029	(0.027)	0.29	-0.043	(0.039)	0.27	0.014	(0.038)	0.72
High education	0.099	(0.047)	0.03	0.164	(0.075)	0.03	-0.065	(0.073)	0.37
Village adoption	-0.205	(1.018)	0.84	2.696	(1.416)	0.06	-2.902	(1.328)	0.03
Wheat farmers	0.004	(0.007)	0.52	-0.021	(0.012)	0.08	0.026	(0.012)	0.03
U. Dinajpur	0.860	(0.949)	0.37	-1.538	(1.311)	0.24	2.398	(1.290)	0.06
D. Dinajpur	1.114	(0.905)	0.22	-0.977	(1.279)	0.45	2.092	(1.258)	0.10
Model intercept	-4.015	(1.494)	0.01	-6.638	(2.324)	0.00	2.623	(2.242)	0.24
N	160								
Log likelihood	-124.96								
LR $\chi^2(24)$	75.55		0.00						
Pseudo R2	0.23								

The mean-variance analysis has already indicated that the drill adoption is positively determined by the farm size. However, the econometric model does not show any such pattern. Further, the status of land tenancy, although having no impact on no-till adoption, favors drill use against broadcasting of seeds. Tenant farmers may increasingly recognize the relevance of line sowing to enhance the short-run farm profits, but not the sustainability of economic benefits associated with ZT technology. The number of adult members in the household is found to be positively affecting the drill adoption, which might be through increased contact with the extension agents. This variable does not distinguish farmers adopting no-till from those getting access to the drills (partial adoption).

The impact of large ruminants on ZT with (at least partial) residue retention is largely ambiguous, given the fact that crop residue after rice cultivation (which is the preceding crop in kharif season in about 65% of the farms surveyed) forms the major component of cattle-feed in the eastern plains. Also the draught power of owned bullocks might facilitate land preparation. On the contrary, the supplementary income assured from livestock production could allow the wheat farmers to experiment with new production technologies. The model estimates indicate that, in general, the cattle owner prefers CT, and each additional animal owned reduces the chances of following ZT over CT by about 33%. However, if a cattle owner were to get access to the drill, he/she may go for no-till and not for partial adoption. This could be due to the increased risk bearing ability associated with resource entitlement in form of cattle and buffalos.

Education is found to have a significant and positive role in adopting both no-till and drill use as seeding device. The chances of adopting z/c and r/c are found to be increasing by 18% and 10% respectively, with one year increase in the maximum education of households, which is measured as years spent for schooling by the highest educated member of the household.

Nevertheless, the impact of location-specific variables was the most prominent amongst all the different sets of explanatory variables. The aggregate community/village adoption levels of drills were found to be facilitating the partial adoption practice over no-till, possibly due to the excess demand for the drill and resulting in the delayed availability of drill. However, the total number of wheat farmers in a given village, which again represents the strength of competition for limited drills available at the KVKs and other public sources, is found to be reducing the chances of drill adoption. This factor is also found to raise the probability of adopting the no-till over reinvention practices. Other location-specific variables like district dummies are also found to be significant. Although there were no differences in drill adoption across districts owing to the stratified sampling procedure, the reinvention of drill is found to be comparatively higher in Malda district, thus increasing the number of tillage operations in wheat cultivation. The farm impact of the drill access and no-till adoption is examined in the next section.

6. Production impacts of zero-tillage

On-farm impacts of ZT wheat in the NW Indo-Gangetic Plains are examined by Erenstein et al. (2008b), confirming the existing on-station and on-farm trial findings that significant -induced resource- and cost-saving effects occur in the farmers' fields. However, the financial impacts of this technology are hardly examined in the Eastern IGP cereal systems. Given that the major yield benefits from ZT are accrued due to early planting of wheat, the technology could enact a crucial role in increasing the wheat productivity of the Eastern IGP, where late planting and terminal heat are major causes of reduced yield. However, there are certain constraints in evaluating the production impacts of ZT in the present study. Partly, it is the nature of the dataset, built upon single-year observation of the early phase of technology diffusion, that limits the generalization of study findings. In addition, the issues associated with the technology dissemination system that pose further challenges to the impact assessment are:

- Supply of inputs at subsidized rate from the ZT promotion agency
- Coupling of technologies (ZT drill with PBW 343 variety) and
- Partial adoption (use of drills with tillage).

The subsidy element is separated from the cost-return statements, and additional analyses performed to identify the impacts of individual technologies. The cost-return figures are estimated separately for the group of farmers, who follow reinvention of drills, to distil the financial effects of this unique practice. The cost of cultivation details are given in Tables 15 and 16, while yield impact is given in Table 17 and Figure 5. The gross margin of wheat farming for different groups of farmers is shown in Table 18. Despite the aforementioned limitations, the data indicate unique resource use patterns that are crucial in determining the profitability of wheat in the existing production system.

Major ZT-induced effects are through altering the establishment and production costs of the wheat crop. Erenstein et al. (2008b) estimated that the technology is associated with a cost-saving of 7-10% in Haryana (India) and Punjab (Pakistan). In the present study, the farmers are getting other inputs like seeds, along with the drill, under subsidy from the promotional agencies. Although the cost impacts of the subsidy element can easily be removed by a simple addition procedure, the effect of the quality of inputs on yield cannot be nullified in this manner, and hence the yield impacts are not covered in detail in the present study. Due to the subsidized provision, cost of seeds paid by the no-till farmers is about 36% less than that by the CT farmers. Most of the adopters also get the drills free of cost, which results in almost no cost for land preparation and seeding, thus saving about Rs. 1,135/acre (US $ 21.6/acre). The cost-saving is also significant with respect to the family labor component. When imputed at the prevailing wage rate, ZT adopters are found to save about 34% or Rs. 1,000/acre (US $ 19/acre) over their CT counterparts. This may have greater system-wide implications (viz. intensifying the production system by cultivating the rabi fallows), which does not come under the purview of the present study.

Interestingly, the use of plant protection chemicals is found to be higher among the drill adopters. Infection of the tea loopers is found to be a production threat of increasing magnitude in the study area, especially in Uttar Dinajpur. Since the study was conducted after a drought year, in which there was significant increase in tea leaf shedding, the loopers are found to be migrating to the wheat crop. The use of chemicals like Carbosulfan, found to be prevalent among the sample farmers, was mainly to manage this pest menace. The study carried out in the KVK of Uttar Dinajpur estimated about 10-12 larvae per square meter of wheat plot.[13] [The farmers can access the plant protection chemicals from the public sources with relative ease, and with their increased awareness about the pest control, this increased accessibility could lead to a higher degree of chemical management. One of the possible explanations for increased pesticide use with ZT adoption is based on the relative availability of working capital with the farmers, which is saved from land preparation and seeding operations for chemical management of the pests. The greater access of information from government extension sources may be another factor behind this trend. However, whether the rice residue retention has any impact on the increased insecticide use is an issue to be addressed further.

In sum, the no-till farmers are found to be saving about 12% of the paid-out cost when subsidy effect is nullified (Table 15). However, when the family labor cost is imputed into the paid-out cost figures, the cost-savings widens to 19% over the CT wheat. Both these figures are significantly higher than what is found in the existing literature on NW IGP (Erenstein et al. 2008b).

Table 15. Paid-out variable cost structure of wheat production.

cost (Rs/acre) incurred on:	tillage type			% change of		
	no-till (*z*)	reinvention (*r*)	conventional (c)	*z* over *c*	*r* over *c*	*z* over *r*
Seed	410.89 (569.64)	584.16 (634.17)	641.80 (544.64)	-36**	ns	ns
Organic manure	37.41 (165.68)	72.72 (251.69)	45.69 (147.69)	ns	ns	ns
Fertilizers	1452.88 (648.27)	1542.00 (928.22)	1577.92 (727.06)	ns	ns	ns
Plant protection chemicals	570.19 (736.29)	693.80 (794.12)	235.08 (430.79)	143***	195***	ns
Hired human labor	1527.72 (1248.12)	2110.16 (1974.59)	1512.32 (1292.71)	ns	40*	-28*
Imputed value of family labor (fl)	1697.25 (1406.13)	2092.20 (1538.28)	2575.03 (2338.50)	-34***	ns	ns
Machine/animal charges	7.08 (41.99)	943.28 (793.97)	1135.37 (801.62)	-99***	ns	-99***
Total paid-out cost	4005.81 (1892.46)	5945.84 (2633.95)	5147.85 (2060.76)	-22***	ns	-33***
Paid-out cost + subsidy	4677.03 (1837.38)	6422.64 (2517.71)	5292.52 (1970.28)	-12*	ns	-27**
Total paid-out cost + subsidy + fl	6374.22 (2387.86)	8514.84 (3208.65)	7867.44 (2832.60)	-19***	ns	-25***

Source: Household survey (2010).

Notes:

(i) Figures in parentheses show standard deviation

(ii) 1 acre = 0.405 ha; 1 US$ = Rs. 52.64 (as on April 2012).

(iii) *, **, ***: Significant difference exists between comparing categories at 0.10, 0.05 and 0.01 levels; ns: no significant difference at 0.10 level.

[13] Source of information: Personal communication with D. Mandal, Entomologist, KVK, U. Dinajpur

However, none of the benefits accrue to the reinvention farmers, who pay significantly higher amounts for hiring out human labor and for plant protection chemicals. The family labor saved among the reinventing farmers is insignificant. In fact, the cost of cultivation using drills and tills together is higher than that of CT, although the difference is statistically insignificant.

Analysis of the yield impact of ZT in the mean variance framework necessitates an examination of the associated input use. We have already observed a significant difference with regard to family labor employment and plant protection chemical use across the tillage categories. There are no significant differences with respect to manure and fertilizers, in either monetary or quantity terms (Tables 15 and 16). The farmers are using the NPK at 49:17:22 kg/acre, which is almost at par with the recommended dosage (40:20:20 kg/acre).[14] ZT drill adoption is found to be helping the farmers to reduce seed rate by 8% (no-till) to 11% (reinvention) over broadcasting practiced by CT farmers. There are no differences across adoption groups with respect to the number of irrigation and weeding practices followed. However, per-operation, 57% more cost is incurred to weed the no-till plot as compared to the CT. This could be an indication of high weed growth associated with no-till practice, especially since the sample farmers seldom depend on chemical measures for weed management.

Table 16. Input use, irrigation and weeding practices in wheat cultivation.

	tillage type			% change of		
	no-till (*z*)	**Reinvention (*r*)**	**conventional tillage (*c*)**	***z* over *c***	***r* over *c***	***z* over *r***
Seed rate (kg/acre)	49.86 (16.11)	47.82 (16.40)	53.91 (17.25)	-8†	-11†	ns
NPK used (kg/acre)	83.67 (33.68)	85.94 (45.49)	92.47 (41.30)	ns	ns	ns
No. of irrigations/wheat	2.94 (1.14)	2.64 (1.11)	2.68 (0.91)	ns	ns	ns
No. of weeding/wheat crop	0.38 (0.58)	0.44 (0.71)	0.46 (0.79)	ns	ns	ns
Average cost of weeding (Rs/acre/weeding)	195.36 (255.24)	148.13 (136.20)	124.75 (165.17)	57*	ns	ns

Source: Household survey (2010).

Notes:

(i) Figures in parentheses show standard deviation.

(ii) 1 acre = 0.405 h; 1 US$ = Rs. 52.64 (as on April 2012)

(iii) ns: no significant difference at 0.10 level between comparing categories; † significant difference at 0.10 level exists in one-tail t-test.

The yield averages across different technology categories are given in Table 17. The wheat yield average in the study area ranges between 9-10.5 quintals/acre (2.2 to 2.6 tons/ha). No significant difference is found in the wheat yield in ZT plots, compared to the CT ones. This pattern is also evident in the Epanechnikov Kernel Density Estimates (Figure 5). The defective practice of reinvention is found to be associated with significantly lower yield averages; 17% lower as compared to CT. It is also hypothesized that the adoption of the PBW-343 variety, which was coupled with the drill adoption by the promotion agencies in the 2009-10 season, has a significant impact on wheat yield. It is observed that the decline in yield with PBW-343 is

[14] There are also no significant differences across technology adoption groups with respect to individual nutrient consumption.

greatest (40%) among re-inventing farmers. Negative technology-variety interaction effect is also observed in case of, but with statistical insignificance.

Table 17. Productivity impact of tillage and variety (PBW 343) use.

yield (q/acre)	tillage type			% change of			equality of population: χ^2 with ties
	no-till (*z*)	reinvention (*r*)	conventional (*c*)	*z* over *c*	*r* over *c*	*z* over *r*	
Overall	9.63 (3.84)	8.88 (4.55)	10.66 (3.76)	ns	-17**	ns	4.809*
PBW 343 adopters	9.14 (4.36)	7.30 (3.93)	10.41 (3.27)	ns	-30**	ns	4.817*
Other variety adopters	10.35 (2.86)	12.25 (4.08)	10.70 (3.84)	ns	ns	ns	1.308ns
% change of PBW 343 over others [χ^2 with ties]	ns [2.393]	-40*** [7.534]	ns [0.059]				

Source: Household survey (2010).

Notes:

(i) Figures in parentheses show standard deviation, and figures in square brackets show χ^2 value (with ties).

(ii) 1 acre = 0.405 ha

(iii) *, **, ***: Significant difference exists between comparing categories at 0.10, 0.05 and 0.01 levels respectively; ns: no significant difference at 0.10 level. Kruskal-Wallis equality-of-populations rank test is employed.

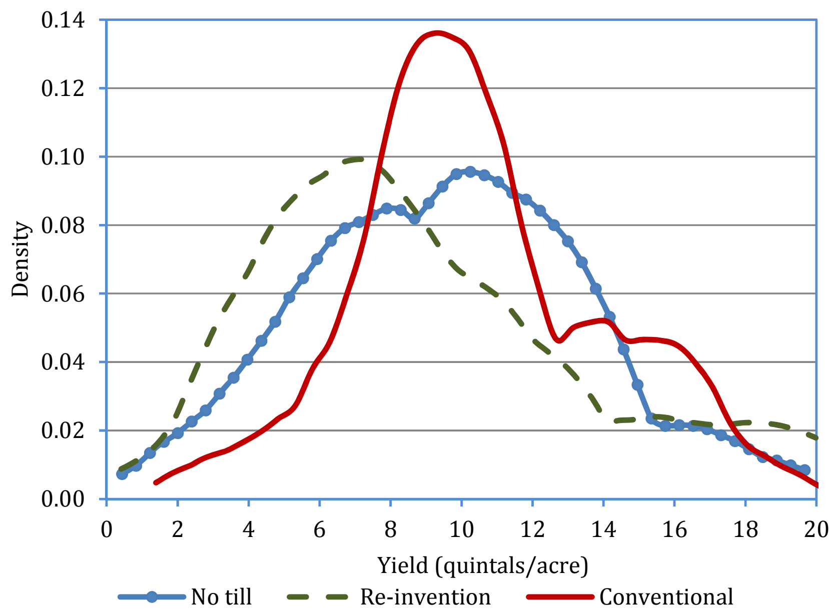

Figure 5. Yield impact of tillage adoption: Kernel Density Estimation

Source: Household survey (2010).

Note: 1 acre = 0.405 ha; 1 quintal = 0.1 tonne.

Despite having remarkable cost-saving effects, gross margin effect of ZT technology is less pronounced, owing largely to insignificant but negative yield effect of the technology (Table 18). It is observed that due to the scarcity of the drills during the wheat sowing season, early planting of wheat has not taken place with technology adoption. When the subsidy element is removed from the cost structure, Rs. 613 (US$ 11.65) is spent to produce 1 quintal of wheat under ZT, whereas Rs. 600 (US$ 11.40) is the cost of production under CT. The cost of production will be Rs. 846 (US$ 16.07) and Rs. 898 (US$ 17.06) per quintal respectively when the family labor cost is imputed. Nonetheless, the difference remains insignificant. Unsurprisingly, the marginal revenue is significantly low in drill reinvention. Cost of production under reinvention is more than double that of CT wheat. In sum, a loss of Rs. 2,776 (US$ 52.74) is accrued per acre due to defective reinvention (tilling the plot instead of ZT use alone), which is mainly due to unavailability of drills on time.

The financial implications of technology access and no-till adoption in the study area are clear only from the cost-side through the simple mean-variance analysis. The yield effect is marred due to differences in input use with tillage technology adoption. In addition, there could also be farm-household factors, determining the wheat productivity through improved managerial practices. Lack of effective instrumental variables to proxy the drill access and no-till adoption prevent the study from analysing the production effects using econometric modeling tools. This is one of the major limitations of the study.

Table 18. Impact of technology adoption on wheat profitability.

	tillage type			% change of		
	no-till (*z*)	**reinvention (*r*)**	**conventional (*c*)**	***z* over *c***	***r* over *c***	***z* over *r***
Profit (Rs/acre) over						
(i) Paid-out cost	4844.58	2268.92	4613.24	ns	-51**	114***
	(3686.38)	(4459.97)	(4425.10)			
(ii) Paid-out cost + subsidy	4173.39	1792.08	4468.55	ns	-60**	133***
	(3734.92)	(4572.10)	(4417.37)			
(iii) Paid-out cost + subsidy + fl	2476.23	-300.00	1893.61	ns	-116*	925***
	(4253.17)	(4565.94)	(5154.66)			
Per-unit cost of wheat production (Rs/Q) with						
(i) Paid-out cost	515.28	960.64	583.80	ns	65**	-46***
	(422.56)	(1082.22)	(520.77)			
(ii) Paid-out cost + subsidy	613.13	1058.72	600.27	ns	76**	-42**
	(518.18)	(1232.67)	(519.13)			
(iii) Paid-out cost + subsidy + fl	845.56	1352.64	897.90	ns	51**	-37**
	(670.03)	(1432.66)	(721.20)			

Source: Household survey (2010).

Notes:

(i) Figures in parentheses show standard deviation

(ii) 1 acre = 0.405 ha; 1 US$ = Rs. 52.64 (as on April 2012); 1 quintal = 0.1 tonne.

(iii) *, **, ***: Significant difference exists between comparing categories at 0.10, 0.05 and 0.01 levels respectively; ns: no significant difference at 0.10 level.

7. Conclusion

The present study has been an attempt to examine the early-stage adoption profile of ZT wheat in the northern disadvantaged districts of West Bengal, along with associated short-run farm impacts. The ZT technology was introduced in the State in the 2006/07 rabi season, and the short history of technology diffusion restricts detailed adoption as well as impact assessments. Having said that, the initial evidence gained from a farm survey conducted among 180 farmers of 10 villages of Malda, Uttar Dinajpur and Dakshin Dinajpur districts, where the ZT diffusion program is on-going, have clearly indicated the farm income potential, alongside the various institutional factors limiting the spread of the technology. In all of the sample villages, majority of wheat farmers were found to favor ZT. Technology diffusion also has been facilitated by the local KVKs, with the help of an effective subsidy program.

The farmers are provided with drills for free as well as subsidy on wheat seed. However, even in the absence of this promotional subsidy, significant cost reduction is attainable with adoption. Nevertheless, under the existing institutional framework and infrastructure limitations, the scope of spreading the economic benefits across the districts is limited. The economic potential of ZT technology is being marred by a critical scarcity of ZT equipment (drill) during the short wheat sowing season. The public service is constrained by financial and man-power limitations, and hence policies to encourage private sector service providers (including farmer-cum-service provider) are inevitable. Scarcity of drills has pushed some of the farmers to follow a practice of combining drills with tillage operation, which is found to strip off the economic benefits of ZT technology, and undermine the CA associated principles. Lack of technical information on working of the CA-system could be one of the reasons behind combining drills with tillage. In addition, the flaws in the seed supply system not only limit the wheat productivity in general, but also impede the relative performance of the technology. In conclusion, the existing limitations in the infrastructure and institutions are found to play a crucial role in defining the success of the CA program in the subsistence cereal production system of the eastern IGP.

Due to the aforementioned constraints, predictably, the major policy recommendations focus on increasing the supply of drills, possibly through altering the machine price structure. The existing price of drills (without subsidy) in West Bengal is almost double what is prevailing in Bihar, the neighboring wheat producing state. Although the government subsidy contributes to a substantially lower machine price, the number of drills available with subsidy is largely restrictive to meet the demand. This factor further limits the emergence of private sector service providers, as in the case of NW IGP. On the other hand, the machines available with the public sector (KVKs, agricultural universities) are limited in number to effectively address the farmer demand for them. In order to attain the critical mass of adopters for self-sustenance of the diffusion process, the number of service providers of the drills should be rapidly increased, potentially through ensuring the participation of the private sector.

Making low-interest credit available to smallholder farmers to procure the locally compatible 9-tine drills could be one of the ways to ensure the participation. Equally important is the provision of other key farm inputs, which have special relevance in CA package. For example, although weed management is critical in defining the success of the CA, most of the sample farmers are not familiar with the chemical measures of weed control, and manual weeding is restricted by labor scarcity and prevailing high wage rate. Nevertheless, the single most important limiting factor is the availability of quality seeds of varieties that are adaptable to the local agro-climatic conditions. At present, farmers are dependent on the age-old wheat varieties developed for the irrigated NW IGP conditions. This practice reduces wheat yield critically, under the late sowing practice prevailing in eastern IGP. Further, coupling of locally less adaptable varieties like PBW-343 by the extension agronomists with drill technology, through the subsidy mechanism, has resulted in partial realization of the economic potential of the technology. Farmer welfare in a subsistence production system, as of the study area, can be effectively enhanced through different CA packages, provided there is an effective coupling of necessary institutional provision of inputs and services with information on cultivation practices.

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Appendix I. Relative risk ratios (rrr), multinomial logit model.

	$\frac{\mathbf{Pr}(\boldsymbol{y}=\boldsymbol{z})}{\mathbf{Pr}(\boldsymbol{y}=\boldsymbol{c})}$		$\frac{\mathbf{Pr}(\boldsymbol{y}=\boldsymbol{r})}{\mathbf{Pr}(\boldsymbol{y}=\boldsymbol{c})}$		$\frac{\mathbf{Pr}(\boldsymbol{y}=\boldsymbol{z})}{\mathbf{Pr}(\boldsymbol{y}=\boldsymbol{r})}$	
	rrr	p value	rrr	p value	rrr	p value
Public info.	1.67	0.00	1.24	0.00	0.74	0.02
Farmer info.	1.11	0.37	0.83	0.01	0.75	0.01
Land owned	1.06	0.70	1.05	0.59	1.00	0.99
Lease-in land	4.20	0.16	5.11	0.03	1.22	0.84
Animal owned	0.67	0.05	0.94	0.62	1.40	0.09
Adult members	1.87	0.03	1.62	0.02	0.87	0.60
Experience	0.96	0.27	0.97	0.29	1.01	0.72
High education	1.18	0.03	1.10	0.03	0.94	0.37
Village adoption	14.83	0.06	0.81	0.84	0.05	0.03
Wheat farmers	0.98	0.08	1.00	0.52	1.03	0.03
U. Dinajpur	0.21	0.24	2.36	0.37	11.00	0.06
D. Dinajpur	0.38	0.45	3.05	0.22	8.10	0.10