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Working Paper 5

December 2012

Characterizing the Cereal Systems and Identifying the Potential of Conservation Agriculture in South Asia

Vijesh V Krishna, Meera Bhatia Mehrotra, Nils Teufel and Dalip Kumar Bishnoi

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December 2012

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Acronyms

BMGF	Bill and Melinda Gates Foundation
BPL	Below poverty line
CA	Conservation agriculture
CIMMYT	International Maize and Wheat Improvement Center
CSISA	Cereal Systems Initiative for South Asia
DSR	Direct seeded rice
FGDs	Focus group discussions
ICM	Integrated crop management
IFPRI	International Food Policy Research Institute
IGP	Indo-Gangetic Plains
ILRI	International Livestock Research Institute
IRRI	International Rice Research Institute
KVK	Krishi Vigyan Kendra
LLL	Laser land leveller
NW	Northwest
QPM	Quality protein maize
RCT	Resource conserving technology
RWC	Rice-Wheat Consortium
UC	Union Council
USAID	United States Agency for International Development
VDCs	Village Development Committees
ZT	Zero tillage

Executive summary

Conservation agriculture (CA) and related resource conserving technologies (RCTs) potentially offer a way to sustainably increase the agricultural productivity in developing countries. These practices, which involve minimal soil disturbance, residue retention and crop rotations, can potentially help farmers increase crop yields and reduce the costs of production. The present paper includes the major findings of a set of village level surveys aiming at the characterization of the cropping systems in the Indo-Gangetic Plains (IGP) with a special focus on the potential entry points for CA-related technologies. The study area comprises of four regions in the IGP, namely Indian Punjab, Haryana, Central Nepal Terai and northwest (NW) Bangladesh. The village surveys were conducted in three districts from each of these regions, which were selected based on the prevailing cropping systems. From each of the selected districts, three sub-district units (blocks in India, Village Development Committees in Nepal and Union Councils in Bangladesh) were chosen randomly from a set of blocks with project intervention. Finally, one intervention village (for the Cereal Systems Initiative for South Asia project or CSISA) and one non-intervention (control) village were selected from each of these units. In this way, data from 72 villages were collected through focus group discussions (FGDs) conducted from April-May 2010. The tools used to gather information for the present study were FGDs and village census.

The IGP has traditionally been the major grain producer of South Asia. On the one hand, the NW Plains, including Indian states of Punjab and Haryana, have a relatively favorable rice-wheat environment, dominated by wheat and irrigated rice. On the other hand, the eastern IGP regions, including the Nepal Terai and Bangladesh, have a less favorable rice-wheat environment, dominated by rainfed rice and partially irrigated wheat. Significant intra-regional differences with respect to resource endowments and incidence of poverty also exist. The NW Plains have a higher level of resource endowment and lower incidence of income poverty as compared to the eastern IGP. The cropping pattern in all the study regions consists primarily of rice and wheat. In addition, some farmers grow cotton and sugarcane in Haryana and Punjab.

The cropping pattern of Central Nepal Terai is more diverse compared to the NW India, with significant share of acreage under vegetables, legumes and oilseeds. Among cereals, rice is more prominent than wheat and other cereals (e.g. finger millet and maize) are also cultivated. In NW Bangladesh, rice is cultivated in all the three cropping seasons while wheat and maize are cultivated on a limited scale. The landholding size is larger in Punjab and Haryana compared to Nepal and Bangladesh. A significantly larger proportion of landless households is engaged in non-farm activities. Land tenure systems also differ widely across the regions. In Punjab and Haryana, it is the relatively large farmers, with average landholding of 5-6 acres, who are engaged in leasing-in of land for cereal production, thereby utilizing economies of scale. On the contrary, marginal and small farmers and the landless are leasing-in land for cultivation in NW Bangladesh. In Central Nepal very few farmers were found to lease-in land for cultivation. This difference in land ownership is of critical importance as the existing land tenure system in the eastern plains could indicate greater livelihood vulnerability, making the farmers more exposed to risks and averse to the adoption of new agricultural practices including the CA-based RCTs.

As part of the characterization of production systems, details of livestock production were collected in both FGDs and village census. According to the village census, nearly all the farming households in India's NW states maintain dairy animals, while this figure is just around 50% in Central Nepal and NW Bangladesh. The considerable importance of dairy animals is also reflected in the herd sizes relative to available farm land. Fodder crops are only grown in NW India and even there the proportion is limited. Crop residues are the major source of fodder for all livestock in the investigated villages.

The study aimed to detect the major production and marketing constraints for cereal production in the IGP, from the farmers' perspective, along with the potential entry point of CA-based RCTs, following qualitative tools. The major constraints identified are:

- *Irrigation water scarcity and limited supply of electricity*: Generally in the IGP, a high dependence on groundwater has led to a decline in water tables during the last decade. This decline is of critical importance in Punjab and Haryana where the well-depth has increased by 60-80% over a period of 10 years. Electricity is free or heavily subsidized for agricultural use in these states, and although the duration of its supply is limited to about six hours or less a day, it directly contributes to the overuse of ground water for irrigation and causes soil salinity in some regions. The RCTs (e.g. laser land leveller) that can aid irrigation water conservation are expected to reduce production risk in the relatively water-scarce regions.
- *Labor shortage*: Demand for labor is highly seasonal in cereal production systems. This is reflected in the sudden increase in wage rate during peak-demand seasons. For example, the peak wage rate is found to be greater by 25% (Bangladesh) to 75% (Punjab) in comparison to the normal wage rate. The CA technologies (e.g., zero tillage in wheat, direct seeded rice) and implements (e.g., turbo/happy seeder) can help reduce farmer dependence on human labor for cereal production. The use of herbicides and combine harvesters can also have a significant labor saving effect.
- *Lack of access to quality fertilizer on time*: The fertilizer prices are lowest and show least variation in Indian states due to strong government intervention in its pricing and distribution, whereas in Nepal and Bangladesh the price is relatively much higher and varies significantly over time. Fertilizer adulteration is also common in Nepal and Bangladesh. Many of the CA components are aimed at positively affecting the soil fertility and can help reduce the severity of this constraint. Precision land levelling can also enable more efficient utilization of available fertilizers by the crops.
- *Lack of access to information*: Farmers quoted lack of access to useful farming information as an important constraint across all the study districts, especially in Nepal and Bangladesh. Access to information is not found to be related to the distance to the knowledge center, as they are not located far from the village.
- *Pest and weed infestation*: Weed management is an important issue in CA-based RCTs. Thus, helping farmers take care of weeds through, for example, dissemination of information on herbicides with different modes of action, has to be an important component in the delivery of the technologies.

Various machinery interventions with respect to land preparation, seeding, and harvesting have taken place in the study area during the past three decades. During the surveys, the farmers are found to have the options of using either the conventional or the CA technologies for cereal production. A newly expanding RCT is the laser land leveller. This technology employs a laser controlled system, ensuring precision land levelling, thereby increasing water, nutrient, and agro-chemical use efficiency and the managerial time required during crop establishment. In general, this increases crop yields and saves irrigation water. Laser levellers are currently present in 72% of the sampled villages of Punjab and Haryana with on average 16% of farmers having adopted the technology so far. In contrast, the number of laser land levelling units is limited in Central Nepal and NW Bangladesh and most of the farmers are not well aware of the technology.

The conventional tillage machines, line cultivator and disc harrow, have a relatively long history of diffusion compared to the other land preparation methods and are prevalent in most of the studied villages except in NW Bangladesh. At present, about 100% of the cereal growing households use these instruments in both or one of the two crop seasons in NW IGP. The initial diffusion was slower in Central Nepal, but it has now reached about 100% of the villages surveyed. But in NW Bangladesh cultivators and disk harrows are completely absent from the farming system. Because of the small landholding and plot sizes in this region, two-wheel tractors are far more common than four-wheel tractors to which cultivators and disc harrows are attached. The rotavator, a multi-utility machine that decreases labor requirements and completes multiple operations in single pass, is a relatively new technology in this area. However, the adoption of rotavators has led to increased residue burning and sub-soil compaction or hard-pan formation leading to yield reduction after years of continuous use. The two-wheel tractor is confined only to Bangladesh and Central Nepal. The adoption of seed/fertilizer drills, which promote line-sowing instead of conventional broadcasting of seeds, thereby reducing seed and fertilizer use and increasing crop productivity, is currently present in almost all the sampled villages of NW India. Seed drills have also been introduced in Central Nepal and NW Bangladesh in the recent past. Adoption of mechanized harvesting of grains and straw using a combine harvester and Bhusa reaper is widely popular in most of the sample villages of NW India, and they have also recently been introduced to four villages in Nepal. About 50-60% of farmers in NW Indian villages adopt these technologies compared to the marginal adoption (3%) in Central Nepal. Mechanized harvesting is yet to be introduced in NW Bangladeshi villages.

Although the aforementioned technologies have direct positive or negative impact on the diffusion of CA-based resource conserving technologies practices, the supply of these machines and related information are determined by a number of institutional factors, including the presence of service providers from private, public and cooperative sectors. The co-operatives and clubs facilitate farmers in getting relevant information, inputs and machinery services easily and at a relatively lower cost. However, the household involvement in group activities related to agriculture is less than 25% in all the study regions, except NW Bangladesh. It is also found that the farmers with larger landholdings participate more frequently in the cooperative activities, the single exception being NW Bangladesh. The landholding size difference between members and non-members are large in NW India, which is noteworthy in designing the diffusion strategies for RCTs through cooperatives and other farmer groups. The issue of small farmers getting excluded from the benefits of RCT diffusion should be considered and rectified while developing different public-private partnership programs for wider dissemination of these technologies.

The study clearly indicates that the Indian, Nepalese and Bangladeshi villages show very distinct patterns with respect to resource (land, water) and input (labor, fertilizer) availability, cropping patterns, and institutional set-ups (leasing-in, cooperatives, NGOs etc.). Cereal production in NW India faces a rather different set of challenges (declining water-table, high wage rate etc.) compared to those in Central Nepal and NW Bangladesh (capital scarcity, access to technologies), which indicate that the nature of CA technologies and their dissemination strategies should not be uniform across the Plains. Further, due to the huge difference in market prices for inputs across countries, the conversion of the input-saving effect into monetary terms would vary widely across the IGP. The labor-saving technologies would yield higher returns in India, while land-saving technologies (especially fertilizer related) would generate more farm income in Nepal and Bangladesh. Lastly, as the dissemination strategies are directly linked with the institutional framework, which differs greatly across the regions, any uniform business model for the CA technology dissemination would fall short of its target. The CA promotion programs may require identifying the issue of social, financial, institutional or agronomic diversity within the IGP, and develop location-specific technologies and dissemination models.

1 Introduction

Stagnation of agricultural productivity, degrading soil and water resources and unsustainable cereal production systems of the Indo-Gangetic plains (IGP) have compelled many agricultural scientists and policy makers to look towards a more sustainable path of conservation agriculture (CA) and resource conserving technologies (RCTs) (Gupta and Sayre 2007; Erenstein and Laxmi 2008). While the CA technology ensemble is based on the principles of minimal soil disturbances, residue retention, rational crop rotations, and controlled traffic (Harrington and Erenstein 2007; FAO 2007; Gupta and Sayre 2007; Erenstein 2009), the RCTs cover all those farming practices or technologies, which facilitate conservation and enhancement of resource use efficiency in farming (Gupta and Sayre 2007; Erenstein 2009). These sustainable agriculture practices, which herald a paradigm shift in tillage and land preparation options, aid farmers in cost saving and yield enhancement by shifting from conventional tillage to minimal or zero tillage; moving from puddled transplanted to zero tillage direct seeding in rice, and engaging in other resource saving practices (Hobbs 2007).

The area under RCTs is steadily expanding in South Asian cereal production systems under different project initiatives like Rice-Wheat Consortium (RWC). These technologies covered more than 8 million acres in the IGP by year 2005/06 (Gupta and Sayre 2007). Most of the adoption (about 74%) is concentrated in India although different RCTs are spreading in Nepal Terai and Bangladesh. There exists a vast potential for further increase in cereal system profitability through promotion of CA-based RCTs in the IGP of South Asia, especially given the challenges posed by climate change and alarmingly declining irrigation water availability in this region. In addition, there is a number of general and location-specific cereal production constraints, many of which can be effectively addressed through wider dissemination of the RCTs. Given this background, the present study aims to characterize the cereal systems of NW India, Central Nepal Terai and NW Bangladesh, provide insights into the associated production constraints and identify potential technology entry points from a socio-economic perspective. Built upon data from village surveys and censuses, it provides *a priori* knowledge base on different aspects of cropping systems existing in the IGP, where the Cereal Systems Initiative for South Asia (CSISA) project is being implemented.

The CSISA project, built mainly on the efforts of RWC, aims to provide an overall strategy for accelerating short- and long-term cereal production growth in South Asia, through dissemination of CA-based RCTs. The project employs a "hub approach" and innovative public-private partnerships for development and dissemination of these technologies. In the initial phase of CSISA, nine hubs were established: five in India, one each in Nepal and Pakistan, and two in Bangladesh. The larger focus of the project is on the small landholder farmers with improved food security and farm returns being critical outcomes. Understanding micro-level constraints to rapid productivity growth and adoption of RCTs in intensive cereals systems is one of the socio-economic activities. Three technologies are given special emphasis in this regard: zero tillage (ZT) wheat, direct seeded rice (DSR) and precision levelling using laser land leveller (LLL), due to their prevalence and/or potential to enhance farm productivity and income.

- ZT wheat is the most widely adopted CA-based RCT in the rice-wheat systems of IGP (Laxmi et al. 2007; Erenstein and Laxmi 2008). Farmers in South Asia have started adopting ZT wheat cultivation since the last two decades and the estimated area under this technology was to the tune of 5 million acres in 2004-05 (www.rwc.cgiar.org). Adoption of ZT was found to be significant in the rice-wheat systems of NW IGP, where, after the initial spread, the area under ZT wheat stabilized between 20-25% (Erenstein 2009). At present, many of the ZT wheat farmers come under the category of partial adopters (Erenstein et al. 2007; Farooq et al. 2007). Farm size (operational holding) and land ownership were found to have strong positive association with its adoption in this belt (Erenstein and Farooq 2009). The major advantages of ZT wheat are found to be earlier planting, control of obnoxious weeds, cost reduction, and water savings. The yield-enhancing and cost-saving effects of ZT wheat have contributed significantly towards the farm income in selected villages of India to the tune of US$ 39/acre (Erenstein and Laxmi 2008).
- The DSR is a water-labor-saving technology that is an alternative to transplanting seedlings to puddled fields, which is found congenial for different production systems of South Asia (Gopal et al. 2010). The technology, by removing the requirement of puddling of the field and transplanting of the rice seedlings, provides an option to resolve the labor scarcity—a constraint of increasing magnitude in cereal production systems.
- Precision land levelling is another intervention which complements the adoption of other RCTs in the uneven soil surfaces of IGP under flood irrigation. This technology aims to save irrigation water, which is highly relevant in the rice-wheat system of the IGP. Laser assisted precision land levelling could potentially save an average of 180 mm of irrigation water (out of 1,382-1,838 mm water demanded annually) in these systems (Gupta and Sayre 2007; Jat et al. 2006), in addition to its effect on improving crop yields, water productivity and fertilizer use efficiency.

For characterizing the cereal production systems of the IGP, diagnostic village surveys were carried out by CIMMYT and the International Rice Research Institute (IRRI), with the technical inputs from the International Livestock Research Institute (ILRI) and the International Food Policy Research Institute (IFPRI). This paper contains the major findings of these village surveys and village censuses conducted by CIMMYT in 72 villages of Indian Punjab, Haryana, Central Nepal and NW Bangladesh regions. Characteristics of cereal production system in each of these regions are presented in Section 2.

2 Study area

The IGP have traditionally been the major cereal basket of South Asia, feeding millions of people more than their vast resident population. The IGP comprises of parts of Bangladesh, India, Nepal, and Pakistan and are one of the most productive agricultural areas of the world. Rice-wheat is the predominant cropping system across this region, with cotton-wheat, rice-maize and sugarcane-wheat having regional prominence. With respect to the associated yield potential, two broad categories of rice-wheat systems in the IGP are defined (Ladha et al. *undated*): Favorable rice-wheat environment, constituting districts with predominantly irrigated rice and wheat, which include the western part of the Plains (that is, Pakistan, the NW Indian states of Punjab and Haryana, and western Uttar Pradesh), and less favourable rice-wheat environment, constituting districts with predominantly rainfed rice and either irrigated or rainfed wheat, which include the eastern part of the Plains (Bangladesh, West Bengal, the northern parts of Bihar and eastern Uttar Pradesh, and the Terai region of Central Nepal).

Wheat is the dominant crop in the first category and rice dominates the second. Data on cereal production from two regions from each of the aforementioned categories is collected through FGDs and village census and analysed for the present research report, making it representative of the existing cereal production scenario of South Asia.

Table 1. CSISA project locations and division of baseline survey responsibility.

	CSISA Hub	Major cropping patterns	Socio-economics surveys are primarily conducted by
1	NW Punjab, India	rice-wheat; cotton-wheat; maize-wheat	CIMMYT
2	Haryana, India	rice-wheat; wheat-sugar cane (intercropped)	CIMMYT
3	Central Nepal	rice-wheat; rice-wheat-maize; rice/maize-potato	CIMMYT
4	NW Bangladesh	rice-rice; rice-wheat; rice/fallow-maize; potato/maize-rice	CIMMYT
5	Eastern UP, India	rice-wheat; maize-wheat; wheat-sugarcane (intercropped with vegetables)	IRRI
6	Central Bihar, India	rice-wheat/maize; maize-wheat; rice-maize (intercropped with potato)	IRRI
7	Tamil Nadu, India	rice-rice-pulse; rice-cotton-maize	IRRI
8	CE Bangladesh	rice-rice; rice-maize; rice-rice-maize+potato	IRRI
9	NE Pakistan	rice-wheat; cotton-wheat; rice-potato/maize	--

Note: The first four sites are covered here, while 5-8 would be included in a separate paper/report by IRRI. Due to the political unrest, the hub characterization and data collection are delayed in NE Pakistan.

The IGP also encompasses significant geographical disparity with respect to the incidence of income poverty, resource endowments and agricultural technology diffusion. A gradient analysis that considered land and labor scarcity showed that the downstream plains (West Bengal state of

India, Bangladesh etc.) have double the population density of the upstream plains, which would, in relative terms, make land relatively scarce and labor an abundant factor of production (Erenstein et al. 2007). The farm size, as one would expect, is negatively correlated with population density, making Punjab and Haryana farmers to possess large tracts of land and limiting the landholding size of Bihar, West Bengal and Bangladesh farmers to less than 2 acres/household. The area irrigated is highest in the western IGP compared to the eastern parts. The high population density in the eastern region is expected to provide a relatively adequate labor force for agriculture in the eastern parts.

It has been pointed out that labor-saving agricultural technologies would be more popular in the western IGP, while land-saving technologies would be favored in the eastern states (Erenstein and Thorpe 2010). For example, the tractor (which is a typical labor-saving technology) is more popular in Indian Punjab (around 10 tractors/km^2 of cultivated land) than West Bengal (<1 tractor/km^2). However, such a pattern is not observed with respect to land-saving technologies (e.g., chemical fertilizers). Agricultural innovations well-suited to the relatively capital-abundant, labor-scarce NW Plain states might not be socially congenial for the capital-scarce, densely populated eastern regions. However, high cropping intensities and complex cropping patterns aimed at maximizing output per land while increasing labor demand ought to be more popular in the Eastern regions.

As mentioned earlier, the CSISA project activities are focused on nine hubs in Pakistan, India, Nepal and Bangladesh. These hubs provide the basis for "active learning about mechanisms for rapid adoption and intensification of improved cereal seed and crop management practices" (Gupta 2009). The list of hubs/locations and major cropping patterns are shown in Table 1. Brief characteristics of the four hubs and their technology dissemination strategies are discussed below.[2]

NW Punjab, India

Semi-arid agro-climatic conditions prevail in this region and the main soil type is silt-clay. Irrigation, traditionally by canal but increasingly by tube-well, is well developed and power supply is heavily subsidized. The major crop rotations of the study area are rice-wheat (62%) and cotton-wheat (14%). The area under maize is negligible. The cropping intensity is 190%. Several technology demonstrations, farmer participatory trials and traveling seminars are conducted in this region by the CSISA project and the public-private sector partners. For example, the State Department of Agriculture, Punjab, conducted demonstrations of the turbo/happy seeder (a direct seeding machine capable of handling large amounts of residue mulch) in Jalandhar and Kapurthala districts in the 2009 winter/rabi season. In addition, the private sector partners (Hariyali, Syngenta, Pepsico etc.) were included in field trials and demonstrations of RCTs (e.g., DSR in monsoon/kharif season of 2009). A number of service providers and input supplier are involved in familiarization of the turbo/happy seeder, which is also facilitated by farmer associations (e.g. Kissan club) and the Punjab State Machinery Manufacturer Association.

[2] Information presented on the hub characteristics is gathered through discussions with hub-managers and field visits between October 2009 and May 2010.

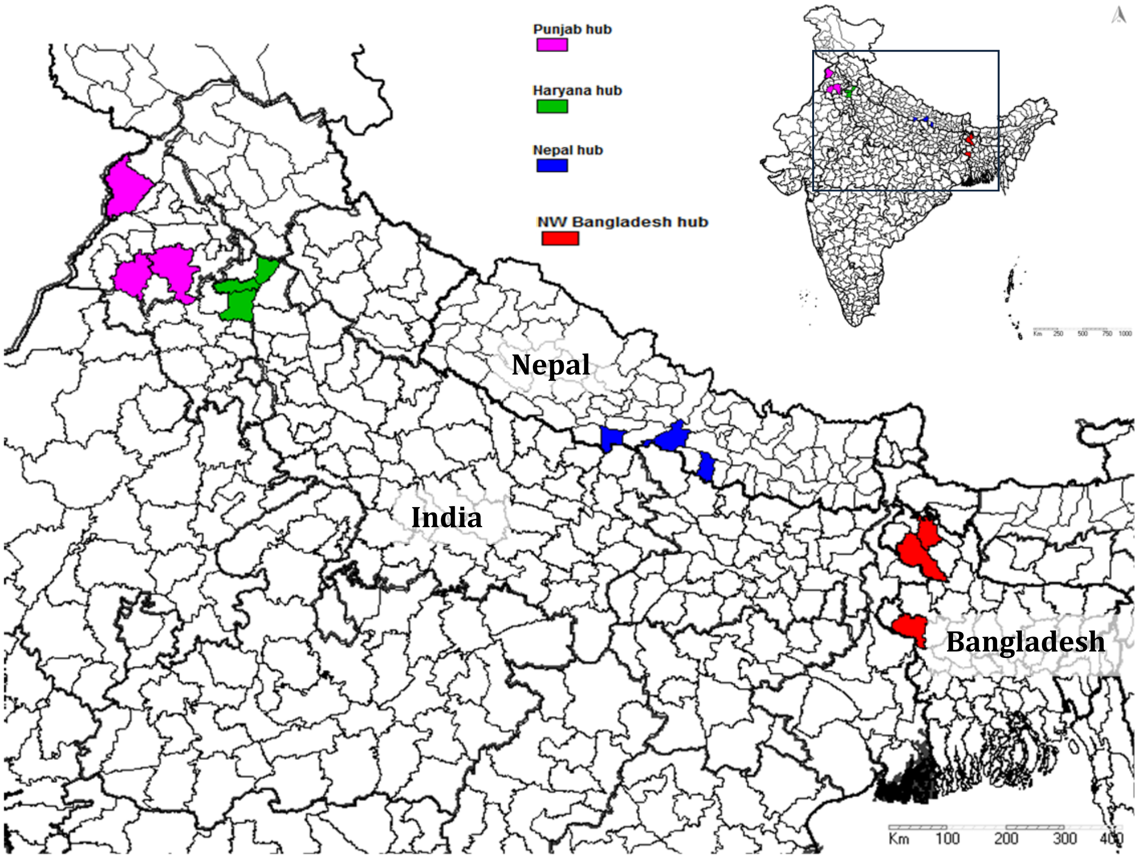

Figure 1: Map of IGP showing the sample districts
Source: Neelam Chowdhuri, AWhere/CSISA

Haryana, India

As in Punjab, a semi-arid agro-climatic condition prevails here too, and the soil type is silt-clay. Farmers also have good access to irrigation water although government support is not quite as strong as in Punjab. Rice-wheat is the major crop rotation, though wheat-sugarcane is also prominent in some parts (e.g., Yamuna Nagar). High-value Basmati rice production is a defining characteristic of some districts (e.g. Karnal). The area under maize is negligible. The cropping intensity is about 200%. There is considerable similarity between Punjab and Haryana hubs with respect to constraints for adoption as well as technology development. Public-private sector partnership is one of the key strategies for technology dissemination in the Haryana hub. Strong linkages have been established with public sector extension institutions (Krishi Vigyan Kendras or KVKs in Kurukshetra, Yamuna Nagar, Panipat, Kaithal and Sonepat) and regional research stations of the Haryana Agricultural University, Hisar. Among the private sector partners, the hub has developed strong links with Hariyali Kisaan Bazar, Bayer Crop Science, Syngenta, and Chambal Fertilizers and Chemical Ltd for rolling out CA-based RCTs in rice, maize and wheat systems. In addition, co-operative and private sugar mills, an NGO Krishi Vigyan Kendra (Tepala), a number of service providers, input dealers, machine manufacturers, and farmers' associations are involved in technology dissemination activities.

Central Nepal

The hub activities in Nepal are focused on six districts in the central Terai region that represents 7.3% of the total geographical area of Nepal and is home to 12 % of the population. The region has 17 % of the rice area and contributes 21 % to the national rice production. A semi-hot moist agro-climate prevails and the soil is mostly loam-clay. Irrigation facilities exist but do not cover all the agricultural area and do not supply water throughout the year. The cropping intensity is 189%. The major crop rotations are rice-wheat, rice-wheat-maize and rice/maize-potato. The research institutions, particularly with the commodity research centers under the National Agriculture Research Centre and District Agricultural Development Offices and Cooperative are collaborating closely in technology development. However, for technology dissemination the national NGOs are found to be equally suitable collaborators. For example, FORWARD is involved in rolling out of the CA technologies. To accelerate the production of quality seeds, private seed growers, seed companies and farmer groups are encouraged by providing them with foundation and certified seeds of wheat, lentil and normal and quality protein maize (QPM). A number of seed production units (e.g. Jaya Krishak, Unnat, High Himal, Pragati, GATE-Nepal etc.) and individual farmers are supported in technical matters.

NW Bangladesh

A semi-hot agro-climate prevails in this region. Only rudimentary irrigation facilities exist, but surface water irrigation and shallow tube-wells using diesel pumps are fast gaining popularity. The major cropping patterns in this region are rice-rice, rice-wheat, rice/fallow-maize and potato/maize-rice. The CSISA project works through different partners in each district for disseminating the technologies to farmers. These partners include the Department of Agricultural Extension (public sector), NGOs (Inter Cooperation, Research Initiatives Bangladesh, and Dipshikha) as well as the corporate sector (Bayer Crop Science, Syngenta and ACI Motors).

Most of these partners operate through farmer clubs or groups. Such groups are formed village-wise for technology delivery and to address the farming constraints in each village. For example, Integrated Crop Management (ICM) clubs were the target groups in Dinajpur district. In Nilphamari and Rajshahi districts, RIB and the Department of Agricultural Extension, which works through individual farmers, are also partners for technology dissemination. Since farmers in this area are small and marginal with respect to farm size, they rarely own the RCT machines themselves. This makes service providers key stakeholders in CSISA in the NW Bangladesh hub domain in regard to the adoption of new machinery. New partners are also being included into the CSISA domain (e.g., Farmer Federation—an NGO—and seed producers like Supreme Seeds, ABC Seeds etc.).

3 Data source and sampling procedure

The village survey instrument was designed to collect general information about the villages or wards regarding cropping patterns, infrastructure facilities, population characteristics etc., which are difficult to gather in a personal interview mode. From the complete list of districts, where the CSISA project was active during 2009/10, we have selected three districts per hub, after discussing with the hub-managers and national partners. The aim of this purposive district selection was, firstly, to capture the major cropping patterns prevailing in the respective hubs and, secondly, to consider the pattern of RCT diffusion. A map of IGP delineating the sample districts is shown as Figure 1.

The next step was to obtain from the respective hub managers a complete list of project intervention villages, alongside their respective sub-districts—blocks in India, village development committees (VDCs) in Nepal or union councils (UCs) in Bangladesh—in each of the selected districts. From this list, three intervention sub-districts were randomly selected for each previously selected district. Subsequently, one intervention village (ward in Nepal) and one control village were randomly selected.[3] The selection of the control villages was drawn from a complete list of villages obtained from public institutions. In India, the data were provided by the National Census Bureau while in Nepal and Bangladesh, the sub-district head offices provided the village lists. A total of 72 villages were covered in the survey, with the project activities started or on-going in 36 of them during the time of survey. The sampling process is presented as Figure 2.

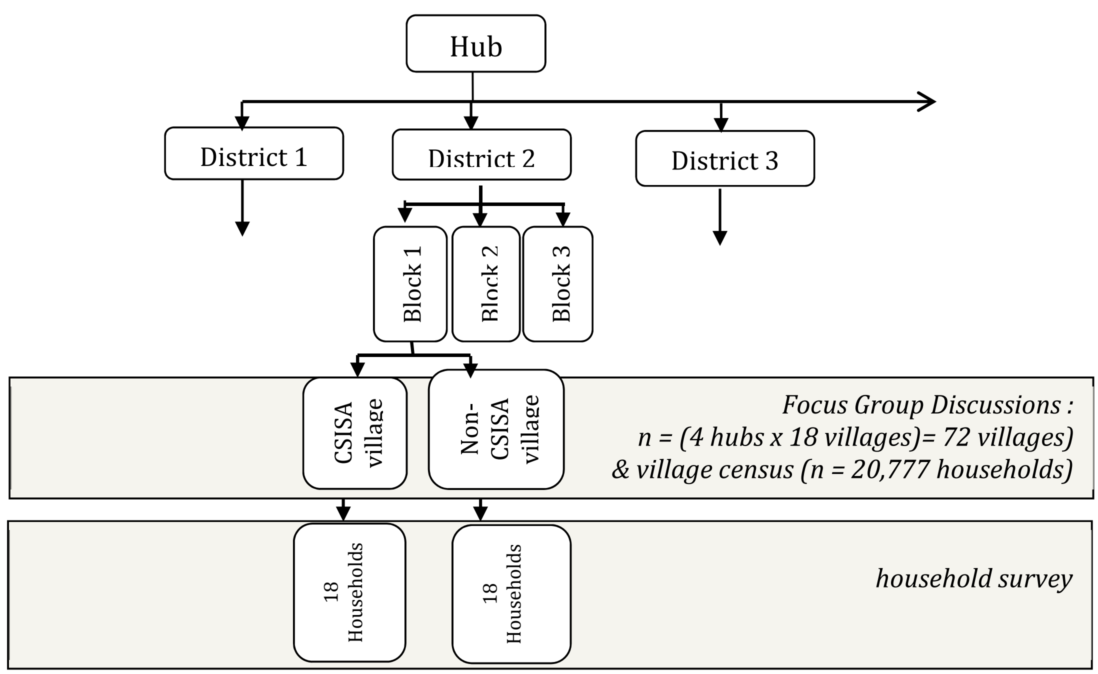

Figure 2: Sample selection within a hub domain for baseline surveys.

3 If, in one of the selected districts, CSISA activities are concentrated only in 2 blocks (i.e. Yamuna Nagar in Haryana), 2 CSISA and 2 non CSISA villages were selected from the second block (instead of 1 each) to make the number of villages selected 3 CSISA and 3 non-CSISA like the other districts.

A structured questionnaire was developed for the data collection in a joint effort of socio-economists from different CG-centres associated in CSISA (CIMMYT, IRRI, ILRI and IFPRI), agronomists and hub managers. The questionnaire was pre-tested in Haryana and Bangladesh and modified before the actual survey was initiated. It consists of four sections:

- village identification and resources
- crops, irrigation, livestock and machinery
- input-output prices and,
- levels and trends in production and market integration.

In other words, information on variables possibly influenced by the project intervention (e.g., details on current RCT adoption, cropping patterns, social indicators) and exogenous variables (e.g., land characteristics, prices of inputs and outputs, market access etc.) were included in this instrument. This information is expected to be supplemented by the data generated through the household surveys.

Focus Group Discussions (FGDs) were employed to get information in the village surveys, which were conducted during April-May 2010, and the interview team comprised of agricultural economists, soil scientists, agronomists and, at times, the hub managers. The interviews were conducted in places like village community halls, schools, other public places or particular farmers' houses. On average, the group interviewed comprised of six to seven farmers. The group composition is provided in Table 2. Large and small farmers were more or less equally represented while the landless were sparse in these groups. One of the reasons behind non-inclusion of the landless in the FGDs was the priority given to information on farm management and technology adoption, which is expected to be answered correctly only by the farmers. Women participation was marginal in these group discussions, with the exception of Central Nepal (25% of the group consisted of women farmers). Women involvement is generally restricted to livestock production and post-harvest operations in Punjab and Haryana. In addition, the prevailing social norms further in this district prevented the inclusion of female farmers in the male-dominated group discussions.

Table 2. Average size of groups in the FGDs.

	Large farmers	Small farmers	Landless	Female farmers	Overall
NW Punjab	3	3	0	0	6
Haryana	3	3	1	0	7
Central Nepal	4	4	0	2	8
NW Bangladesh	3	5	0	0	8

Figures represent the average values (n = 18 villages/location).

Although group interviews are often used as a quick and convenient way to collect relevant data from several people simultaneously, employing the synergies of group interaction, there are a number of limitations to the village survey data generated through FGDs. We have observed that at times "articulation of group norms may silence individual voices of dissent", as also reported by Kitzinger (1995). We have also observed that the presence of government extension agents and CSISA hub staff often acts as an inhibition to obtaining the sincere impressions about the technology, fearing generation of negative opinions about the group or village and thereby hampering the future flow of benefits from these sources. This was to a great extent avoided by using young research personnel whom the farmers do not identify with any projects or the public extension system. Another limitation of the FGD data was that the accuracy of the estimates of some variables, for which measurement is relatively difficult (e.g., total size of landholding in the village), could be questioned. To a certain extent we have tried to overcome this limitation by using the estimates from the village censuses. Comprehensive censuses in the selected villages were conducted to enlist all the farming and non-farming households in each of these villages, which included names of household head, landholding and livestock ownership, cereal cultivation status, and farmer participation in group activities. It was done by an educated villager, in each of the sample villages, during May-July 2010. Apart from providing useful insights on the land use pattern and livestock ownership, this database was helpful in selecting farmers for the baseline household survey, succeeding the FGDs, in a stratified random sampling framework. The village survey data collected were analyzed and reported in Sections 4 and 5.

4 Study area characterization

The basic village characteristics across the four regions are provided in this section in Table 3 and Figures 3 and 4. As evident in earlier studies and secondary statistics, the villages in NW India are relatively larger than those in the eastern IGP region in terms of both the population size and geographical area. The wards in Central Nepal include fewer households (about 1,200-1,300) compared to the villages in India (2,800-3,400). Moreover, there is a significant inter-regional variation in geographical area of villages. To facilitate the cross-sectional comparison on land-labor availability, the ratio of cultivated land to number of farmer households is computed. In Punjab and Haryana, an average farmer cultivates about 7 acres of land, while in Central Nepal and NW Bangladesh, the per-farmer land is limited to less than 2 acres (Table 3).

The landholding statistics obtained from the village censuses (Figure 4) that excludes cultivation of the leased-in lands from aforementioned figures more or less confine to this pattern. The gender of the household head is also important in technology adoption and, with the exception of Central Nepal, the share of female-headed households is limited (< 10%) in the study area. The below-poverty-line (BPL) households comprise about 25% of the population in Indian Punjab and Haryana villages, less than 18% in Central Nepal, but about 40% in NW Bangladesh. Significant share of households (40-60%) in NW India comes under the scheduled caste and schedule tribe (SC/ST) category.

The inter-regional differences in population, land holding and ultimately the scale of operation are significant factors determining the appropriate type of technology (land-saving vs. labour saving). As the land-farmer ratio being higher in the NW India, the labour-saving technologies (e.g. tractors) are prevalent in this zone (Erenstein et al., 2007), which would also be true for those CA technologies of similar impact (e.g. DSR). However, the social implications of new technologies are more intriguing. A large number of households in Punjab and Haryana (40-60%) are landless, who contribute to the agricultural labour. Nevertheless, the scarcity of labour is still highly prevalent in this region as indicated by the prevailing high wage rate.
On the other hand, in NW Bangladesh, the landholding is smaller, while the share of landless household is still considerable (25-45%). More importantly, most of these landless households (99%) fall under the BPL category. Hence, the land-saving technologies (e.g. HYVs) would be of greater impact here, while the technologies that replace labour may not be as attractive because of low wage rates and even have considerable negative social implications.

Equally important for assessing the role and potential impacts of CA-based RCTs are the differences between project and control villages. If, in comparison to the control village, those with CSISA project activities stand out with respect to the aforementioned basic characteristics, then the comparison during the impact evaluation would be rather difficult. Recognizing the importance of the village attributes in the adoption and impact studies, the statistical significance of differences (intervention versus control) in the village characteristics are tested. In NW Indian states and Central Nepal, differences in almost all the village characteristics listed in Table 3 are statistically insignificant.[4]

Table 3. Village/ward description.

	NW Punjab		Haryana		Central Nepal		NW Bangladesh	
	CSISA	**Control**	**CSISA**	**Control**	**CSISA**	**Control**	**CSISA**	**Control**
Population (no./village)	3400 (2338)	2852 (2539)	3333 (2427)	3176 (2573)	1256 (1086)	1211 (759)	1718 (720)	1330 (1117)
No. of households/village	554 (364)	418 (436)	521 (399)	376 (277)	192 (119)	160 (88)	348 (161)	237 (183)
Land area (acre/village)	2460 (2007)	1664 (2142)	4181 (8462)	1161 (859)	199 (124)	232 (140)	611 (550)	257 (155)
Cultivated land (acre/village)	2369 (1926)	1541 (1851)	3945 (7977)	1038 (817)	168 (110)	201 (118)	500 (453)	200 (125)
Average cultivated land per farmer-household (acres)	7.5 (2.6)	6.9 (3.7)	12.4 (15.0)	7.2 (4.0)	1.0 (0.6)	1.8 (1.7)	2.9 (2.3)	1.3 (0.5)
% average of female headed households	0.3	9	5	5	21	15	7	11
% average of BPL households	18	30	27	26	18	8	40	41
% average of SC/ST/backward caste	43	41	66	46	8	6	NA	NA

Figures in parentheses show the standard deviation of sample mean, taken across 9 villages.
Source: FGDs

The distribution of farmer households with respect to landholding (represented in Figure 3) is comparable across intervention and control villages in every region. In NW India, the largest share of households is formed by the landless, followed by small farmers. In Nepal, the small and large farmer households comprise more than 90% of village population.

Another important parameter that determines the potential of farmers to adopt new technologies is the remoteness of the villages in which they reside. The distance from the village to important institutions, which is provided in Appendix I, reflects only insignificant differences between project and control villages in the most cases. The sample villages are located about 10-16 km away from the respective district headquarters. The input and output markets are nearer to the villages in Central Nepal and NW Bangladesh, compared to the Indian villages. Nevertheless, all-weather roads pass through every sample village in NW India, making the transportation of goods an easier task. In Punjab, the project villages are more remote with respect to the output market and co-operative societies, and in Central Nepal with respect to the agricultural extension office. Other than these, the village categories do not differ in terms of remoteness, for which the pair-wise village selection procedure (both project and control villages are selected from same sub-district) could be the main reason.

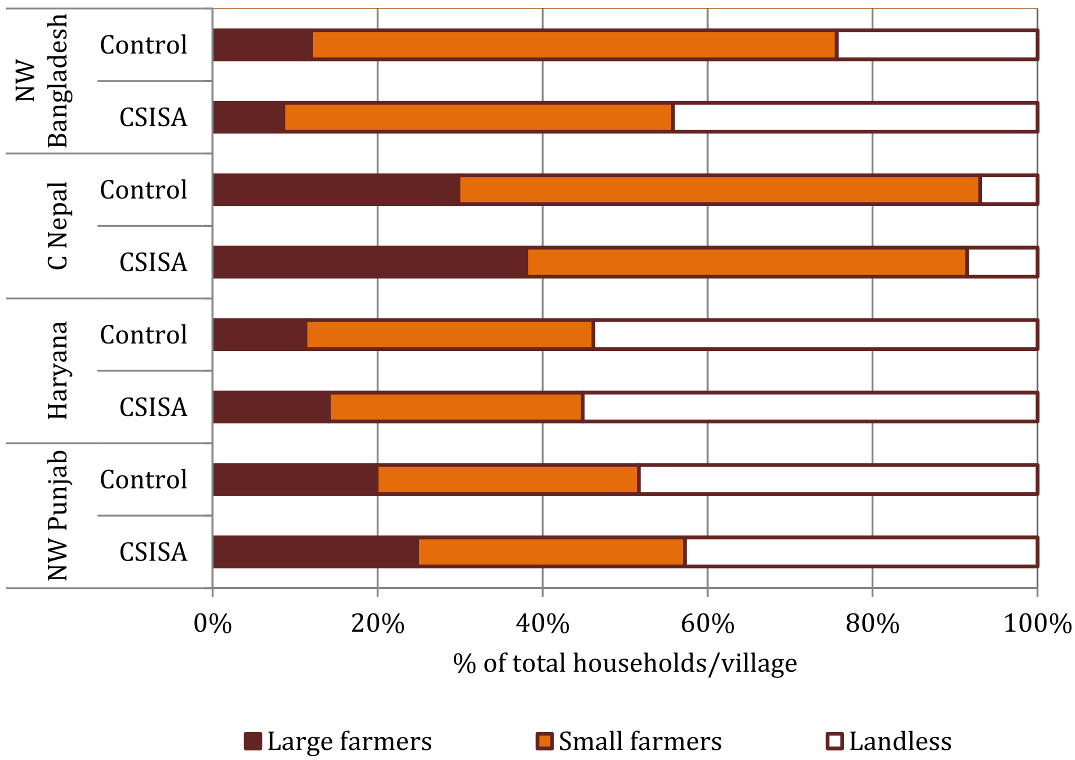

Figure 3: Classification of village households according to landholding.
Source: FGDs

Details of cropping pattern in different study regions are given in Tables 4-7. As indicated in the description of the study area, a rice-wheat system dominates in all the four regions. However, there are other non-cereal crops, including cotton, sugarcane, mustard, vegetables etc., grown in significant areas across regions. The crop diversity is high in Central Nepal and NW Bangladesh, where millets, pulses, fibre crops and oilseeds co-exist with cereals, in contrast to the Indian states. Different crop rotations observed in the study areas are given in Table 6, indicating a higher cropping diversity in the eastern plains compared to Punjab and Haryana, thus confirming the initial assumption.

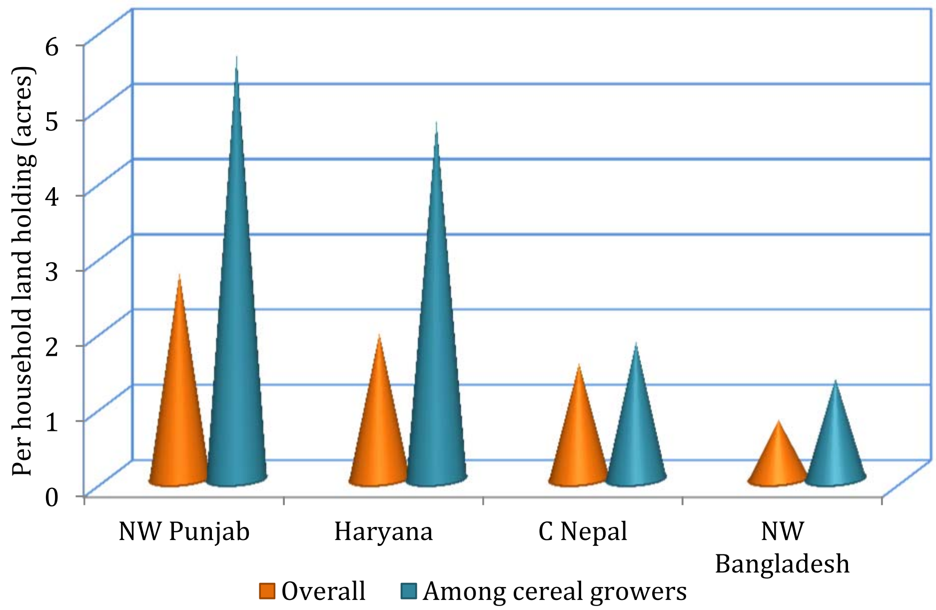

Figure 4: Landholding of households in sample villages.
Source: Village census

Table 7 provides a snapshot of existing pattern of cereal cultivation (area and household share) across the study area. In Punjab, about 54% of cultivated area in sample villages is cultivated by rice and 35% of households are involved in rice farming. Similarly, in Haryana, 87% of cultivated area and 39% of households are engaged in rice farming. In Nepal, 83% of area is under rice, but unlike in Punjab and Haryana, majority (81%) of households are engaged in rice production. The share of the landless is low in Central Nepal, and this is reflected in the high household cultivation of cereal crops. Hence, any technological advancement in rice would benefit a larger share of households in Central Nepal compared to NW India. Three seasons of rice are grown in NW Bangladesh with kharif rice (monsoon crop, being harvested in autumn) being predominant as 54% of households are engaged in its cultivation. With respect to farming households, apart from one Punjab district (Bathinda, having predominant kharif cotton cultivation), almost all the farming households are engaged in rice production.

Wheat is the major crop in NW India in terms of both area and households cultivating the crop. In Punjab 84% of area is under wheat during rabi (winter) and 44% of households are engaged in its cultivation. Similarly, 39% of households cultivate wheat in 93% of total cultivated land in Haryana. The importance of wheat in the cropping system is relatively low in Central Nepal and NW Bangladesh as only 34% and 18% of total cultivated area respectively is under this crop. However, more households are engaged in the production (63% and 25% respectively), reflecting small-scale and subsistence level wheat cultivation in the eastern IGP. Here, too, the increase in farm profit through a wheat-based CA practice would reach more farmers of the eastern Plains. However, the lesser share of cultivated land under wheat in Nepal and Bangladesh may pose a hurdle to the rapid diffusion of technologies among farmers. More than 75% of the farming households are engaged in wheat production in the three regions, other than NW Bangladesh.

Only an insignificant maize growing area has been reported from the sample villages of Punjab and Haryana. However, maize is cultivated in all the three seasons in Central Nepal and in two seasons in NW Bangladesh. More importantly, one of the major cultivation seasons for the crop is summer (also known as spring season), indicating the importance of increasing land use intensity in these areas and the relevance of developing drought tolerant traits in maize, congenial for the agro-climatic characteristics and poorly developed irrigation systems of eastern IGP. The maize-based technologies could reach maximum number of farming households (57%) in the Central Nepal villages.

The cropping pattern, intensity, technology adoption and ultimately the sustainability and livelihood security of the farming systems may critically depend on the existing land tenure system. The land tenure system existing in the study area differs widely across the hubs, as shown by the results of the village census data analysis (Table 8). In Punjab and Haryana, it is the relatively larger farmers, with average landholding of 5-6 acres, who are engaged in leasing-in of land for cereal production, and thereby fully utilizing the economies of scale.

On the contrary, marginal and smaller farmers and the landless are engaged in cultivation of leased-in lands in NW Bangladesh. Prevalence of cultivation in leased-in lands is found to be extremely rare in Central Nepal. This difference is critical as the existing land tenure system in the eastern Plains could indicate greater livelihood vulnerability, making the farmers more risk-prone and averse to the adoption of new agricultural practices including CA-based RCTs. Hence, new institutional mechanisms (e.g., coupling the technology diffusion with a scheme of crop insurance) is necessary for realizing rapid diffusion of these technologies in Bangladesh. The difference shows the trend of moving out of agriculture because of increasing non-farm income opportunities in India's north-west, while in northwest Bangladesh the intensification of agriculture appears to be attractive even for very small farmers.

Table 4. Cropping seasons.

	Kharif	Rabi	Summer
NW Punjab	June – October	November – April	April – June
Haryana	June – October	November – April	April – June
Central Nepal	May/June – Sept/October	Nov/Dec – Feb/March	March/April – May June
NW Bangladesh	July – November	November – April	April – June

Source: FGDs

Table 5. Crops cultivated in different seasons.

	Kharif	Rabi	Summer
NW Punjab	major crops: rice (basmati and non-basmati) other crops: cotton, sugarcane, maize, fodder	major crops: wheat, fodder other crops: mustard, barley, sugarcane, pulses, oilseeds, potato	green gram
Haryana	major crops: rice, sugarcane, vegetables other crops: sorghum, maize	major crops: wheat, berseem other crops: vegetables, sugarcane, gram, fodder oats and mustard	green gram, sunflower, vegetables, fodder and green manure crops
Central Nepal	major crops: rice, vegetables, pulses (red gram & black gram) other crops: millets, maize, sugarcane, sesame, green manures, and soybean	major crops: wheat, vegetables, pulses (esp. kidney bean) other crops: mustard, sugarcane, maize, linseed, buck wheat, pea, barley, oat	vegetables, green gram, cowpea, sesame, finger millet, rice
NW Bangladesh	major crops: Rice other crops: vegetables, sugarcane	major crops: rice, wheat, potato other crops: rice, vegetables, maize, pulses, sugarcane, tobacco, mustard	green gram, rice, maize, vegetables, sugarcane, jute, sesame, chilli

Source: FGDs

Table 6. Major crop rotations.

	Crop rotations
NW Punjab	Rice-wheat-fallow; cotton-wheat-fallow
Haryana	Rice-wheat-fallow; wheat-sugarcane/vegetables
Central Nepal	Rice-wheat-vegetables; rice-wheat-maize; rice-wheat-fallow; rice-vegetable-maize; rice-wheat-rice; rice-maize-fallow; rice-pulse-fallow; maize-mustard-fallow.
NW Bangladesh	Rice-wheat-fallow; rice-rice-fallow; rice-tobacco-fallow; rice-wheat-jute; rice-Wheat-pulse; vegetable-wheat-fallow; rice-pulses-vegetables; rice-wheat-sugarcane

Source: FGDs

Table 7. Proportion of area under cereal crops.

	% of cultivable area under		
	Rice	**Wheat**	**Maize (grain)**
NW Punjab	54 (kharif) [35; 68]	84 (rabi) [44; 95]	Negligible [<2; 3]
Haryana	87(kharif) [39; 100]	93 (rabi) [39; 100]	Negligible [<1; 5]
Central Nepal	83 (kharif) [81; 99]	34 (rabi) [63; 78]	3 (kharif); 4 (rabi); 28 (summer) [46; 57]
NW Bangladesh	78 (kharif); 32 (rabi); 17 (summer) [54; 96]	18 (rabi) [25; 45]	4 (rabi); 8 (summer) [15; 28]

*Calculated as: (sum of particular cereal area in all the 18 villages)/(sum of cultivated area in 18 villages)
Figures in square brackets give the % of households and % of farmers involved in respective crop production in 2009-10 (derived from village census data).
Source: FGDs

Table 8. Cultivation in the leased-in land.

	No. of cereal cultivating households		Land owned in acres (std. dev)			Land cultivated in acres (std. dev)		
	Total	**# leased-in (% to total)**	**Farmers leased-in**	**Others**	**difference**	**Farmers leased-in**	**Others**	**difference**
NW Punjab	3860	349 (9.0%)	5.56 (5.72)	5.64 (6.76)	-1.44%	11.15 (8.18)	5.20 (6.49)	114.3%***
Haryana	1587	134 (8.4%)	6.08 (5.75)	4.63 (6.27)	31.4%*	12.19 (9.61)	4.38 (5.17)	178.0%***
Central Nepal	2274	13 (0. 6%)	0.92 (1.24)	1.83 (2.04)	-49.9%	3.32 (2.15)	1.73 (2.01)	91.8%***
NW Bangladesh	3079	563 (18.3%)	0.42 (0.78)	1.54 (1.99)	-72.4%***	1.39 (1.59)	1.40 (1.78)	-0.5%

†: shows the % difference of variable value of leased-in farmers over others
*; ***: statistically significant at 0.10 and 0.01 levels, respectively.
Source: Village census

Major rice, wheat and maize varieties under cultivation are given in Tables 9-11. In the case of rice, improved open pollinated varieties are popular in Punjab and Haryana, with limited adoption of hybrid seeds. In Nepal, there is a great diversity and co-existence of rice landraces, improved varieties and hybrids. The popular wheat breeds are open pollinated and hybrid adoption is zero in the tract. In the case of maize, hybrids and improved lines co-exist in Central Nepal, while only hybrid maize is being cultivated in NW Bangladesh.

In summary, the study area characterization shows that the CA-based RCTs would have differential impact in each of the regions due to the existing differences in resource scarcity and prominence of cereal crops. A technological advancement of given potential, either land-saving (yield enhancing) and input-saving (cost cutting), will benefit relatively more households in the eastern Plains. However, the prevailing low land-farmer ratio existing in Nepal and Bangladesh would act as a major detrimental factor for spread of new technologies that are capital intensive. The existing land tenure system would generate further hurdles in RCT dissemination in the latter hub domain. In addition, the social implications of labor-saving technologies in these regions should be studied in-depth.

Table 9: Popular rice varieties: the list.

	Varieties
NW Punjab	Pusa 44, Pusa 1121, Basmati 386, PAU 201, PR 127, PR 114, PR 118, PR 47, PR 111
Haryana	Pusa 44, CSR 30, Pusa 1121, PB 1, PEPSICO, PR 114, Arize-6444, CSR 30, NK 6235, PHB 71, HKR 47, PR 113, Arize-6129, RH 257, PB 1
Central Nepal	Sona Masuri, Sabitri, Katarni (local), Basmati (local), Makawanpur, BG-1442 (Hardinath 1), NP 360, Loknath (hybrid), Sundar (hybrid), Radha-4, Ramdhan (also known as OR), Mayur (hybrid), Sindupuri, Saktiman, Manisha (hybrid), Gorakhnath (hybrid), Anandi (local), Mithila, Malaysia (local), Loktantra, Sindur (hybrid), Pankaj (hybrid), Chavasi (hybrid), Golden (Indian variety), Mayur (hybrid)
NW Bangladesh	Swarna (origin in India), BRRI Dhan 28, BRRI 29, Hira 2 (hybrid), BR 11, BR 34, Hori, BRRI Dhan 33, Bina Dhan 7, BR 10, BR 16, BR 6, Eratom, Katari (Local aromatic fine rice), Pari (Local)

Source: FGDs

Table 10. Popular wheat varieties: the list.

	Varieties
W Punjab	PBW 343, PBW 550, PBW 542, PBW 502, PBW 512, PBW 560, PBW 547, R 711,HD 2329, HD 2894, HD 2733, HD 2687, DBW 17
Haryana	DBW 17, PBW 343, HD 2687, WH 711, PBW 550, PBW 502, HD 2894, WH 542, HD 2851, HD 2329
Central Nepal	NL 297, Gautam, Bhrikuti, NL 932, NL 971, HD 2824, BL 3264, Sonalika, UP 262, HD 343, BL 1473, BL 3128
NW Bangladesh	Prodip, Shatabdi, Bijoy, Gourab, Kanchan

Source: FGDs

Table 11: Popular maize varieties: the list.

	Varieties
NW Punjab	NA
Haryana	NA
Central Nepal	Khumal Yellow, Rampur composite, Arun 2, unknown hybrids (Pioneer, Bioseeds, Monsanto)
NW Bangladesh	N 640, 200 M, NK 40, 1837 C, N 04, 900 M, 900 M gold

Source: FGDs

The position of livestock and feeding in the survey area cannot be characterized in detail by the village survey and census alone. However, a broad indication of livestock ownership and feeding resources may outline the links between livestock and cereal production as well as the challenges for further development. According to the village census, nearly all farming households in India's NW keep dairy animals while this figure is only about half in Central Nepal and NW Bangladesh (Table 12). The considerable importance of dairy animals is also reflected in the herd sizes relative to available farm land. According to the survey data, livestock densities range from 0.8 large ruminants/acre in Central Nepal and Punjab to 1.6 large ruminants/acre in Haryana (Table 13). Fodder crops are only really grown in NW India and even there the proportion is limited. Similarly, grazing is practically non-existent in any of the four hubs surveyed. Therefore, crop residues remain as the major source of fodder for all livestock farmers in the investigated villages.

Table 12. Households keeping dairy animals.

	% of households		
	large farm %	**small farm %**	**Landless %**
NW Punjab	86	100	78
Haryana	94	96	86
Central Nepal	52	58	36
NW Bangladesh	60	48	41

Source: Village census

Table 13: Livestock density.

	large ruminants (no.)/ total household	**land [acre]/ total household**	**land [acre]/ farm households**	**large ruminants / land [acre]**	**village grazing area [acre]**
NW Punjab	2.2	2.7	5.6	0.8	40.4
Haryana	3.0	1.9	4.8	1.6	0.6
Central Nepal	1.3	1.5	1.8	0.8	0.0
NW Bangladesh	0.8	0.8	1.3	1.0	0.0

Source: FGDs and village census

Assuming a requirement of roughly 3 metric tons (t) of fodder per dairy animal per year and yields of around 2 t per acre and year for both rice and wheat one can already see that overall residue availability for feeding is limited. The situation is compounded by the fact that considerable preferences exist for the type of straw to feed to livestock. In NW India, rice straw is hardly fed as it is not chopped during threshing (as is wheat after manual harvesting). In Haryana, basmati straw is deemed to be suitable for feeding. Therefore, large amounts of rice straw are burnt or sold to industries while the demand for wheat straw pushes prices ever higher. According to the nutritional value, wheat straw is generally superior to rice straw by about 10%. However, this cannot reasonably justify the huge difference in demand in NW India. On the contrary, farmers in Central Nepal and NW Bangladesh prefer to feed rice straw to their animals. Because straw is not chopped during threshing in these areas, wheat straw is usually fed long.

However, the long wheat straw is much harder and more brittle than long rice straw. Wheat straw is, therefore, often burnt for cooking purposes or used as construction material.

The variation in preferences and demand in the surveyed areas is also indicated by the ratio of straw-to-grain prices found during the survey (Table 14). The demand for wheat straw is so high, especially in NW India, that its price can reach nearly half the price of grain during peak season just before the harvest. This indicates how difficult it will be to convince farmers to retain significant amounts of wheat straw within their fields as mulch. However, the value of rice straw was either non-recordable (Punjab) or very low, which is consistent with the common practice of burning (see below). In regard to both livestock feeding and soil maintenance, this resource appears to be under-utilized and various improvement options could be explored.

Table 14. Straw to grain price ratios (%).

	Wheat		Rice	
	Normal	**Peak**	**Normal**	**Peak**
NW Punjab	35 (18)	44 (18)	-- (0)	-- (0)
Haryana	19 (18)	30 (18)	2 (18)	3 (18)
Central Nepal	-- (0)	-- (0)	-- (0)	-- (0)
NW Bangladesh	6 (8)	7 (8)	8 (11)	10 (11)

* Figures in brackets show number of villages from where data is collected.
Source: FGDs

In the study wards of Central Nepal, straw was hardly traded at all. This could be explained with the fact that landless livestock production, either by rural landless households and or by peri-urban dairy producers, which usually generates the greatest market demand for straw, hardly exists. However, in other locations of Central Nepal some farmers sell rice straw to both paper pulp industries and to large livestock producers.[5] (In NW Bangladesh both wheat and rice straw are traded. Yet the price ratio does not exceed 10% even for rice straw, the preferred fodder, as the comparatively abundant supply easily meets the demand of the relatively extensive livestock production. The supply is sufficient despite the high-yielding boro (winter) rice crop being less used for feeding. Farmers report that the high use of chemical inputs, the hard texture and the early monsoon rains during harvest all contribute to its being less favored as feed. However, this residue might offer attractive options for enhancing soil fertility.

Maize stover is the least common crop residue feed in the studied areas even though nutritional analysis ranks it above rice straw. However, when un-chopped (the common form in Central Nepal and NW Bangladesh), it is difficult for livestock to take in large amounts. A more detailed analysis of opportunities and constraints regarding the feeding of maize stover is expected from the household survey.

[5] Source: personal communication, DP Sherchan, Hub manager, Central Nepal

5 Constraints in cereal production & technology entry points

The major production constraints in the cereal systems of the IGP and the potential of CA-based RCTs within that context are analyzed in this section. The constraints were elicited from farmer groups in a scale of 1-4 on increasing level of significance in limiting farm profitability. Changes over time in the intensity of these constraints were also elicited. Table 15 summarizes the major constraints observed in more than 50% of the villages in each study area, with the intensity of most of them increasing over time.

The limitation of the analysis is a potential bias of respondents towards the emerging constraints as critical ones, irrespective of their actual impact on farm profitability, in order to boost claims for more support. However, seen from an expert's perspective, the identified issues are the most significant ones in limiting farm production. The major constraints in cereal production systems of study areas can be categorized as follows:

1. Input scarcity
    - Irrigation water scarcity and lack of access to electricity
    - Human labor scarcity
    - Chemical fertilizer scarcity
    - Feed/fodder scarcity
2. Pest and weed infestation
3. Farm information inaccessibility
4. Soil and weather constraints
    - Unfavorable soil conditions
    - Extreme heat

This section elaborates each of these constraints, and explains how different CA practices and RCTs propagated under the CSISA project could help resolve or ameliorate these issues. However, at times these production constraints could also limit the diffusion of RCTs in the study area.

Table 15. Major production constraints in the study area.

Hubs	Kharif		Rabi	
NW Punjab	Water scarcity/ extreme heat	[11]	Pests and diseases	[12]
	Pests and diseases	[11]	Credit availability at low interest rate	[12]
	Labor unavailability	[11]	Labor unavailability	[10]
	(Lack of) Market access for outputs	[11]	Unfavorable soil factors (e.g. acidity)	[10]
	Weed infestation	[10]	Water scarcity/ extreme heat	[9]
	Unavailability of fodder/feed	[9]	(Lack of) Access to fertilizer	[9]
Haryana	(Lack of) Access to irrigation water/power	[18]	Weed infestation	[16]
	Labor unavailability	[18]	Labor unavailability	[15]
	Pests and diseases	[16]	(Lack of) Access to fertilizer	[14]
	Water scarcity/ extreme heat	[14]		
	(Lack of) Access to fertilizer	[12]		
Central Nepal	Labor unavailability	[18]	Labor unavailability	[14]
	Weed infestation	[15]	Weed infestation	[12]
	Pests and diseases	[15]	Water scarcity/ extreme heat	[12]
	Unfavorable soil factors (e.g. acidity)	[11]	(Lack of) Access to fertilizer	[10]
	(Lack of) Access to fertilizer	[10]	(Lack of) Access to irrigation water/power	[9]
	Water scarcity/ extreme heat	[10]	(Lack of) Access to information on crops	[9]
			Unavailability of fodder/feed	[9]
NW Bangladesh	Unavailability of fodder/feed	[10]	(Lack of) Access to information on crops	[10]
	(Lack of) Access to information on crops	[9]	Unfavorable soil factors (e.g. acidity)	[10]

Figures in parentheses indicate number of villages (out of 18) reporting the particular constraint.
Source: FGDs

Input scarcity

The CA-based RCT development projects (e.g., RWC, CSISA) are commonly implemented in the irrigated cereal production tract of South Asia. Due to the purposive sampling of sub-districts where CSISA is active, it is unsurprising to find about 100% of the cultivated land in sample villages of NW Punjab, Haryana and NW Bangladesh are under irrigation facilities. In Central Nepal, the area share under irrigation is found to be about 74% (at least during the summer season), which is also high compared to other parts of the country. However, the source of irrigation water varies widely, as shown in Table 16. In NW Punjab and Haryana, most of the farmers use electric tube-wells as sources of irrigation. A major reasons behind this could be the electricity supply at subsidized rates. In the absence of electricity supply, many of the farmers derive power through diesel generators or tractors. In Central Nepal, canal, electric and diesel tube wells and river water are more or less of equal importance. Ground water is the major irrigation source in NW Bangladesh, but unlike in the western IGP, the farmers depend on diesel pumps.

Table 16. Sources of irrigation.

	% of cultivated area irrigated with				
	Canal	**Electric tube-well**	**Diesel tube-well**	**River**	**Total**
NW Punjab	20	80	0	0	100
	(26)	(26)	(0)	(0)	
Haryana	6	92	3	0	100
	(11)	(15)	(12)	(0)	
Central Nepal	37	21	31	12	100
	(36)	(31)	(35)	(30)	
NW Bangladesh	3	4	93	0	100
	(14)	(7)	(17)	(0)	

Figures in parenthesis are standard deviations.
Source: FGDs

Table 17. Number of tube-wells in the villages and depth of water table.

	Number of tube-wells per village		Number of tube-wells per '000 acres	Depth of water-table (m)	
	Electric	**Diesel**		**in 2000**	**in 2010**
NW Punjab	163	0	111	9.55	17.25
	(145)	(0)	(64)	(6.1)	(9.2)
Haryana	275	4	173	16.99	27.19
	(317)	(19)	(110)	(8.2)	(9.6)
Central Nepal	30	9	185	22.88	24.67
	(61)	(11)	(213)	(12.7)	(14.3)
NW Bangladesh	2	45	113	8.67	12.33
	(4)	(49)	(74)	(2.0)	(2.7)

Figures in parentheses are standard deviations of sample means (N = 18/location).
Source: FGDs

Significant difference also exists across hub domains with respect to the intensity of ground water extraction, as indicated by the number of tube-wells per village (Table 17). Haryana farmers' dependence on ground water is the greatest (95% of farmers use tube-wells), and so is the number of tube-wells (279 tube-wells/village; 99% are operated with electricity). This high dependence leads to significant decline in the water-table. Water-table depth in 2010 is at 27 m, which is 59% lower than 10 years ago. However, it is in NW Punjab that the decline of the ground water-table has been most drastic over the past 10 years (80% increase in depth). At present, there is an average of 163 electric tube-wells in each village. There are about 39 tube-wells per ward in Central Nepal, but the pump-sets used in Nepal are relatively low-powered (hp) compared to those in NW India. Both Indian and Chinese-made pumps are available in the Central Nepal region: the former being preferred for durability and the latter for price.[6] Chinese-

[6] For example, the Birla Power pump-set (Indian-made) operated with petrol or kerosene costs about USD 336, while its Chinese alternative of same horse-power cost only USD 171. However in farmers'

made pumps are also popular in NW Bangladesh. Ground water depth is less in NW Bangladesh, and hence farmers use low cost, 3.5-8 hp, diesel-pumps. However, as the number of tube-wells per land unit is more or less equal across the locations (111 per 1,000 acres in Punjab against 113 in NW Bangladesh), it is the quantity and frequency of extraction per well that primarily determine the rate of decline in the ground water table.

The supply of power (electricity) is a closely linked constraint to water scarcity. Although the electricity supply is free of cost or is heavily subsidized for agricultural use in NW Punjab and Haryana, the duration of its supply is critically limited to about six hours or less (three to four hours in rabi season in Punjab) a day. The erratic power supply, often available at an inconvenient time of the day, is one of the major constraints that get aggravated by the declining water-table and shortage of human labor in the Indian IGP. It should also be mentioned that these constraints are imposed by the government to reduce overdrawing of ground water by the cereal farmers of the region instead of taking politically sensitive decisions like reduction or withdrawal of power subsidy for the farmers.

Given the economic and ecological relevance of this constraint, it is not surprising that many of the major RCTs propagated are intended to conserve irrigation water. This includes LLL (saves about 30% of irrigation water), DSR (20% water saving is reported), and bed planting (Gupta 2010). To a certain extent, zero or minimum tillage also helps farmers reduce irrigation requirements use and prevents over-application of water that often leads to water logging, fertilizer leaching and yellowing of the crop (Hobbs and Gupta 2003b).

The shortage of human labor for farming is a constraint observed across all the four hubs despite the fact that out of all the households in a village — 40% in Punjab, 31% in Haryana, 75% in Central Nepal and 56% in NW Bangladesh — hire out agricultural labor for farming activities. The major source of human labor in the NW India is landless farmers from the same village, while small farmers form the major source in Central Nepal and NW Bangladesh. However, demand for labor in cereal production is highly seasonal and labor scarcity is critical especially during planting and harvesting. This is reflected in the sudden increase in wage rate during peak-demand seasons: the wage rate of male laborers is increased between 25% (NW Bangladesh) and 75% (NW Punjab) above the normal wage rate. The ratio of peak to off peak wage rate ratio is equally high for female labor, between 19% (Central Nepal) and 92% (NW Punjab). The normal-peak wage structure across the four hubs is given in Figure 5.

Mechanization of agriculture addresses the issue of labor shortage directly. In addition, the CA technologies (e.g. ZT in wheat, direct seeding in rice) and implements (e.g. turbo/happy seeder) reduce the number of operations per field and thereby further reduce labor demands.

This leads to direct costs savings through reducing the amount of labor required and also works against the trend of raising labor rates by reducing the overall demand for labor. Use of herbicides and combined harvesters also has a significant labor saving effect in cereal systems.

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perspective, the durability of Indian pumps is significantly higher (*Sources: Siddi Binayak Machinery Stores at Bhairahawa; Mr. NK Shakya; Dr. D Sherchan*).

However, some of the RCTs, LLL being a typical example, demand skilled labor to carry out associated operations during the actual levelling process, while reducing labor requirements for irrigation activities in the following years. In addition, CA is often associated with capital intensive technologies and hence there exist a number of demand-supply factors in successful implementation of RCTs among resource poor farmers. Marginal farm benefit of labor savings would differ widely across the regions due to the difference in wage structure. For example, one unit labor saved out of DSR adoption would generate a net profit that is two times higher in India than in Bangladesh, even if the agronomic performance of the technology remains comparable across the regions.

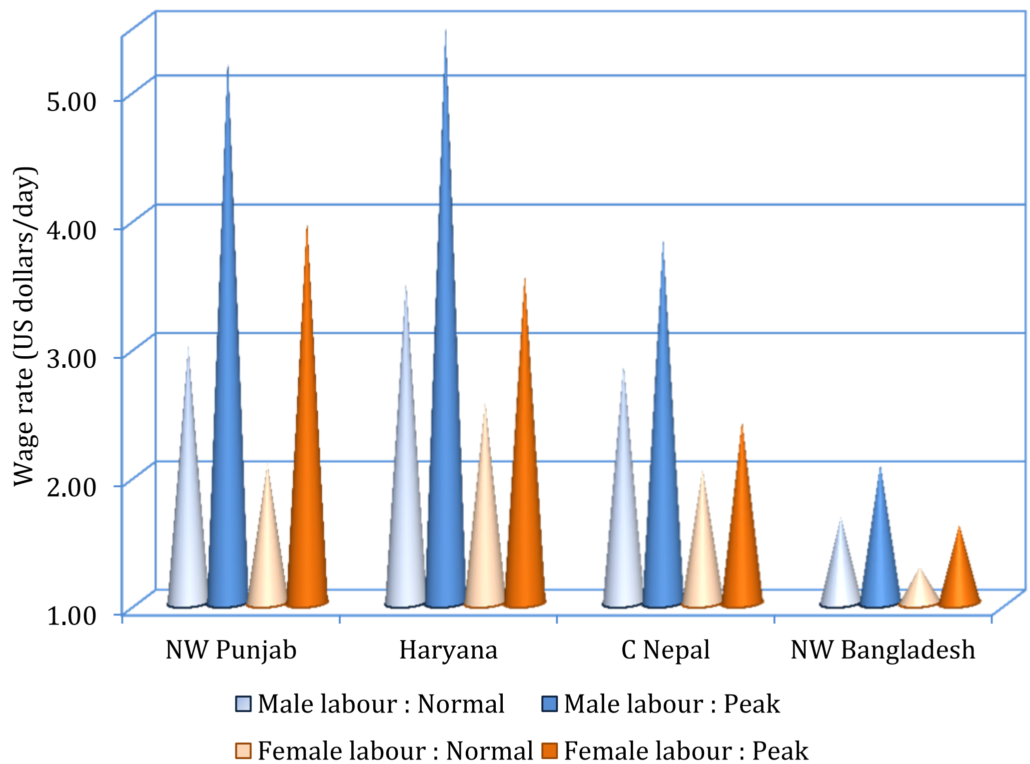

Figure 5: Human labor wage rate across study area.

Note: The conversion rate used 1 USD = 45.7 Indian rupees = 72.9 Nepalese rupees = 71.08 Bangladeshi Taka (Exchange rates of January 2011).
Source: FGDs

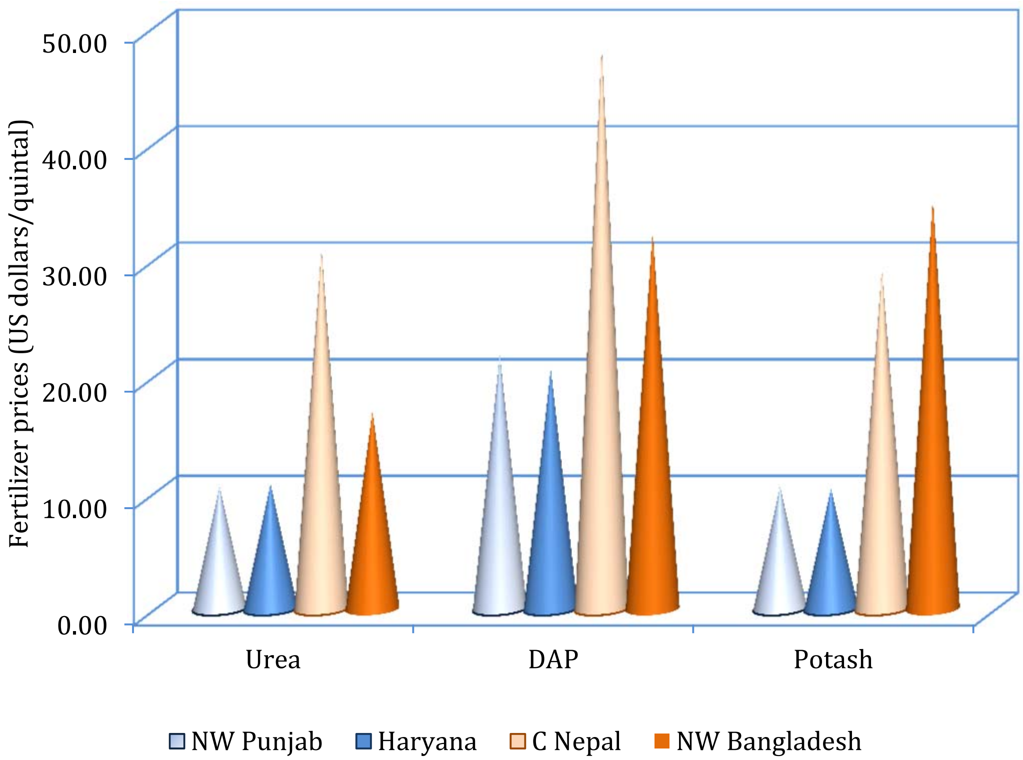

Figure 6: Fertilizer prices across study area.

Note: The conversion rate used 1 USD = 45.7 Indian Rs = 72.9 Nepalese Rs = 71.08 Bangladeshi Taka (Exchange rates on January 2010).

Source: Village census

Lack of access to quality fertilizer on time is identified as another major constraint in cereal production across all the study regions, except NW Bangladesh. In South Asia, many of the fertilizers are imported and relevant government policies determine the supply and price. Farmer constraint in this regard also depends on the extent of fertilizer adulteration that in turn depends on the quality assurance programs of national governments. Figure 6 shows the fertilizer prices across the study area, which may not fully reflect the scarcity as they have been heavily subsidized by the government. Where prices are not allowed to reflect market conditions, supply is often restricted, as can be observed in India. Unsurprisingly, black marketing and adulteration of fertilizers are common, especially in Central Nepal districts. The prices are the lowest and show the least variation in Indian states, whereas in Central Nepal and NW Bangladesh, the price is generally high and the difference exceeds 100% of respective prices prevailing in Indian states. While it has been acknowledged that adequate and timely availability of fertilizers and other inputs is essential for realizing the effects of CA practices, many of the CA components (for example, ZT-using fertilizer drills, summer cropping of legumes etc.) positively affect soil fertility and alleviate the constraint of fertilizer scarcity to some extent. Some water conserving technologies like laser leveller would also facilitate a more efficient utilization of available fertilizers by cereal crops. However, as the fertilizer prices vary significantly across the study area, the monetary impact of fertilizer saving through CA would also vary significantly. One unit of potash, saved through CA practices, would cost farmers of Nepal and Bangladesh three times more than the same unit saved in India.

One of the major challenges for promoting CA-based RCTs in the IGP is the existing crop residue management practices, which clash with the recommendations of retaining residue as mulch. In the north-western IGP, around 74% of surplus rice straw is being burnt *in situ* after combine (machine) harvesting compared to 22% after manual harvesting, whereas in the lower Gangetic plains with extensive manual harvesting only 4% of the rice straw is burnt and 62% is fed to livestock (Teufel et al. 2008). The potential negative consequences of inadequate residue retention in RCT plots have so far been insignificant mainly because of the seasonal nature of ZT usage with the plots being tilled for the forthcoming rice crop (Erenstein 2009). The rice straw/residue retention for ZT wheat is more difficult in the eastern IGP owing to its alternative use of as livestock feed. Altering the cropping patterns by introducing summer fodder crops and developing dual purpose wheat varieties could partly reduce the demand for fodder and help farmers retain the residue on farm in this region. However, rice straw is not used as fodder in the NW IGP unless it is of basmati variety. Effective no-till machineries, like happy seeder, that will facilitate sowing seeds under full residue retention would be a solution in this zone.

Pest and weed infestation

Farmers' inability to effectively manage insect pests, diseases and weed infestations are indicated as major production constraints in global cereal systems, and the study area is no different. The problems are cited as especially relevant in the kharif season, while access to pesticides is not found as a critical constraint. On an average, the input shops selling plant protection chemicals are situated less than 8 km from the village center. The advantage of this proximity could be marred by lack of information at farmer level on choice of pesticides.

Weeds pose a significant threat to cereal cultivation in both kharif and rabi seasons. In Haryana, farmers cited weed menace as the most significant constraint to cereal production. Weed management is an issue of prime importance in successful implementation of RCTs (e.g., ZT, DSR etc.). Under the CSISA project, different herbicide formulations (e.g., clodinafop-propargyl, sulfosulfuron, metasulfuron etc.) are being tested in the conventional and CA systems. Weed management gains special relevance in DSR systems, and different pre-emergent herbicides (e.g., pendimethlin) are being field tested to combat weed menace in this system. Farmer awareness on mode of action and dosage of herbicides could be studied further using the information derived from household surveys.

Farm information inaccessibility

Farmers' inaccessibility to information on agricultural practices and the inability to disseminate the available knowledge are widely cited as two major constraints in the developing countries. Although this situation exists in all the four hub domains, information requirements on farming practices was expressed as a felt-need, especially in Central Nepal and NW Bangladesh districts. Public extension networks are found to be less relevant or accessible in all the hubs, with the exception of Haryana, where 35-40% of farmers utilize services offered by public extension agents (Table 18).

Use of information is not always related to geographical distance to the knowledge centers. For example, there is an agricultural extension office or establishment in 30% of the Punjab villages, and in the rest of the villages the nearest knowledge centre lies within 10 km radius. Further, the majority of villages report a visit by extension agents at least once every quarter. Despite these facts, only 10-15% of the farmers utilize services from extension agents. The situation is similar in NW Bangladesh while in Nepal villages are only rarely visited by extension agents anyway. In Central Nepal, farmers are supposed to visit one of the four Agricultural Service Centres located in the district and there is no policy or mandate that necessitates extension agents' visit to the farmers (source: personal communication with DP Sherchan, CSISA hub manager, Central Nepal).

Another source of information is non-governmental programs focusing on farmers. This is of special relevance in Nepal and Bangladesh as NGO activity is rather intensified. Table 19 shows the list of programs run in the sample villages. These programs may have a significant role in social development through micro-credit provision, sanitation, women empowerment etc. However, their emphasis on agricultural technology dissemination and farmer training is rather limited.

The single exception we have noted is the activity of Agricultural Technology Management Agency (ATMA) in Punjab. Although the focus groups have not indicated presence of ATMA in Haryana, the agency is active among the cereal farmers (source: personal communication with Dr. BR Kamboj, CSISA hub manager, Karnal). Keeping in view this wide knowledge gap farmers face, the extension activities pertaining to CA and RCTs would be the major task and this can be attained by more focused action plans. The effectiveness of existing dissemination activities is yet to be studied. The use of the existing extension networks to demonstrate the benefits of different futuristic technologies may not be expected as a superior strategy.

Table 18: Availability of formal extension service.

	NW Punjab		**Haryana**		**Central Nepal**		**NW Bangladesh**	
	CSISA (n = 9)	**Control (n = 9)**	**CSISA (n = 9)**	**Control (n = 9)**	**CSISA (n = 9)**	**Control (n = 9)**	**CSISA (n = 9)**	**Control (n = 9)**
Presence of agrl. extension office in village (no. of villages)	2	3	1	0	1	0	0	0
Average distance to agrl. knowledge centers from village* (km)	8.71 (5.28)	9.58 (5.50)	6.13 (2.85)	6.56 (3.13)	8.38 (6.48)	5.11 (3.30)	3.72 (2.00)	3.17 (1.87)
Frequency of village visit by the extension personnel (no. of villages)								
i. Daily	0	0	1	0	0	0	1	0
ii. Weekly	5	3	2	4	2	1	0	0
iii. Quarterly	1	0	1	1	0	0	3	4
iv. Monthly	2	1	3	2	0	0	3	3
v. Yearly	0	1	1	2	1	2	0	0
Farm households (%) getting service of extension agents	11.44 (11.99)	14.44 (12.86)	39.22 (24.63)	36.11 (24.85)	13.11 (15.28)	7.44 (16.16)	15.78 (14.51)	21.43 (34.69)

Figures in parentheses show standard deviation to sample mean.
* where extension centers are located outside the village.
Source: FGDs

Table 19. Government and non-Government programs.

	Govt. or NGO program		Activity	N0. of villages where program is active	
				CSISA	Non CSISA
NW Punjab	NREGA (Mahatma Gandhi National Rural Employment Guarantee Act)	[www.nrega.nic.in]	Employment generation	2	2
	Agricultural Technology Management Agency	[www.atma-aims.org]	Technology dissemination	2	2
Haryana	NREGA	[www.nrega.nic.in]	Employment generation	2	2
Central Nepal	Nirdhan	[www.nirdhan.com]	Micro-credit	5	4
	Chhimek Biswas	[www.chhimekbank.org]	Micro-credit	1	3
	Grameen	[www.grameenfoundation.org]	Micro-credit	2	0
	World Vision International	[www.wvi.org]	Development	1	1
	Deprosc	[www.deprosc.org]	Social development, micro-credit	1	1
	Govt programs	--	Integrated pest management, micro-credit, irrigation, poverty alleviation	3	1
	Other NGOs (N = 5)	--	Credit	3	2
NW Bangladesh	Grameen	[www.grameenfoundation.org]	Micro-credit	8	8
	Bangladesh Rehabilitation Assistance Committee)	[www.brac.net]	Credit and development	8	8
	Asa	[www.asa.org]	Micro-credit	8	9
	RIB (Research Initiatives, Bangladesh)	[www.rib-bangladesh.org]	Poverty alleviation	2	0
	Proshika	--	Rural development	2	2
	TMSS (Thengamara Mohila Sabuj Sangha)	[www.tmss-bd.org]	Women empowerment	4	3
	RDRS (Rangpur Dinajpur Rural Service)	[www.rdrsbangla.net]	Sanitation	1	2
	Other NGOs (N = 19)	--	Education, credit, sanitation	7	7

Source: FGDs

Soil and weather constraints

Soil sodicity and acidity or alkalinity are conceived as cereal production constraints in many villages of the study area. Minhas and Bajwa (2001) have reported that alkali water constitutes about 25-42% of ground water in the north-western states of IGP, and this significantly limits the cereal yield. Many times, the recommended practices to ameliorate soil alkalinity (e.g., deep ploughing/chiseling) may critically prevent the spread of CA practices. The use of soil amendments to rectify soil acidity/alkalinity is widely practiced in the study areas, but this only serves to ameliorate the surface soil. It has been pointed out that tillage by inversion plough or harrow will bring the saline soil underneath to the surface, increasing the salinity in the seed zone. Since ZT does not disturb soil, crop stand establishment is often better under these conditions (Jat et al., 2010).

Extreme heat is another major weather constraint, especially in wheat production where late planting is already a major cause of reduced yields. Terminal heat implies that wheat yield potential is reduced by 1-1.5% per day if planting occurs after 20 November (Hobbs and Gupta 2003a). The magnitude of yield loss is greater in the eastern Plains, where planting is already late due to rain-dependent planting of the preceding rice crop (Jat et al. 2010). Adoption of ZT would allow the wheat crop to be planted sooner than would be possible using conventional methods by reducing turnaround time.

6 Diffusion of RCTs: Technical and institutional dimensions

This section focuses on various machinery interventions with respect to land preparation, seeding and harvesting that have taken place in the study area during the past three decades. Some of these technologies are conventional and/or an anti-thesis to the intentions and principles of CA, which are still discussed here to provide the complete picture of tillage alternatives available to farmers. The introduction history of these technologies to the sample villages across hubs is presented in Figures 7a-7d, and the farmer adoption rates are given in Table 20. Some of the technologies (e.g., cultivator) were introduced in the distant past (1970s and 1980s) and, as this information is elicited from farmers' memory, the long history could have generated a certain degree of measurement error. However, the information is broadly useful in understanding the patterns of substitution and co-existence. During the survey, adoption rates were elicited mainly for eight technologies; most are related to tillage (tine cultivator, disc harrow, rotavator, and two-wheel tractor). In addition, adoption of land levelling, seeding and harvesting machineries were studied as having important implication on resource conservation in cereal production.

Table 20. Adoption of selected technologies (% of farmers using the technology).

		Tine cultivator	Disc harrow	Rotavator	2-wheel tractor	Seed drill	Laser leveller	Combine harvester	Bhusa reaper
NW Punjab	CSISA	100	100	26	0	>90	40	85	59
	Control	100	99	23	0	>90	11	79	45
Haryana	CSISA	32	91	18	0	38	11	58	58
	Control	44	97	23	0	36	1	53	52
Central	CSISA	98	98	2	18	7	0	3	0
Nepal	Control	99	99	2	10	0	0	3	0
NW	CSISA	0	0	27	81	2	0	0	0
Bangladesh	Control	0	0	21	84	0	0	0	0

Source: FGDs

Laser land leveller

Laser leveller, which employs a laser controlled system, ensures precision land levelling, reduces the water, nutrients, and agro-chemicals use and managerial time required during crop establishment. This in turn increases the crop yields and environmental quality (Rickman 2002). The LLL technology was first introduced in India by CIMMYT in Western Uttar Pradesh in 2002 by providing a unit procured from Pakistan and later spread rapidly to other states of NW IGP (Jat et al. 2006). In our survey, the farmers indicated that they started using the equipment from 2000 (Punjab), and this could be due to the recall bias, unless they had been imported from neighboring countries (like Pakistan). Nevertheless, the technology is currently present in 72% of the sampled villages of Punjab and Haryana with an average of 16% of farmers having so far adopted the technology. The adoption rate is already higher in the project villages compared to the control villages at the time of the FGDs. The total number of LLL units is very limited in Central Nepal and NW Bangladesh and hence farmers are not aware of any of these precision levelling instruments being available in their villages.

Tine cultivator and disc harrow

These machines are used for land preparation in the conventional tillage. The adoption has a relatively long history, in relation to other land preparation methods, and is prevalent in most of the studied villages except in NW Bangladesh. These methods are widely adopted in NW India, even before 1995. In most of the villages of Punjab, adoption of cultivator preceded that of mechanized harrowing, while disc harrow became prevalent before the cultivator in Haryana. At present, about 100% of the cereal growing households use these instruments in either or both of the crop seasons in north-western IGP. Although the diffusion was slower in Central Nepal, during the time of FGDs it was present in all the villages and the adoption by farmers is about 100%. The number of tines of cultivator and discs of harrow differs, depending on the power of tractor popular in the locality. In contrast with these three zones, cultivators and disc harrows are completely absent in NW Bangladesh. Because of the small landholding and plot sizes, two-wheel tractors are far more common than four-wheel tractors to which cultivators and disc harrows are attached.

Rotavators

Rotavators, or more specifically rotary tillers, are multi-utility machines that decrease labor requirements by completing multiple operations in single pass. This technology is relatively new in dissemination, having been introduced over the last five to eight years in NW IGP. It is also present in Central Nepal and NW Bangladesh, and has been found to be spreading fast in the recent past. Compared to the preceding tillage technologies, the rotavator spread in both Punjab and Haryana (as shown in Figures 7a and 7b) was supported by considerable private sector initiatives. It was shown that the adoption of rotavators has led to increased residue burning, broadcast seeding and creating sub-soil compaction or hard-pan. This has consequently led to yield reduction after years of continuous use. Possibly due to these unwanted effects, the adoption has achieved only moderate rates among farmers (18-26%) in NW IGP compared to conventional tillage equipment. In Central Nepal, the technology has started spreading across villages, but only <2% of farmers had adopted this technology at the time of the survey (Figure 7.3). The technology is spreading rapidly in NW Bangladesh (introduced in 50% of sampled villages) and was adopted by one-fourth of the farmers in 2010.

Two-wheel tractors

This equipment, self-powered and propelled, can pull various farm implements. They are confined mainly to the eastern IGP districts. The technology has been present in the study villages of Bangladesh and Nepal from 1980 onwards and is now present in most of the surveyed villages of the former and half of the latter. The rate of adoption of two-wheel tractors for ploughing is above 80% in NW Bangladesh where the only available machine alternative is the rotavator. However, a closer look at the adoption would reveal that these technologies are complementary to each other, and not substitutes. For example in Batason and Purba Shadipur, the two project villages of Dinajpur District, the adoption of the two-wheel tractor is about 100% and that of rotavators above 70%, indicating the existence of overlapping adoption of tillage technologies. However, in the village of Akaskuri (a control village in Nilphamari district), the adoption of both rotavators and two-wheel tractors is nil and farmers still resort to animal power for land preparation. Hence, in short, the village attributes (location, presence of service providers etc.) have an important role in deciding the spread of CA practices.

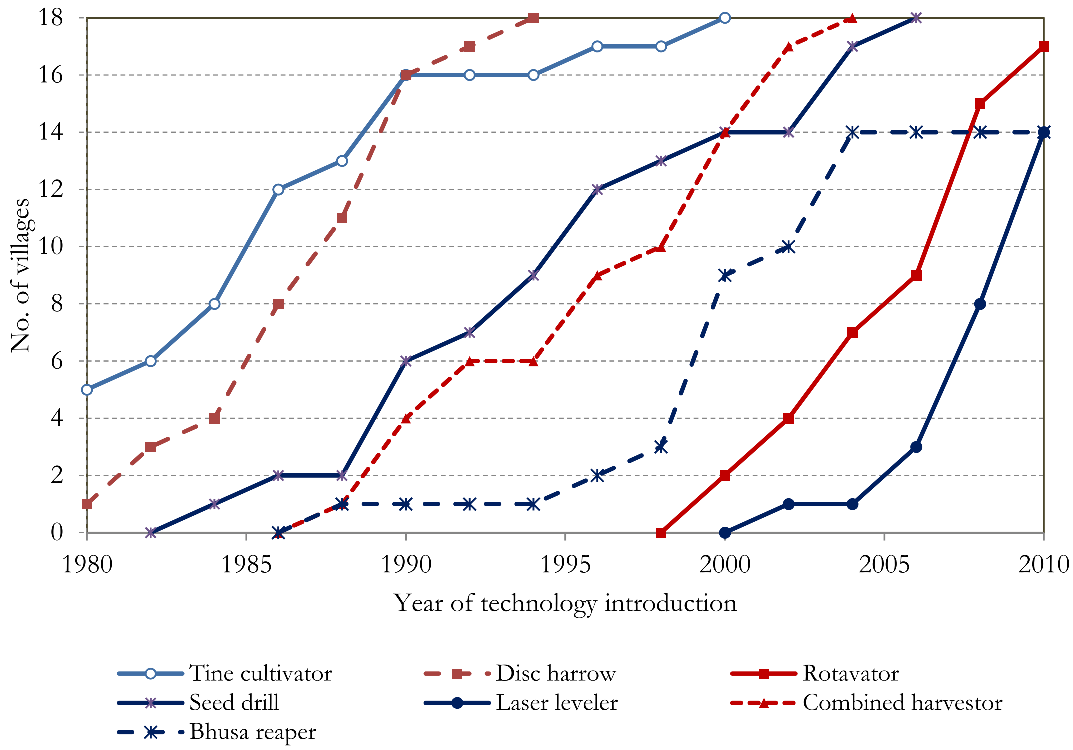

Figure 7a: Year of introduction of land preparation and harvesting machineries: NW Punjab
Note: 2-wheel tractors are yet to be introduced in the study villages.

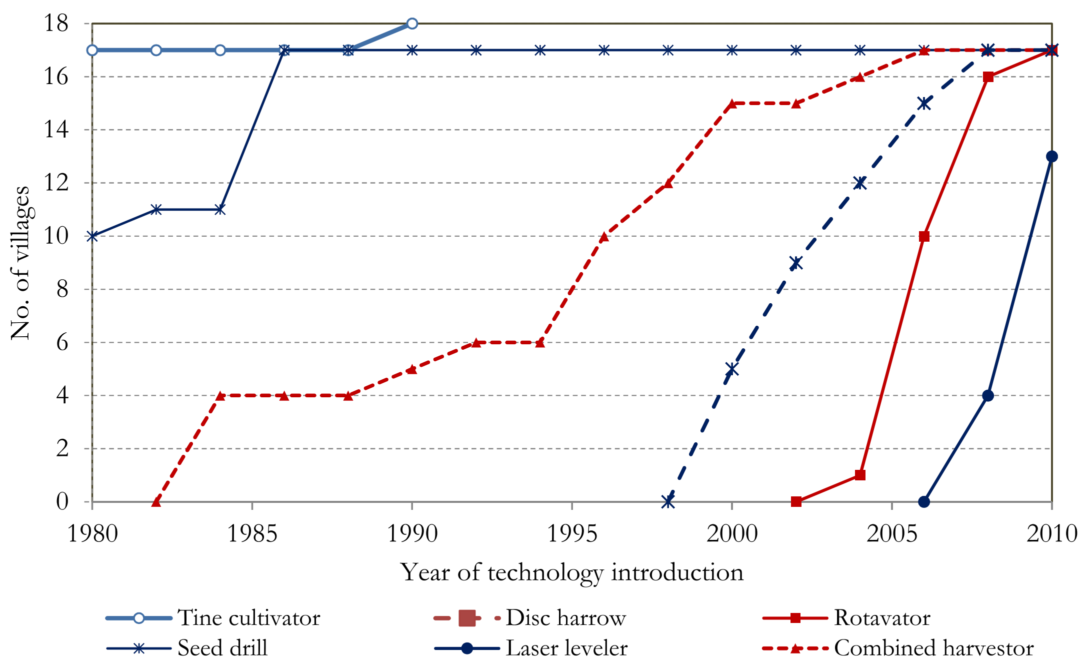

Figure 7b: Year of introduction of land preparation and harvesting machineries: Haryana
Note: 2-wheel tractors are yet to be introduced in the study villages.

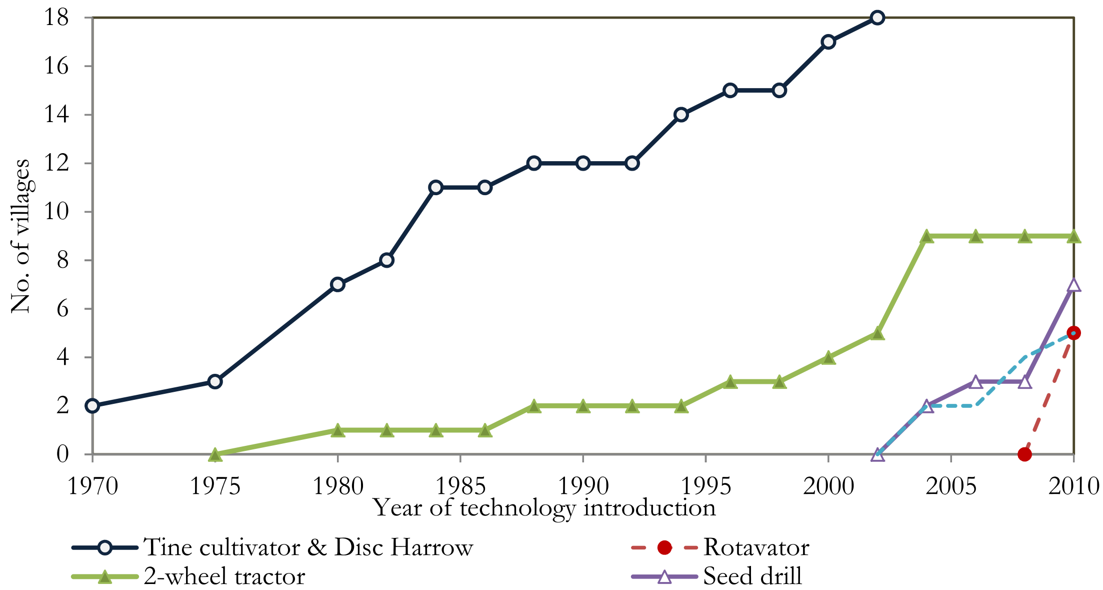

Figure 7c: Year of introduction of land preparation and harvesting machineries: Central Nepal
Note: Laser leveller and Bhusa reaper are yet to be introduced in the study villages.

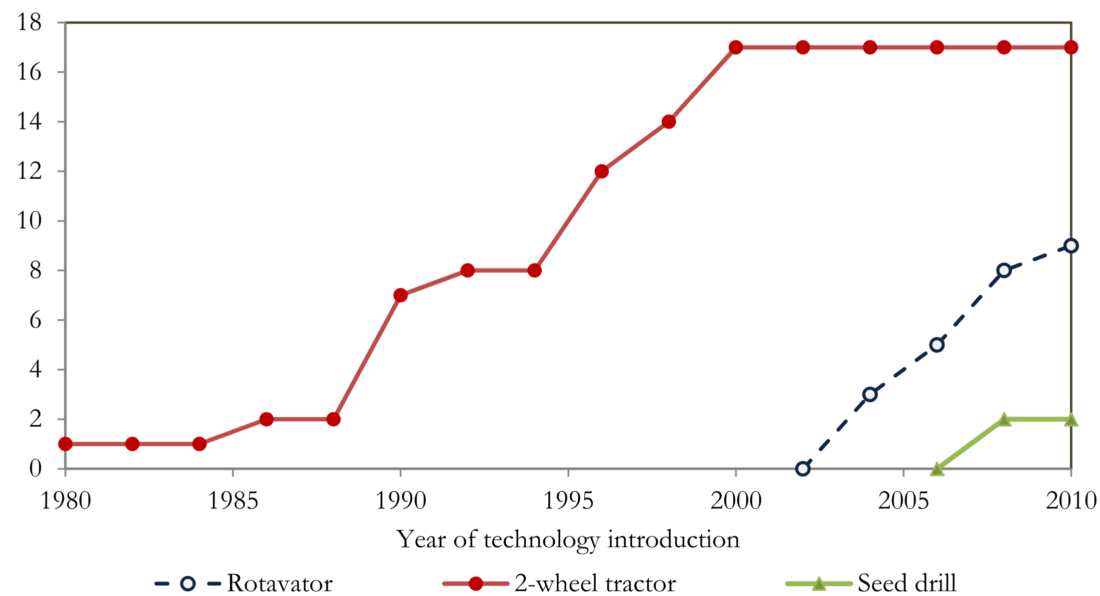

Figure 7d: Year of introduction of land preparation and harvesting machineries: NW Bangladesh
Note: Laser leveller, disc harrow, tine cultivator, combine harvester and Bhusa reaper are yet to be introduced in the study villages.

Seed/fertilizer drills

Seed/fertilizer drills promote line-sowing, instead of conventional broadcasting of seeds, thereby reducing seed and fertilizer use and increasing crop productivity. The adoption of seed drills started even before 1985, gradually gaining popularity over the years and is currently present in almost all the sampled villages of NW India. Seed drills had been introduced in Central Nepal and NW Bangladesh by the RWC in the last decade. Diffusion of this innovation is limited to the CSISA hubs, where on an average only 7% of farmers resort to drills for line sowing.

Combine harvester and bhusa reaper

Adoption of mechanized harvesting of grains and straw is widely popular in most of the sample village of Punjab and Haryana, and it was also recently introduced to four villages in Nepal. About 50-60% of farmers in NW Indian villages adopt these technologies, while the adoption is still marginal (3%) in Nepal. Mechanized harvesting is yet to be introduced in NW Bangladesh. The mode of harvest has a key role in determining the adoption of CA practices by farmers.

Institutional dimensions in diffusion of RCTs

Although the above mentioned technologies are having direct (positive or negative) impacts on the diffusion of CA technologies, the supply of these machines and related information are determined by a number of institutional factors, including the presence of service providers from private, public and cooperative sectors. The presence of project extension personnel also influences the potential adoption pattern of the aforementioned technologies. The FGDs showed a high level of understanding of villagers CA-based RCTs disseminated across all the hubs in the project villages.

The information has not percolated into the control villages at this early stage of the project implementation. In addition, the CSISA project is being implemented indirectly through a number of public-private partnerships. In each region, the RCT dissemination is accomplished with the partnership of 35-45 different agencies, which include public-private firms, NGOs, farmer clubs and co-operatives and others. The role of service provision in machinery hiring is equally important to the information delivery. The co-operatives and farmer clubs facilitate farmers in getting farming information, agrochemicals, other inputs and machinery services at relatively lower cost. However, the access of small farmers to these farmer groups is critical in deriving the associated benefits, which is discussed in the remaining part of this section. Farmer participation in group activities (that is, co-operatives and farmer clubs) is an important determinant of adoption of CA technologies. Tables 21 and 22 present the extent of household participation in group activities, as derived from the village census data.

However, the farmer understanding of co-operatives and other groups is not very precise, and often they use the terms interchangeably. The household involvement in group activities is broadly related to agriculture is less than 25% in all the regions, except NW Bangladesh. Among cereal growers, one-third is associated with co-operatives and/or farmer clubs in NW India and Central Nepal. Household participation in co-operatives is rather high in NW Bangladesh and this includes even the non-farming households. More interestingly, it is the farmers with larger landholdings who participate more in cooperative activities. The single exception to this is the case of NW Bangladesh where the small farmers involve themselves in the co-operative activities, corresponding to their eagerness to expand their cropping activities by leasing-in additional land. The landholding difference between members and non-members are huge in NW India, which is noteworthy in designing the diffusion strategies for RCTs through cooperatives and other farmer groups. The potential caveat of small farmers getting excluded from the benefits of RCTs should be considered while involving in different public-private partnerships for the technology dissemination.

Table 21. Membership in groups and landholding: total households.

	Number (% of total) of			Average land holding in acres (std.devn)	Average land holding in acres (std.devn) among					
	Total households	Co-operative members	Farmer group members		Co-operative members	Others	difference†	Farmer group member	Others	difference†
NW Punjab	8473	1304	39	2.73	6.77	1.99	239.7%***	10.04	2.69	272.5%***
		(15.4%)	(0.5%)	(5.36)	(8.70)	(4.08)		(6.91)	(5.33)	
Haryana	4024	642	19	1.93	4.10	1.52	170.1%***	6.92	1.91	263.1%***
		(16.0%)	(0.5%)	(4.56)	(6.09)	(4.08)		(6.19)	(4.54)	
Central Nepal	2786	617	320	1.53	1.61	1.48	9.2%	2.39	1.39	71.9%***
		(22.1%)	(11.5%)	(2.01)	(2.10)	(1.79)		(2.47)	(1.73)	
NW Bangladesh	5492	3402	74	0.78	0.59	1.09	-45.7%***	1.81	0.77	136.3%***
		(61.9%)	(1.3%)	(1.55)	(1.23)	(1.93)		(2.12)	(1.54)	

†: shows the % difference of variable value of tenant farmers over non-tenants
***: statistically significant at 0.01 level.
Source: Village census

Table 22. Membership in groups and landholding: farming households.

	Number (% of total) of			Average land holding in acres (std.devn)	Average land holding in acres (std.devn) among					
	Total households	Co-operative members	Farmer group members		Co-operative members	Others	difference†	Farmer group member	Others	% difference†
NW Punjab	3860	1011	39	5.63	8.37	4.66	79.6%***	10.04	5.59	79.6%***
		(26.2%)[1]	(1.0%)	(6.67)	(9.12)	(5.22)		(6.91)	(6.66)	
Haryana	1587	481	19	4.75	5.41	4.66	16.1%**	6.92	4.73	46.4%
		(30.3%)	(1.2%)	(6.24)	(6.50)	(5.22)		(6.19)	(6.24)	
Central Nepal	2274	473	308	1.82	2.05	1.68	22.3%***	2.44	1.65	47.3%***
		(20.8%)	(13.5%)	(2.04)	(2.15)	(1.78)		(2.43)	(1.74)	
NW Bangladesh	3079	1773	61	1.33	1.07	1.69	-36.59%***	2.18	1.32	65.6%***
		(57.6%)	(2.0%)	(1.88)	(1.53)	(2.22)		(2.16)	(1.87)	

†: shows the % difference of variable value of tenant farmers over non-tenants.
** ,***: statistically significant at 0.05 and 0.01 levels, respectively.
Source: Village census

7 Conclusion

The study is aimed at providing background information from FGDs and village census for the forthcoming and detailed impact evaluations on CA-based RCT diffusion in the IGP. The information was collected from 72 villages of 12 districts of India, Nepal and Bangladesh to characterize the cereal systems, identify the major production constraints and estimate the technology adoption rates in associated production systems. Although the survey is done after stratifying the villages into project and control, we have observed that there are no significant differences between these two groups with respect to infrastructure and rate of technology diffusion, as the project is in the early stage of implementation. This observation is relevant for the potential impact assessments associated with the CSISA project as the selection bias of project intervention sites is apparently only to a limited extent.

Different village-level characteristics viz. land use, cropping pattern, varietal use, production constraints, technology adoption and institutions were examined and will be supplemented through the forthcoming household survey findings. Although the FGDs are often used as a quick and convenient way to collect relevant data from several people simultaneously, employing the synergies of group interaction, there are a number of limitations to the village-level data so generated, against the detailed (and costly) household surveys. In our experience, we have observed that extra care should be taken to avoid group discussions being dominated by opinions of a few individuals in positions of authority such as village heads. We have also observed that the presence of government extension agents and project staff often acts as an inhibition to obtaining the sincere impressions about the technology (especially dissents on working of technology and the information system). This is perhaps due to the fear of generating negative opinions about the group/village and thereby hampering the future flow of benefits from these sources. This was to a great extent avoided by using young research personnel, whom the farmers do not identify with any projects or the public extension system.

Another limitation of the FGD data was that the accuracy of the estimates of some variables, for which measurement is relatively difficult (e.g., total size of landholding in the village), could be questioned. We have tried to overcome this limitation by using the estimates from the village censuses to a certain extent. When the village census enumerators were paid per household basis, they tended to report more households than the actual number. In this case, tallying the number of households obtained from FGDs to that of village censuses was helpful.

The report showed that the Indian, Nepalese and Bangladeshi villagers have distinct patterns with respect to resource (land, water) and input (labor, fertilizer) availability, cropping patterns, and institutional set-ups (leasing-in, cooperatives, NGOs etc.). The cereal production systems in NW India face a rather different set of challenges (declining water-table, high wage rate etc.) compared to those in Central Nepal and NW Bangladesh (capital scarcity, access to technologies). This indicates that the nature of the RCTs and their dissemination strategies should not be uniform across all hubs. Due to the huge difference in market prices for inputs across countries, the input-saving effect may also get converted into monetary terms disproportionately. The labor-saving technologies would yield higher returns in India, while fertilizer-saving would generate more farm income in Nepal and Bangladesh.

Lastly, as the dissemination strategies are directly linked with the institutional framework, and institutional framework differs across regions, there should also not be any uniform business model for the CA technology dissemination across the IGP. Although the CSISA identifies the issue of social, financial, institutional and agronomic diversity within the project area, and develop location-specific technologies and dissemination models, there is a constant constraint of information availability across all the project hubs. The varying degrees of intensity could significantly limit the adoption of CA practices. Managing the knowledge gaps would be the major challenge for the extension agronomists regarding the technologies.

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Appendix I: Village / ward remoteness

Distance (km) to:	NW Punjab		Haryana		C Nepal		NW Bangladesh	
	CSISA	Control	CSISA	Control	CSISA	Control	CSISA	Control
All weather road	0.00	0.00	0.00	0.00	2.41	3.28	0.61	0.89
	(0.00)	(0.00)	(0.00)	(0.00)	(2.81)	(4.24)	(1.65)	(1.11)
Local input market	5.78	8.00	3.78	4.28	2.22	4.56	0.81	1.39
	(6.18)	(6.80)	(3.07)	(3.15)	(1.46)	(4.12)	(1.04)	(1.17)
Local output market	5.89	2.56	6.78	7.89	2.39	4.67	3.28	2.00
	(4.96)	(2.19)	(2.44)	(5.18)	(3.14)	(3.99)	(2.65)	(1.22)
Machinery repair shop	2.89	3.56	5.89	4.94	6.72	5.17	4.17	2.33
	(4.28)	(4.56)	(3.26)	(3.57)	(4.83)	(3.62)	(5.40)	(1.58)
Agrl. extension office	7.89	7.17	5.44	6.56	8.56	4.33*	3.72	3.17
	(4.88)	(6.01)	(3.36)	(3.13)	(6.09)	(2.78)	(2.00)	(1.87)
Co-op society / Farmer group	3.33	1.22	3.33	3.22	0.50	1.72	0.56	0.29
	(2.24)	(1.48)	(3.35)	(2.55)	(0.79)	(3.23)	(0.97)	(0.76)
Microfinance institution	NA	NA	NA	NA	4.83	5.61	1.36	2.11
					(3.84)	(5.12)	(1.65)	(1.45)
Commercial bank	4.67	2.39	3.11	3.72	6.78	5.83	3.11	4.67
	(4.30)	(2.37)	(2.76)	(2.02)	(6.55)	(3.30)	(2.86)	(3.12)
Veterinary clinic	3.78	2.17	1.56	2.44	2.44	3.06	3.47	5.22
	(4.84)	(2.45)	(1.88)	(1.83)	(1.93)	(3.50)	(3.52)	(3.62)
Primary school	0.33	0.78	0.00	0.00	0.89	0.39	0.61	0.44
	(1.00)	(2.33)	(0.00)	(0.00)	(0.78)	(0.60)	(0.88)	(0.58)
Health centre	2.44	2.78	3.00	3.00	1.22	1.78	2.25	2.17
	(3.13)	(2.99)	(3.77)	(3.29)	(1.09)	(1.64)	(2.06)	(1.54)
District head-quarters	10.00	8.88	16.56	17.78	11.22	12.33	15.33	17.56
	(5.57)	(6.69)	(7.60)	(5.83)	(6.28)	(6.02)	(8.80)	(9.70)

Figures in parentheses show the standard deviation of sample mean (n = 9).