SOCIOECONOMICS

October 2013

Cereal Systems Initiative for South Asia

Factors Affecting the Adoption of Direct-Seeded Rice in the Northeastern Indo-Gangetic Plain

Takashi Yamano, Sampriti Baruah, Raman Sharma, and Anurag Kumar

INTERNATIONAL RICE RESEARCH INSTITUTE

NASC COMPLEX, DPS MARG, NEW DELHI, INDIA

http://csisaportal.org

Factors Affecting the Adoption of Direct- Seeded Rice in the Northeastern Indo- Gangetic Plain

A study conducted in the states of Bihar and Uttar Pradesh to understand the adoption trends of technology on direct-seeded rice, promoted under the CSISA project.

Takashi Yamano, Sampriti Baruah, Raman Sharma, and Anurag Kumar

INTERNATIONAL RICE RESEARCH INSTITUTE
INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER

NASC COMPLEX, DPS MARG, NEW DELHI, INDIA

November 2013

2013

Mailing Address

CSISA Project Management Office
IRRI India, 9th floor, Aggarwal Corporate Towers
Rajendra Place, New Delhi 110028, India

www.csisaportal.org

Contents

List of Figures

List of Tables

Acknowledgments

This study was conducted as part of the Cereal Systems Initiative for South Asia (CSISA) project, which is jointly funded by the Bill & Melinda Gates Foundation (BMGF) and the United States Agency for International Development (USAID).

CSISA is mandated to enhance farm productivity and increase incomes of resource-poor farm families in South Asia through the accelerated development and inclusive deployment of new varieties, sustainable management technologies, partnerships, and policies.

The views expressed in this report are those of the authors and do not necessarily reflect the views of USAID, BMGF, the International Rice Research Institute (IRRI), International Maize and Wheat Improvement Center (CIMMYT), International Livestock Research Institute (ILRI), International Food Policy Research Institute (IFPRI), or the CSISA project.

Acronyms

BMGF	Bill & Melinda Gates Foundation
CA	conservation agriculture
CIMMYT	International Maize and Wheat Improvement Center
CT	conventional tillage
CSISA	Cereal Systems Initiative for South Asia
DSR	direct-seeded rice
EGP	Eastern Gangetic Plain
EUP	eastern Uttar Pradesh
HYV	high-yielding variety
ICAR	Indian Council of Agricultural Research
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
IPM	integrated pest management
IRRI	International Rice Research Institute
KVK	Krishi Vigyan Kendra
LLL	laser land leveler
NGO	nongovernment organization
PACS	Primary Agriculture Credit Society
PRA	participatory rural appraisal
RCT	resource-conserving technology
UP	Uttar Pradesh
USAID	United States Agency for International Development
ZT	zero tillage

Executive Summary

In this report, we describe CSISA training on direct-seeded rice (DSR), identify constraints to the continuous use of DSR, compare DSR and non-DSR rice production, and summarize perceptions of DSR among male and female farmers. Rising labor costs for manual transplanting of rice, concerns about depleting underground water, and increasing costs of irrigation have made transplanting less appealing to farmers. DSR is an alternative method that could reduce the labor and irrigation water requirements for crop establishment. During CSISA Phase I, the project conducted numerous training activities for farmers and service providers. To evaluate the CSISA training and identify constraints to farmers in adopting DSR, we conducted a survey of farmers who have used DSR in the 4-year period of 2009 to 2012 and conducted a study on their continuous use of DSR in eastern Uttar Pradesh and Bihar. Some of the sample farmers evaluated DSR in their own fields, often with project support, and documented what happened in subsequent years as they gained more experience with the technology.

To identify sample farmers, we obtained the list of farmers who participated in DSR training conducted by CSISA from 2009 to 2012 and farmers who received DSR services from CSISA-assisted service providers in the same period. The aggregated list consists of 2,386 farmers. From this list, we randomly selected 342 farmers by stratifying them by district and the year that they were listed.

In this study, we found out the following:

(1) All of our sample farmers used DSR at least once from 2009 to 2012. About one-quarter of them never attended any DSR training. Among those who attended DSR training, about 75% of them attended CSISA-organized DSR training.

(2) About 57% of our sample farmers applied DSR in 2012—the last rice-cropping season before this survey. The major reasons for not applying DSR in 2012 were water scarcity (65%), weed problems (23%), and unavailability of service providers (11%).

(3) Among small farmers, whose landholding size is less than 0.5 ha, unavailability of service providers was one of the major reasons for not applying DSR in 2012, while it was not a major problem for medium and large farmers.

(4) We found about a 40% reduction in labor use when farmers use DSR. The reduction in labor mainly comes from transplanting rice, which is conducted mostly by hired female workers.

(5) We found no significant difference in profit between DSR and manually transplanted rice (TR) plots. Although the average total cost is lower in DSR than in TR plots by more than Rs. 3,200 per ha, the low average yield in DSR plots reduces the difference in the average profits of DSR and TR plots.

(6) Among men, DSR users in 2012 had a better perception of DSR than nonusers. They thought that DSR was a very good practice and that it saved labor and water.

(7) The perceptions of DSR among female farmers show patterns similar to the perceptions of men. The perception index of women is positively correlated with that of men.

These findings suggest several policy recommendations and recommendations for CSISA hub activities. First, small farmers need assistance in receiving DSR service from service providers. Small farmers listed unavailability of service providers as one major reason for not applying DSR. However, medium and large farmers who live in the same areas do not list this as a major constraint. This suggests that service providers exist in the areas, but they may consider providing services to small farmers not economical because of large transaction costs, especially at the peak season for planting. Second, we find a very low rice yield of hybrid rice in DSR plots. Because hybrid rice needs to be cultivated in controlled production environments, some abiotic stresses or mismanagement might have caused the loss. Cultivating hybrid rice in DSR plots appears to be riskier than cultivating high-yielding varieties in DSR plots. Third, as we find in farmers' perceptions, farmers recognize that DSR saves labor and water and protects the soil. Some of the benefits of conserving resources are not captured by the economic factors, but the knowledge of such benefits of DSR should be disseminated to farmers.

1. Introduction

The dominant method of rice establishment is transplanting in the rice-wheat growing areas of the Indo-Gangetic Plains (IGP). However, rising labor costs for establishing a nursery, puddling fields, and transplanting have increased costs for transplanting in the region. Furthermore, concerns about depleting underground water and increasing costs of irrigation have made transplanting less appealing to farmers. Direct seeding of rice is an alternative method that could reduce the labor and irrigation water requirements for crop establishment (Kumar and Ladha 2011). Direct seeding would also enable farmers to establish rice early, allowing them to harvest early, so that they can start sowing a subsequent crop, that is, wheat, in areas in eastern India, leading to higher yield of the crop (Singh et al 2008).

During CSISA Phase I (2009-12), a total of 441 training events were conducted. The major focus of the training was on rice residue management using conservation agriculture technology, direct-seeded rice (DSR), laser land leveling, zero tillage, and others. In total, 3,718 professionals and 32,736 farmers were trained. Regarding DSR, training was conducted on the following topics: production technology of DSR, weed management in DSR, the laser land leveler, and others. In addition to training farmers, the CSISA project has trained progressive farmers to become service providers. When necessary, the project has helped them to purchase machines for DSR. The CSISA-trained service providers have provided services to farmers who cannot afford to buy seeders or who do not own tractors.

Numerous studies have been conducted to evaluate DSR technologies on reducing labor, saving water, managing weeds, and protecting the soil (Timsina and Connor 2001, Rao et al 2007, Kumar and Ladha 2011). Most of the studies have been conducted, however, on agricultural experimental fields or among farmers contracted for trials. To our knowledge, only a few nonexperimental studies have been conducted to evaluate the technology among farmers in developing countries, including India.

In this report, we use information from farmers who used DSR at least once from 2009 to 2012. We selected our sample farmers from lists of known DSR users. We had several reasons for sampling known DSR users, instead of randomly selecting representative farmers. First, the number of DSR users[1] is still small among representative farmers in the target areas. Thus, if we had simply conducted a random sampling, we would have found an inadequate number of DSR users in our survey to conduct meaningful statistical analyses. Second, by sampling farmers who adopted DSR at least once in the past, we could investigate the reasons for not using DSR. Those farmers who used DSR in the past can provide more useful information to identify constraints to the adoption of DSR than those farmers who never used DSR in the past.

[1] In this report, we define DSR as a line seeding of rice seeds by using seeders, either attached to tractors or manually operated, and distinguish it from broadcasting.

Furthermore, we compared rice production and input use between DSR users and non-DSR users in 2012 because not all sample farmers used DSR in 2012. By comparing the two groups, we obtained an estimate of the impact of adopting DSR: reduced input use and especially less labor use. This estimate is not as rigorous as an estimate obtained from a randomized control trial, but it is a reliable estimate because we were comparing current DSR users and nonusers who used it in the past. In other words, we use a realistic counterfactual group to estimate the impact.

The objectives of the study were to

(1) Describe DSR training that farmers received;

(2) Identify the constraints to adopting DSR;

(3) Compare rice production and input use in 2012 between DSR and non-DSR farmers;

(4) Analyze perceptions about DSR among male and female farmers; and

(5) Examine (2) to (4) across three groups of farmers based on their landholding size.

From a list of known DSR users, we randomly selected 342 farmers and investigated their use of DSR in the past and in 2012. In Section 3, we describe our sampling method. By using the data, we found, first, that about one-quarter of the sample farmers had never attended any DSR training but used DSR at least once. About three-quarters of those who attended DSR training participated in CSISA-organized training. Second, 57% of our sample farmers used DSR in 2012. The major reasons for not using DSR in 2012 were water scarcity, weed problems, and unavailability of service providers. Third, among small farmers, whose landholding size is less than 0.5 ha, unavailability of service providers is one of the major reasons for not using DSR, while it is not a major problem for medium and large farmers although they are located in the same geographic areas. Fourth, we found little difference in rice yield between DSR and non-DSR, except for hybrid rice, but we found about a 40% reduction in labor use when farmers used DSR. The reduction in labor use is larger among small farmers than among larger farmers, probably because small farmers use labor more intensively. Fifth, although the labor cost is lower in DSR plots than in non-DSR plots, there is no difference in profits between DSR and non-DSR because of the service provider cost for DSR and a slightly lower yield in DSR plots than in non-DSR plots. Sixth, the perception of DSR is better among farmers who used DSR in 2012 than farmers who did not use DSR in 2012. The farmers who used DSR in 2012 think that DSR is a very good practice and that it saves labor and water. The perception of DSR is better among small farmers than large farmers. And, finally, seventh, we found that the wives of the DSR users had a better perception of DSR than the wives of the non-DSR users. At the end of this study, we discuss policy implications based on the findings.

This report is organized as follows: in Section 2, we describe our study areas in eastern Uttar Pradesh and Bihar. In Section 3, we explain our sampling method and present some basic statistics of our sample farmers. In Section 4, we show farmers' experience with CSISA training on DSR. Their experience with DSR production from 2008 to 2012 is presented in Section 5. In 2012, about 60% of the sample farmers had used DSR, while 40% had not. Thus, in Section 6, we compare rice production and input use in 2012 between DSR users and non-DSR users. In the same section, we also compare revenues and costs and calculate the profits of DSR and non-DSR rice production. In Section 7, we analyze perceptions of DSR among male and female farmers. Finally, policy implications and conclusions are discussed in Section 8.

Picture 1. DSR training in a field.

Picture 2. DSR training in a field.

2. Study areas

In line with the initiative of Bringing Green Revolution to Eastern India (BGREI), CSISA in its Phase II also focuses primarily on the eastern region of India. Eastern Uttar Pradesh (EUP) and Bihar are two of the three regions where CSISA has decided to focus in its Phase II. In this report, we use data from seven districts in EUP and Bihar: Kushinagar, East Champaran, and Deoria of EUP and Samastipur, Patna, Begusarai, and Lakhisarai of Bihar (Fig. 1). These districts were chosen because CSISA has conducted DSR training in these districts since 2008 in its Phase I, as we described in the Introduction.

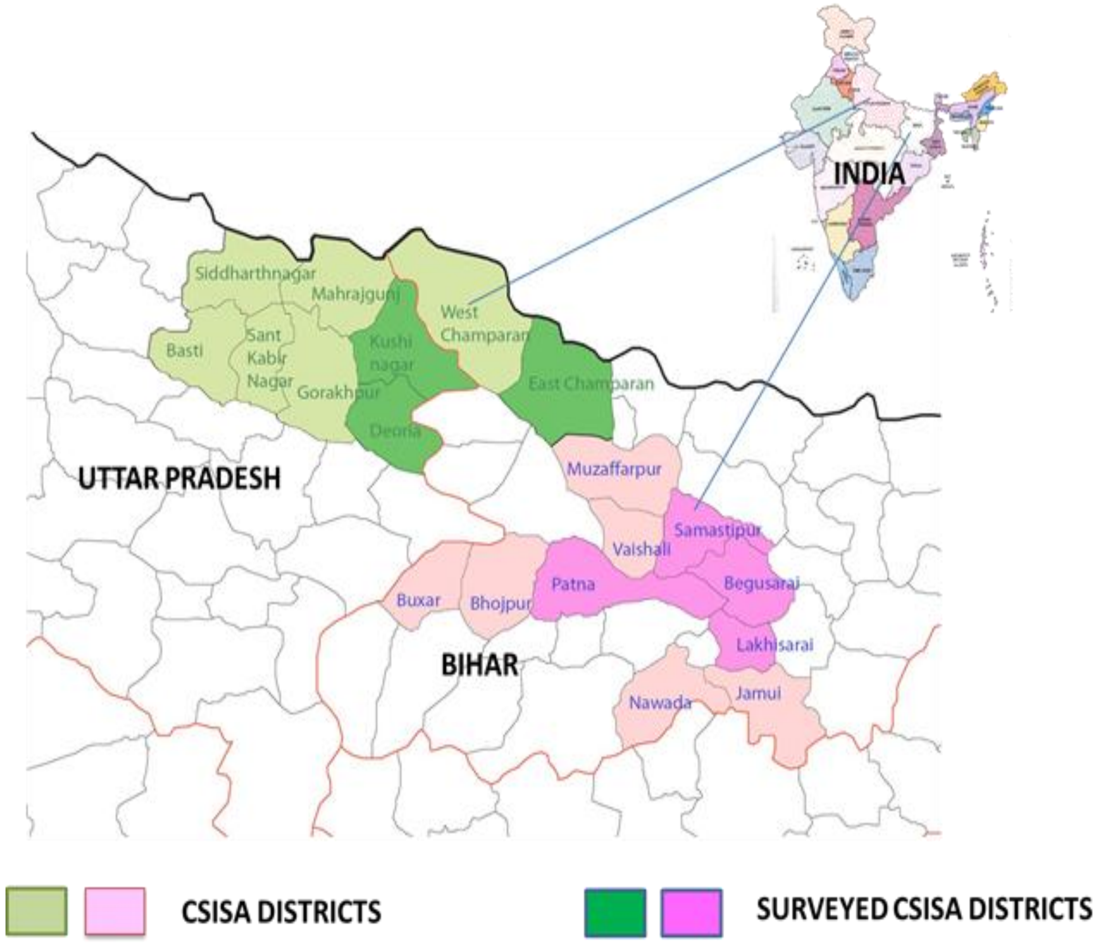

Fig. 1. Map highlighting the districts in EUP and Bihar where CSISA operates and the districts where a DSR survey was conducted.

Bihar

Bihar is located in the eastern part of the country between 83°30' and 88°00' E longitude. Bihar lies in the river plains of the basin of the Ganga. It is endowed with fertile alluvial soil with abundant water resources, especially groundwater resources. This makes the agriculture of Bihar rich and diverse. Rice, wheat, and maize are the major cereal crops of Bihar. Pigeon pea, black gram, mung bean, chickpea, and lathyrus are some of the pulses cultivated in Bihar. The annual average rainfall is 1,052 mm. The rainfall in Bihar is largely due to southwest monsoon which accounts for around 85% of the total rainfall in the state. The other sources, winter rain, hot-weather rain, and northwest monsoon, account for the remaining 15%. The average normal rainfall in the state is more or less adequate for all its agricultural operations. However, it is the year-to-year changes that lead to drought or flood. This causes extensive damage to crop production and the overall income of the state.

Net sown area in Bihar is 60% of its geographic area. This is much higher than the all-India average of 42%. Such a high percentage is possible for two reasons. First, most of Bihar is plain area suitable for agriculture. Second, most of the forest had been converted into farmland during the last 2,000 years. But, the state also faces multiple production constraints. The major ones are small and fragmented landholdings, poor purchasing power of small and marginal farmers to buy agricultural inputs, power shortage for agriculture, risk-prone agriculture (fear of droughts or floods), marginal lowlands, untimely planting, unavailability of appropriate quality seeds and other farm inputs coupled with poor market access for selling farm produce, and poor infrastructure. The public extension system is not effective for catering to the technological needs of farmers because of scarce resources. All these problems lead to an increased cost of production and poor profit margins for farmers, resulting in farmers' inability to invest in farming, thus causing poverty and powerlessness among the rural masses, a lack of labor due to migration, and MGNREGA.[2] Under these circumstances, rolling out new conservation agriculture (CA)-based technologies is difficult as they are often time- and location-specific. Therefore, they require some fine-tuning to fit in the socioeconomic structures of farmers before a widespread rollout could be pushed.

The CSISA Bihar hub revisited its strategy for overcoming low productivity in rice-based cropping systems. Direct seeding of rice (DSR), machine transplanting, and the concept of community nurseries are the primary technologies introduced to enhance the rice-based cropping system. The hub disseminates the technologies through demonstrations of all available technologies in farmers' fields by conducting farmer training, exposure visits, traveling seminars, field days, video presentations, and other awareness programs through partners and media.

[2]The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) is an Indian job guarantee scheme, which provides a legal guarantee for at least 100 days of employment in every financial year to adult members of any household willing to do public work-related unskilled manual labor at the statutory minimum wage per day.

The hub has been promoting DSR under conventional tillage (CT) since 2008. Though the acceleration of DSR did not pick up as expected, a critical mass of adopters has been created. During 2012-13, the area expansion of DSR was hindered by a drought-like situation in 2012 as the first monsoon was received after the sowing time lapsed. Due to late rains, 51 cases of crop failure were observed in DSR fields in the hub domain.

Eastern Uttar Pradesh

Eastern Uttar Pradesh (EUP) is located between 24^{o} to 27^{o} N latitude and 81^{o} to 84^{o} E longitude. The region contains 25 districts of UP and has been divided into three agro-climatic zones: the Northeastern Plain Zone (NEPZ), Eastern Plain Zone (EPZ), and Vindhyan Zone (VZ).

The average annual rainfall in EUP is around 1,100 mm, but it is quite erratic and confined to July-September (85−90%). The water table varies from 1 to 14.5 m during premonsoon and from 0.5 to 7.5 m during postmonsoon. EUP faces waterlogging and flood as well as drought conditions. So, in the waterlogging areas, drainage is a problem. In most of the poorly drained areas, the soil type is clay and calcareous in nature, whereas, in well-drained areas, the soil type is loamy or sandy.

The population is about 35% of the total population of UP state. Nearly 85% of the population lives in rural areas. Landholding size is also very small. Nearly 82% of the farmers possess holding size of less than 1 ha (0.39 ha) and 12% of the farmers hold from 1 to 2 ha (1.41 ha) of land. The irrigation status of agricultural land in EUP indicates that about 40% of the net sown area is wholly rain dependent and 60% is irrigated, out of which only 18% of the area is fully irrigated. The major area of the region is occupied by the rice-wheat cropping system, with a cropping intensity of 150%. EUP contributes about 30% of the total food grain production of the state.

The CSISA EUP hub covers nine districts, eight from Uttar Pradesh (UP), Bahraich, Sidharthnagar, SantKabir Nagar, Maharajganj, Gorakhpur, Kushinagar, Deoria, Paschim, and Champaran, and one from Bihar, Purvi (East) Champaran.

Various CA-based resource-conserving technologies (RCTs) have been rolled out in the hub domain regions. The four major RCTs promoted by the hub are ZT, raised beds, surface seeding, and reduced till. The number of farmers monitored for the adoption of hybrid rice in puddled conditions (dominated by varieties Arize 6444 and PHB 71) was 976, covering an area of 503 ha. Some 751 farmers covering an area of 584 ha adopted DSR under conventional tillage. Some 117 farmers covering an area of 164 ha adopted machine-transplanted unpuddled rice (MTUPR). Based on data collected from 260 DSR plots and 124 MTUPR plots, 148 farmers reported puddled rice plots. A market survey of 64 herbicide dealers showed that, within the EUP hub domain, the market for “bispyribac,” a DSR herbicide, increased from 4,000 liters in 2009 to 10,180, 15,900, and 21,200 liters in 2010, 2011, and 2012, respectively. The corresponding area coverage and market capitalization of this herbicide in 2012 was 84,800 ha (at 250 g product/ha) and US$0.23 million.

Capacity building was expanded with the involvement of dealers and distributors (48), field officers/extension personnel (52), and farmers (825), including women farmers (110). CSISA has managed the project through the Department of Agriculture (DOA), KVKs, dealers, NGOs, and service providers (136 for zero tillage, 11 for the laser land leveler, and 9 for machine-transplanted rice).

3. Data sources and sampling procedures

Sampling

To disseminate DSR technologies to a large population of farmers, we need to identify possible constraints to the farmers who consider adopting DSR. One possible place to identify adoption constraints is a group of farmers who had adopted DSR earlier but discontinued it. By comparing them with those who continuously use DSR, we can identify the factors that cause farmers to discontinue DSR. Therefore, to identify adoption constraints among the farmers who had adopted DSR at least once in the past, we collected a list of farmers who had used it. The list comes from two sources.

The first source is a list of farmers who participated in DSR training provided by the CSISA project from 2009 to 2012. The second source is a list of farmers who contracted CSISA-assisted service providers for DSR. As part of the CSISA project, some service providers have received training on DSR machines, which machines to purchase and how to purchase them, how to operate them, and so on. From such CSISA-assisted farmers, we collected lists of farmers who asked for their service to adopt DSR. The aggregated list contains the names of 2,386 farmers. Figure 2 presents the aggregated list by the year that farmers were listed. This is a list of known farmers who adopted DSR at least once from 2009 to 2012. Out of 2,386 farmers, 60% of them are from eastern Uttar Pradesh and the rest are from Bihar.

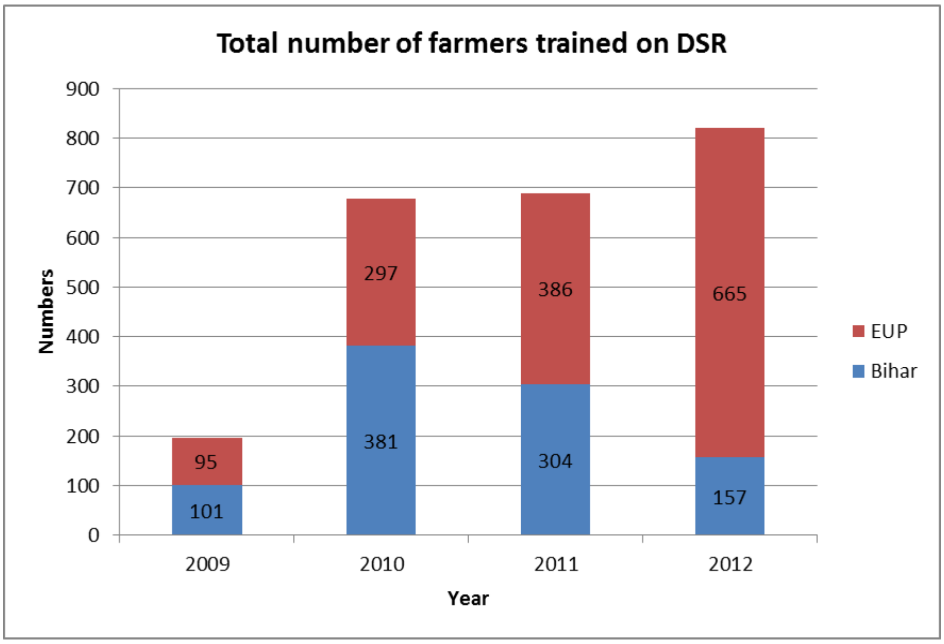

Figure 2: Total number of farmers in Bihar and EUP who have received DSR training

From the aggregated list of 2,386 farmers, we selected 360 by using a stratified sampling method as follows: First, we purposively selected seven districts where most of the CSISA DSR training was conducted in Uttar Pradesh and Bihar. Second, we stratified the sample by the year that the farmers were listed on the aggregated list for the first time because we wanted to study the continuous use of DSR among the farmers who started using it in different years.

Although our sampling is nonexperimental and cross-sectional, we still believe that we can obtain a reasonable proxy for the causal impact for the following reason. Our samples are taken from farmers who have adopted DSR at least once in the past four years. Thus, both DSR users and nonusers in 2012 have similar characteristics. Because of this sampling method, we can consider non-DSR users as a counterfactual group to DSR users. Otherwise, if we had simply compared farmers who were randomly selected from the target areas, we might be comparing DSR users with farmers who would never adopt DSR.

The interviews were conducted by using software called *Surveybe*. *Surveybe* is computer-assisted personal interview (CAPI) software that can be used for designing surveys and collecting data. The interviews were conducted by seven enumerators, who were first provided with classroom training to understand the questionnaire and they practiced interviews during a pretest. Each enumerator was provided with one mini-laptop computer to collect data from the field. On average, the enumerators completed interviews in about an hour. In the interviews, the enumerators asked about farmers' past experience with DSR, rice production and input use in the 2012 kharif season, their perceptions about DSR, and their perceptions about their own ability to adopt new technologies.

Before we describe our data, we need to note that our sample households are not representative farmers in the survey areas. We randomly selected our respondents from a list of farmers who applied DSR at least once from 2008 to 2012. The selected farmers are mostly better-off and progressive farmers who are keen to learn about adopting new agricultural technologies. Therefore, as we mentioned earlier in the report, we do not try to estimate an adoption rate for DSR in the target areas, but we study the continuous use of DSR among farmers who once used it in the past to identify the reasons for discontinuing it.

Table 1. Sample households in EUP and Bihar.

State	Number of households	Average land size[a]	Household head's education	Unclassified caste[b]	Other backward class	Scheduled caste
		(ha)	(years)	(%)	(%)	(%)
EUP	**195**	**1.0**	**8.5**	**60.7**	**19.6**	**19.6**
Kushinagar	128	1.1	8.3	57.8	19.5	22.7
Deoria	40	0.9	9.1	70.0	20.0	10.0
E. Champaran	27	3.3	7.0	63.0	37.0	0
Bihar	**147**	**1.6**	**9.4**	**74.0**	**22.8**	**2.5**
Begusarai	24	0.7	9.3	45.8	50.0	4.2
Lakhisarai	56	1.6	9.6	80.4	17.9	1.8
Patna	15	1.9	11.3	100.0	0	0
Samastipur	52	1.0	10.1	86.5	7.7	3.9
Total	**342**	**1.3**	**9.0**	**67.2**	**21.2**	**11.4**

[a]To calculate the average land size of the sample households, only owned land is included in the calculation. [b]Caste groups that are not classified as scheduled caste or other backward class.

Table 1 presents the basic household information on the sample households. Although we interviewed 360 households in our survey, we present data from 342 households in this report because data from 18 were unusable for this report because of technical problems that occurred when exporting the interview files from the interview software. Out of the 342 households, 168 farmers came from eastern Uttar Pradesh and 158 from Bihar. We found that the average size of land owned by the households is 1.3 ha. The average land owned is smaller in EUP than in Bihar: the average land owned is 1.0 ha in EUP, while it is 1.6 ha in Bihar. In Bihar, the education level of household heads is slightly higher also. The average education is 9.4 years in Bihar, while it is 8.5 years in EUP. Regarding caste, we found that the proportion of households that belong to the scheduled caste (SC) is about 20% in EUP, but only 2.5% in Bihar. The proportion of households that belong to other backward class (OBC) is around 20% in both states.

Table 2. DSR use among sample households in EUP and Bihar.

State	Did you apply DSR in 2012?	Years since first application of DSR	Average size of DSR plots in 2008-12	Average yield of DSR plots in 2008-12
	(%)		(ha)	(t/ha)
EUP	**54.8**	**2.5**	**0.69**	**4.77**
Kushinagar	59.4	2.7	0.67	4.86
Deoria	40.0	2.0	0.79	4.38
E. Champaran	88.9	3.0	1.58	3.52
Bihar	**69.2**	**3.3**	**0.94**	**2.96**
Begusarai	66.7	3.0	0.43	2.00
Lakhisarai	81.1	3.1	1.14	3.23
Patna	60.0	4.1	0.54	3.94
Samastipur	43.6	3.7	0.84	2.43
Total	**61.4**	**2.9**	**0.84**	**3.67**

Table 2 shows the distribution of sample farmers by district. On average, it has been three years since their first use of DSR. The farmers in Bihar are more experienced than farmers in EUP. On average, the farmers in Bihar used DSR more than three years ago, while the farmers in EUP used it less than three years ago.

The average plot size under DSR is also larger in Bihar than in EUP. The average size of DSR plots is 0.9 ha in Bihar but only 0.7 ha in EUP. However, the average rice yield is much higher in EUP than in Bihar: 4.8 t/ha in UP and 3.0 t/ha in Bihar.

4. Participation in DSR training

About three-quarters of our sample farmers have participated in DSR training in the past (Table 3). Less than 10% of them attended their first DSR training in 2008 or earlier. The rest attended their first DSR training between 2009 and 2012. In 2009, CSISA started providing DSR training to farmers. Because we chose farmers from the list of farmers who had been trained at CSISA hubs or received service from CSISA-trained service providers, it is reasonable to find farmers who were trained in the period when CSISA started providing DSR training.

Table 3. Participation in DSR training by the year of participation.

Year attended DSR training for the first time	Number and (%) of farmers
2008 or earlier	33 (9.7)
2009	85 (24.9)
2010	65 (19.0)
2011	58 (17.0)
2012	11 (3.2)
Never attended DSR training	90 (26.3)
Total	342 (100.0)

Table 4 shows that about three-quarters of those who participated in DSR training participated in training that was organized by CSISA. The rest participated in training that was organized by KVK or other public agencies (9.9%), farmers (6.8%), and others (8.7%). Table 4 also shows that about 45% of the training lasted for 1 day, 27% of the farmers attended 2-day training, and the rest (27.8%) attended training for 3 days or longer.

Table 4. Organizers of DSR training.

Training information		Number and (%)
Who provided the training?		
CSISA		188 (74.6)
KVK or other public agencies		25 (9.9)
Farmers		17 (6.8)
Others		22 (8.7)
	Total	252 (100.0)
How long was the training?		
1 day		114 (45.2)
2 days		68 (27.0)
3 days or longer		70 (27.8)
Sample size[a]		252 (100.0)

[a]The total sample size is 342. However, since 90 farmers have never attended any training, we use data from 252 (i.e., 342 minus 90) farmers.

Table 5. Timing of DSR training and application.

Year used DSR for the first time	Year participated in DSR training (no.)					
	2008 or earlier	2009	2010	2011	2012	Never
2008 or earlier	20	4	2	2	1	6
2009	10	62	4	1	1	22
2010	1	16	44	1		7
2011	2	3	15	38	2	24
2012				16	7	31
Total	33	85	65	58	11	90

Farmers who attended DSR training and applied it in the same year.

About half of the farmers who participated in the DSR training also used DSR in the same year in which they participated in the training (Table 5). Table 3 shows that 90 farmers from the sample never participated in any DSR training and the rest attended DSR training. Table 5 shows that 33 farmers attended DSR training in 2008 or earlier, 85 farmers attended in 2009, 65 farmers attended in 2010, 58 attended in 2011, and 11 attended in 2012.

More than 65% of the farmers who attended the DSR training applied it in the same year they participated in it in 2009, 2010, and 2011. Table 5 indicates that, between 2009 and 2012, some farmers used DSR even before getting any training (numbers to the upper-right side of the shaded area), and other farmers waited one year or more to use DSR after participating in DSR training (the last column of Table 5).

We also found that 46% of the farmers used DSR only once. (Note that this group includes farmers who used DSR in 2012 for the first time. Thus, some of them may use DSR again in 2013.) The rest of the farmers (54%) used DSR at least twice. Indeed, 32% of the farmers have been using it continuously after participating in DSR training.

5. Experience with DSR from 2008 to 2012

In our survey, we asked farmers about their experience with DSR from 2008 to 2012. In 2008, only 0.5% of the sampled farmers had used DSR. In 2009, about 30% of the sampled farmers had used DSR on 0.7 ha of land. They achieved a yield of 3.7 t/ha (Table 6). Since then, the percentage of farmers who used DSR increased to 56.5% in 2012. The average land size under DSR increased but it remains below 1 ha and yield increased to 3.8 t/ha but stayed below 3.7 t/ha in 2011 and 2012.

Table 6. DSR use in 2008-12 in Uttar Pradesh and Bihar.

Experience with DSR	2008	2009	2010	2011	2012
Used DSR (%)	0.5	29.5	38.0	54.0	56.5
Area (ha) under DSR among users	0.67	0.66	0.83	0.88	0.97
Yield of DSR plot (t/ha)	3.03	3.72	3.80	3.68	3.64

To investigate more on the reasons for not using DSR, we have classified rice farmers into three groups by their landholding. The first group is farmers whose total land owned in 2012 is below 0.5 ha; the second group is farmers whose total land owned is between 0.5 ha and 2.0 ha; and the last group is farmers whose total land owned surpasses 2.0 ha. We have selected thresholds of 0.5 ha and 2.0 ha because we find that farmers who belong to the medium landholder group have similar household and rice production characteristics, while farmers who use less than 0.5 ha or more than 2.0 ha are different from those in the middle.

Table 7 shows that the proportion of small, medium, and large landholders is about 32%, 48%, and 20%, respectively. The adoption rate of DSR is higher among the large landholders. About 62% of the farmers who are large landholders adopted DSR in 2012. The adoption rates of the other two groups were slightly above 50%. Regarding rice yield in DSR plots, yield is higher among farmers who are large landholders. The average yield is about 4 t/ha for large landholders, while it is 3.8 t/ha and 3.5 t/ha among small and medium landholders, respectively.

Table 7. DSR use in 2008-12 in Uttar Pradesh and Bihar by land owned.

	All	Landholding size		
		Small (0–0.5 ha)	Medium (0.5–2.0 ha)	Large (>2 .0 ha)
Distribution of farmers by landholding size (%)	100	31.6	47.7	20.7
Average land size (ha)	1.40 (1.81)	0.30 (0.14)	1.04 (0.35)	3.91 (2.66)
Used DSR in 2012 (%)	56.5	53.1	51.8	61.9
Yield of DSR plot (t/ha) in 2008-12	3.75 (1.94)	3.81 (1.69)	3.50 (2.28)	4.13 (1.39)

Reasons for not using DSR

Since the study's prime aim is to identify the reasons for discontinuing DSR use in subsequent years, the survey asked farmers to list one main reason for not using DSR in each year since 2008. This subsection tries to explore these reasons. The main reason for not using it before 2008 was that farmers did not know about DSR in the early years. In 2008, about 86% of the farmers responded that they did not know about DSR and about 13% indicated that they were waiting for more information (Table 8). In 2009, farmers who did not know about DSR declined to 69% as some of them participated in DSR training in 2009. Yet, about 26% of the farmers were still waiting for more information in 2009. From 2010 to 2012, the percentage of farmers who did not know about DSR declined to zero as most of the farmers in our sample participated in DSR training and all of them used DSR at least once as we mentioned earlier. Less than 1% of the farmers were still waiting for more information in 2012.

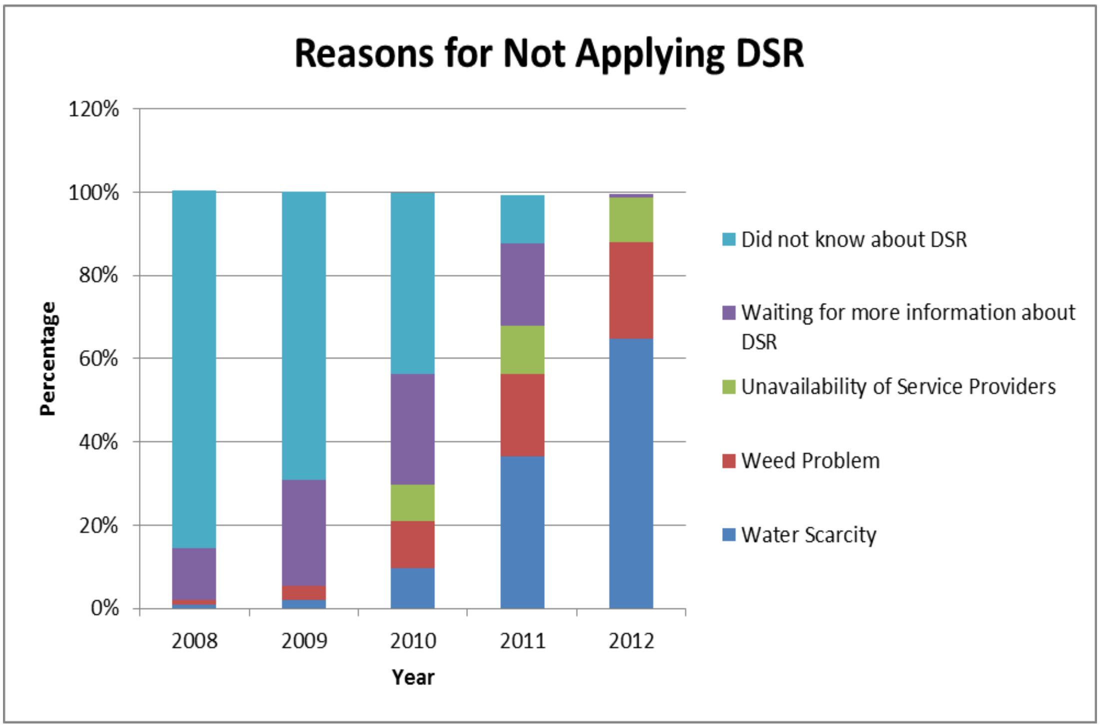

Figure 3: Reasons for not applying DSR

Table 8. Reasons for not using DSR.

Reasons for not using DSR	2008	2009	2010	2011	2012
			(%)		
Water scarcity	1.0	2.0	9.6	36.5	64.8
Weed problems	1.0	3.3	11.4	19.7	23.1
Unavailability of service providers	0	0	8.7	11.7	10.9
Waiting for more information about DSR	12.6	25.7	26.6	19.7	0.7
Did not know about DSR	85.8	69.1	43.5	11.7	0

Instead, we found that about half of the sample farmers did not use DSR in 2012 because of water scarcity, which included delayed monsoon, drought, and limited access to irrigation. Because of late rains, 51 cases of crop failure were observed in DSR fields in the hub domain.

According to our field interviews with farmers, they indicated that they prefer sowing rice seeds directly on their plots right after the first rain because the soil contains some moisture. Then, after sowing, they hope to see some more rain so that the seeds will germinate. If rain fails, the seeds could become dried in the fields and fail to germinate.

Farmers can avoid germination failure by relying on irrigation by using groundwater, but this is costly. Drought right after planting also makes direct seeding riskier than manual transplanting. Thus, water scarcity, especially right after planting, is a serious concern to the farmers who use DSR. Once seeds fail to germinate, farmers may need to switch to manual transplanting to avoid total failure.

Even after learning about DSR, some farmers decided not to use DSR because of weed problems. Table 8 showed that weed problems were the second most frequently cited reason for not using DSR in 2012. This could be because weeds grow and compete with rice after rice seeds are planted since, unlike transplanted rice fields, rice fields are not covered by water under DSR. In the case of manual transplanting, rice seedlings are already grown to some degree, and the fields are cleared before transplanting and remain flooded to suppress germinations of weeds. Thus, it is easier for farmers to identify weeds when the water subsides and weeds start germinating. However, in DSR, the rice germinates and grows as weeds germinate and grow. It is often difficult to identify rice among weeds. Through CSISA training, farmers learn how to control weeds by using herbicides. But, despite this, weeds remain a constant problem for even trained farmers to deal with.

Most farmers do not own seeders for DSR and thus they rely on service providers. In Table 8, about 11% of the farmers indicated that they did not use DSR in 2012 because of the unavailability of service providers at the time of seeding. In our survey areas, close to 90% of DSR users rely on service providers, while the remaining 10% use their own machines, as we describe later in the report. But, the demand for service providers increases at about the same time in one area for seeding. Thus, the demand may exceed the capacity of the service providers in the particular area during the peak period. To reduce transaction costs, service providers prefer providing service to large landholders or farmer groups that aggregate demand for service providers. Individual small landholders who are not part of demand aggregation are often left unattended by service providers, as shown in Table 9.

Resource-rich or large landholders in many ways escape from many of the aforementioned problems but small farmers always suffer more. Since the majority of our sample farmers are small and medium (as we defined earlier, less than 2 ha), it is important to understand why farmers have different land sizes. Considering this, we grouped farmers by landholding size, as we did previously, and present the results in Table 9. We found that water scarcity was the main reason for not using DSR in 2012 among all three groups. But, this is a more serious problem for large farmers: 70.8% of the large farmers cite water scarcity as the reason for not using DSR in 2012, whereas 58.5% and 63.7% of small and medium farmers, respectively, cited that problem. For large farmers, to irrigate their large land area is difficult or costly.

The second reason for not using DSR in 2012 was weed problems for all farmer groups. To control weeds, large farmers need to hire more labor or apply more herbicide, or both, than small farmers. This could be why they cited weed problems as the reason for not using DSR in 2012. We investigate more about input use below.

Regarding the availability of service providers, about 20% of small landholders indicated that they did not use DSR because service providers were not available in 2012. However, only 4.2% and 9.1% of large and medium landholders suggested this was the reason for not using DSR in 2012. This finding suggests that service providers are not providing services to small landholders probably because it is not economical to provide them to small landholders unless their demand is aggregated.

Table 9. Reasons for not applying DSR in 2012 by size of land owned.

Reasons for not using DSR	Landholding size		
	Small (0–0.5 ha)	Medium (0.5–2.0 ha)	Large (2.0 ha or larger)
		(%)	
Water scarcity	59.5	63.7	67.0
Weed problems	20.5	25.8	24.5
Unavailability of service providers	19.5	9.1	4.2
Waiting for more information about DSR	0	1.5	0
Did not know about DSR	0	0	0

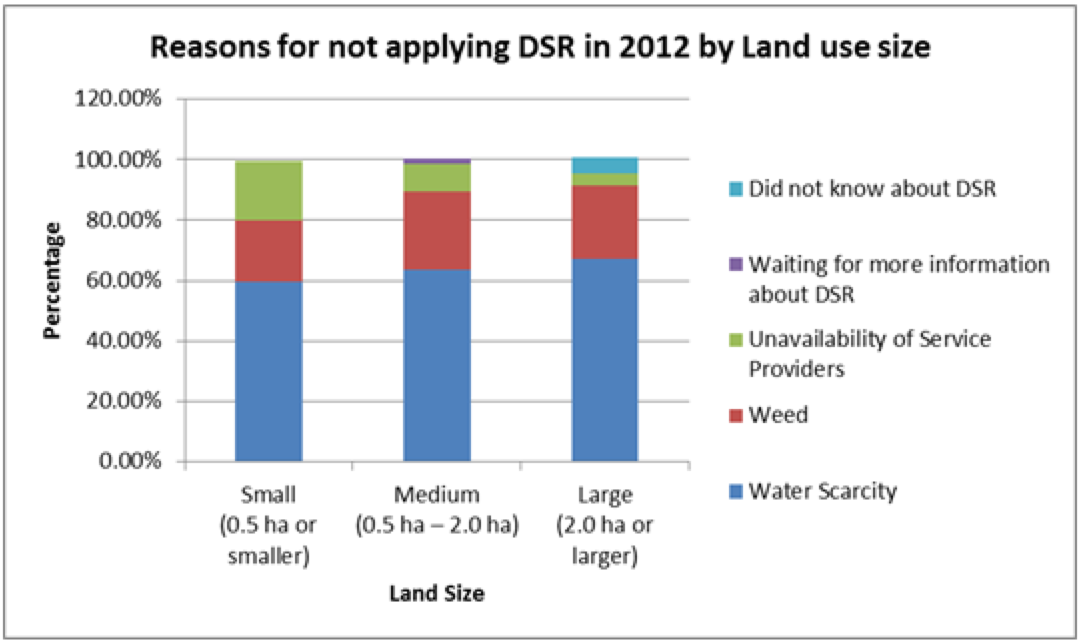

Figure 4: Reasons for not applying DSR in 2012 by the land holding size

To farmers who applied DSR in the past, we asked them to list the most severe problem that they faced in each year. Table 10 shows that the most severe problem that DSR users faced is weeds. In every year from 2008 to 2012, about half of the DSR users identified weeds as the most severe problem they faced when using DSR. Note, however, that weeds were not the most important reason for not using DSR. Thus, although farmers face weed problems when they use DSR, it seems that they can deal with the problem to some extent so that they do not choose not to use DSR because of it.

Water scarcity is the second most severe problem that DSR farmers face. DSR farmers who listed this as the most severe problems were 43.8% in 2012. Note that this percentage was lower in earlier years. Less than 27% of the farmers indicated water scarcity as the most severe problem before 2011.

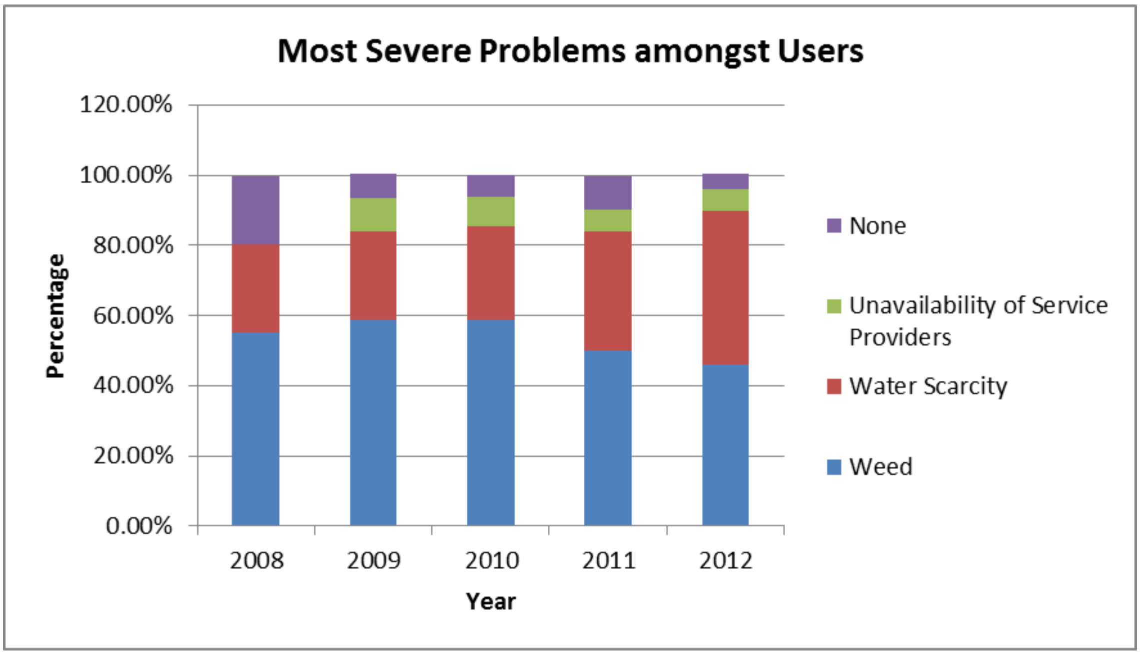

Figure 5: Most severe problems amongst users in UP and Bihar

Table 10. The most severe problems among DSR users in Uttar Pradesh and Bihar.

Most severe problem	2008	2009	2010	2011	2012
			(%)		
Weeds	55.0	58.9	58.8	50.0	46.0
Water scarcity	25.2	25.0	26.6	33.9	43.8
Unavailability of service providers	0	9.6	8.6	6.3	6.3
None	19.4	7.0	6.1	9.4	4.3

Again, to investigate the problems faced by DSR users by their landholding size, we listed the most severe problems they faced. Table 11 shows that weeds are the most severe problem faced by DSR users in all categories. Water scarcity is their second most severe problem. Water scarcity was the most frequently cited reason for not using DSR but is listed second in this table. This is probably because farmers decide to use DSR by overcoming water scarcity problems. Thus, it is no longer the most serious problem for them. The same can be said about unavailability of service providers. Table 6 shows that about 20% of small landholders listed this as the reason for not using DSR. Yet, only 5.9% of them listed it as the most serious problem in 2012. This is probably because they have used DSR through service providers and they faced more serious problems once they adopted DSR. Thus, Table 10 shows that weeds and water scarcity are the two major problems for DSR users regardless of their landholding size.

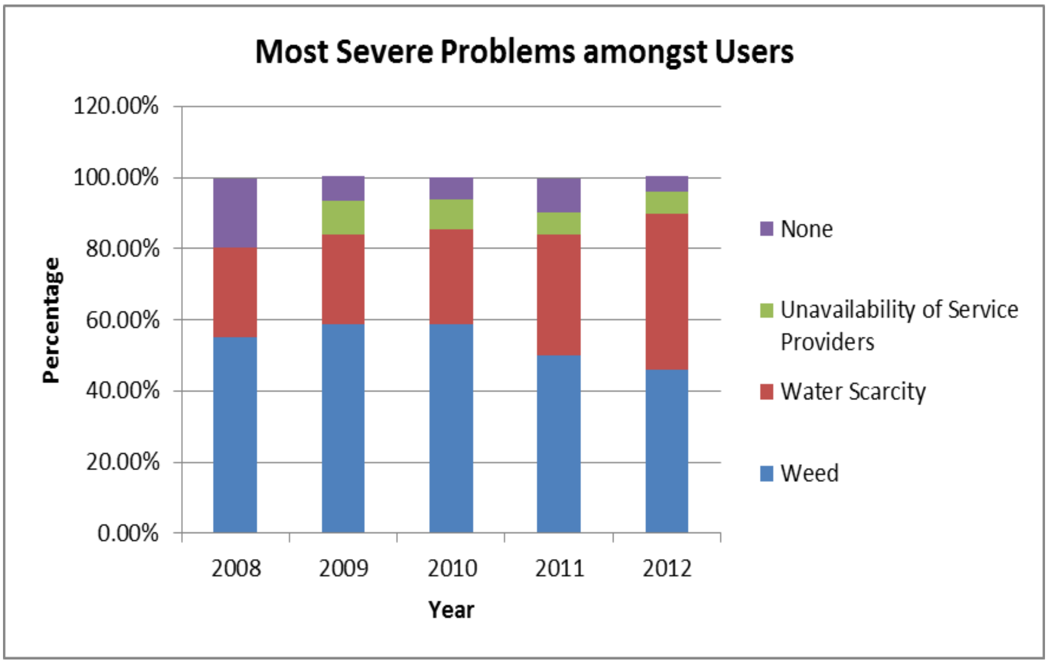

Figure 6: Most Severe Problems according to landholding size

Table 11. The most severe problems which occurred in 2012 among users by the size of landholding.

Reason for not using DSR	Landholding size (ha)		
	Small (0.5 ha or less)	Medium (0.5–2.0 ha)	Large (2.0 ha or more)
Weed infestation	51.0	34.3	56.4
Water scarcity	39.0	55.6	35.9
Unavailability of service providers	6.1	2.7	5.1
None	3.9	7.7	2.6

6. Benefits and costs of DSR in 2012

6.1. Production and yield

Rice production in DSR and non-DSR plots

The survey emphasized collecting detailed information regarding rice production from sample farmers. In particular, we asked each sample farmer detailed input and output questions about one DSR plot if the farmer had used DSR in 2012 or the largest non-DSR plot if the farmer did not use DSR in 2012 so that we could compare DSR plots of DSR users and non-DSR plots of non-DSR users (Table 12). We have detailed rice production information on 302 plots: 171 DSR plots and 131 non-DSR plots. The average size of DSR plots is 0.68 ha, while the average size of non-DSR plots is only 0.48 ha.

To distinguish DSR from broadcasting, we defined DSR as a direct line-seeding of rice by using machines and explained the definition to respondents. By definition, the planting method in DSR plots is DSR (Table 12). When farmers use DSR, they can use dry rice seeds and "wet" rice seeds, whichever have initiated germination. In our survey, we found that less than 10% of the DSR plots were planted using "wet" seeds. Thus, farmers mostly use dry rice seeds in DSR plots.

Table 12. Planting methods of rice in DSR and non-DSR plots.

Descriptors	All	Rice establishment method	
		DSR plots	Non-DSR plots
Number of plots	302	171	131
Plot size in ha	0.59	0.68	0.48
Planting methods (%)			
DSR[a]	56.7	100	
Manual transplanting	36.7		85.2
Broadcasting	5.3		11.9
Machine transplanting	1.3		3.0
All	100	100	100

[a]Line-planting, mostly dry seeds.

In non-DSR plots, we found that manual transplanting is the dominant planting method (85.2%). Broadcasting of rice seeds is the second popular planting method on non-DSR plots at 11.9%. Machine transplanting was used in only 3% of the non-DSR plots.

When farmers use DSR, they need to use seeders to plant seeds in the fields. Since most of the farmers in our study areas do not own seeders or tractors to use seeders, they need to rely on service providers. Table 13 shows that about 87% of the farmers who used DSR in 2012 used service providers and paid about 2,710 rupees per ha.

Table 13. Service Provider Use on DSR and Non-DSR plots

	All	By DSR use	
		DSR Plots	Non-DSR Plots
	(A)	(B)	(C)
Service Provider Use for planting			
Yes (%)	75.8	86.5	61.8
Total costs per plot	1,309	1,262	1,395
Total costs per ha	2,822	2,710	3,028

Rice yield in DSR and non-DSR plots

Next, we compared rice yield in DSR and non-DSR plots. However, rice yield depends on which rice varieties farmers produce. Thus, we first show the distribution of rice variety types in DSR and non-DSR plots (Table 14). The most common rice variety type is high-yielding varieties (HYVs). HYVs are grown in about half of the DSR plots and 63.4% of non-DSR plots. Hybrid rice is the second most common rice variety type, grown in 22% of DSR plots and 19% of non-DSR plots. Traditional varieties (TVs) are as common as hybrids in DSR plots: they are grown in 20% of DSR plots. TVs are not as popular in non-DSR plots. They are grown in only 10% of non-DSR plots.

Some new rice varieties are tolerant of submergence. The most popular submergence-tolerant variety is called Swarna-Sub1. In the early 2000s, scientists successfully generated Swarna-Sub1 by using marker-assisted backcrossing from two rice varieties: Swarna and FR13A. Swarna is a popular high-yielding Indian rice variety developed in India in the 1980s. Since then, it has become one of the most popular varieties in eastern India. FR13A is a rice variety known for its tolerance of submergence. By using a new breeding technology, scientists created a new variety by crossing Swarna and FR13A. The new variety is similar to

Swarna but possesses the submergence tolerance trait of FR13A. Because the new variety, called Swarna-Sub1, is similar to Swarna, scientists thought that it would be easy for farmers to grow Swarna-Sub1 because they can grow it just like they grow Swarna. Under normal conditions, studies find no significant differences in agronomic performance, grain yield, and grain quality between Swarna and Swarna-Sub1, indicating complete restoration of the Swarna background in Swarna-Sub1 (Sankar et al 2006, Neeraja et al 2007). Swarna-Sub1, however, shows a twofold or higher yield advantage over Swarna after submergence up to 14 days. Although the *SUB1* gene has been successfully introgressed into other rice mega-varieties in recent years, Swarna-Sub1 remains the most successful Sub1 variety (Septiningsih et al 2009).

In 2008, the project called Stress-Tolerant Rice for Africa and South Asia (STRASA) started distributing Swarna-Sub1 seeds to farmers. The STRASA project coordinates seed multiplication with local counterparts, such as universities and national agricultural research centers, and distributes Swarna-Sub1 seeds through NGOs and government agencies. In 2008, the project distributed the seeds to only 117 farmers but expanded coverage exponentially to 3 million farmers in 2012. The expansion occurred when the National Food Security Mission (NFSM) started distributing Swarna-Sub1 seeds in 2010. Table 14 shows that Swarna-Sub1 is grown in more than 8% of DSR and non-DSR plots.

Table 14. Distribution of rice variety type cultivated in DSR and non-DSR plots in 2012.

Variety type	All	Rice establishment method	
		DSR plots	Non-DSR plots
	Number and (%)		
High-yielding varieties	167 (55.3)	84 (49.1)	83 (63.4)
Traditional varieties	47 (15.6)	34 (20.0)	13 (9.9)
Hybrid rice	63 (20.9)	38 (22.2)	25 (19.1)
Submergence-tolerant rice[a]	25 (8.3)	15 (8.8)	14 (8.2)
Total	302 (100)	171 (100)	131 (100)

[a]Except for one case, all submergence-tolerant rice is Swarna-Sub1.

It can be observed that rice yield is lower in DSR plots than in non-DSR plots, and we find a large difference with hybrid rice (Table 15). The overall yield average is 4.4 t/ha in non-DSR plots and 3.88 t/ha in DSR plots. Thus, rice yield is about half a ton per ha lower in DSR plots than in non-DSR plots. The lower rice yield in DSR plots is mostly because of low yield among hybrid rice in DSR plots. Table 15 shows that the average rice yield is less than 3 t/ha when hybrid rice is cultivated in DSR plots, while the average yield of hybrid rice is much higher in non-DSR plots, at 4.5 t/ha. It is not clear why the yield of hybrid rice is so low in DSR plots. But, hybrid rice is cultivated in only 22% of DSR plots (Table 15).

When we compare the yield among HYVs, there is no difference between the yield in DSR and non-DSR plots. HYVs yield 4.3 t/ha in DSR plots and 4.4 t/ha in non-DSR plots. Among TVs, the difference is larger. The yield is 3.4 t/ha in DSR plots and 3.8 t/ha in non-DSR plots. Finally, we find that the yield of submergence-tolerant rice varieties (i.e., Swarna-Sub1) is the highest among all variety types at 4.6 t/ha, and there is no difference in yield between DSR and non-DSR plots.

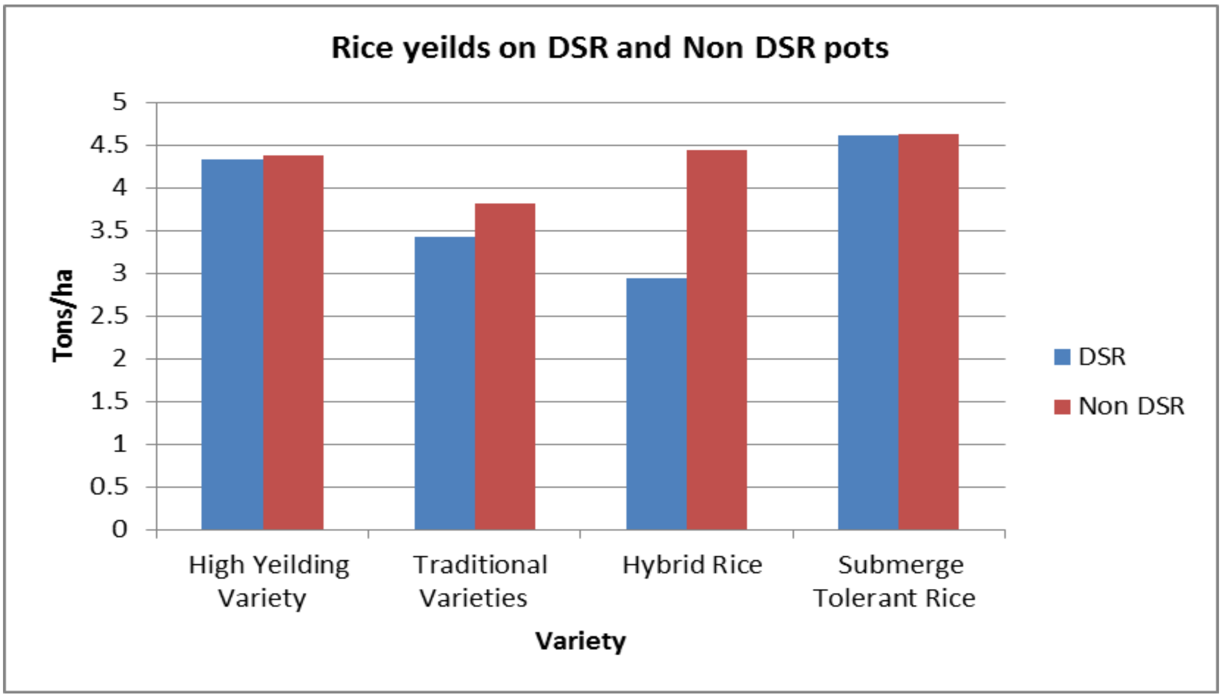

Figure 7: Rice Yields on DSR and Non DSR plots

Table 15. Rice yields on DSR and Non-DSR plots by rice variety.

Descriptors	All	DSR use		Difference
		DSR	Non-DSR	
	(A)	(B)	(C)	(D)
Rice yield (t/ha)	4.08 (1.70)	3.88 (1.79)	4.35 (1.54)	-0.47*
Rice yield by variety				
High-yielding varieties	4.35 (1.49)	4.33 (1.52)	4.38 (1.46)	-0.05
Traditional varieties	3.54 (1.57)	3.43 (1.52)	3.82 (1.74)	-0.39
Hybrid rice	3.55 (2.19)	2.95 (2.30)	4.45 (1.68)	-1.50**
Submergence-tolerant rice[a]	4.63 (1.26)	4.62 (0.99)	4.63 (1.64)	-0.01

[a]The numbers in parentheses are standard errors. * and ** indicate the 5% and 1% significance levels, respectively.

Thus, Table 15 clearly shows that the significant difference in rice yield between DSR and non-DSR plots is mostly driven by the low average yield of hybrid rice in DSR plots in 2012. Because a majority of the farmers have grown HYVs (and because this is what the CSISA project recommends), we have included only HYVs, including submergence-tolerant rice varieties that are also HYVs, in Table 16 and compared the yield between DSR and non-DSR plots. At the bottom of Table 16, we find that there is a difference in rice yield of HYVs between DSR and non-DSR plots: the yield is about 4.4 t/ha in both.

Furthermore, in Table 16, we have divided the sample by landholdings as we did earlier and find that rice yield is higher in DSR plots than in non-DSR plots among medium and large farmers. To be specific, rice yield is 4.5 t/ha in DSR plots of large farmers, while it is 4.1 t/ha in non-DSR plots of large farmers, a difference of 0.4 t/ha. The yield is also higher by 0.2 t/ha in DSR plots than in non-DSR plots among medium landholders. Although these differences are not statistically significant due to the small sample size, they suggest that DSR provides higher rice yield to large rice farmers than to small rice farmers.

Table 16. Rice yield of high-yielding varieties (including submergence-tolerant varieties) in DSR and non-DSR plots by landholdings.

Descriptors	All	By DSR use		Difference B − C
		DSR	Non-DSR	
	(A)	(B)	(C)	(D)
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	
Total	4.39 (1.47)	4.38 (1.46)	4.39 (1.47)	−0.01
Landholding size				
Small	4.64 (1.45)	4.35 (1.34)	4.87 (1.50)	−0.52
Medium	4.24 (1.61)	4.34 (1.78)	4.12 (1.40)	+0.22
Large	4.31 (1.26)	4.48 (1.07)	4.10 (1.47)	+0.38

6.2. Input use

A comparison of data on input use shows that farmers use substantially more herbicide and moderately more DAP in a DSR plot than in a non-DSR plot (Table 17). Herbicide use is 45% in the sampled DSR plots as against 23% in the non-DSR plots. The average amount of herbicide used is also high in DSR plots: 76.6 kg/ha in DSR plots and 46 kg/ha in non-DSR plots. The difference of about 30 kg/ha is statistically significant. The high use of herbicide may be attributed to the high growth of weeds in DSR plots, as we explained in earlier sections.

On the other hand, Table 17 also shows that the use of certain other inputs such as urea and insecticide is lower in DSR than in non-DSR plots. Almost all farmers apply urea in rice plots: urea use is 99% in DSR plots and 100% in non-DSR plots. But the amount used is significantly lower in DSR plots than in non-DSR plots: the average use is about 190 kg/ha in DSR plots and 212 kg/ha in non-DSR plots. The average amount of insecticide is also lower in DSR plots than in non-DSR plots, although the difference is not statistically significant.

Table 17. Input application in DSR vs. non-DSR plots.

	Percentage used (%)		Quantity used (kg)		
Input	DSR plots	Non-DSR plots	DSR plots	Non-DSR plots	Difference[a]
Urea	98.9	100	189.7	212.0	−22.3*
DAP	97.4	81.7	112.0	101.8	+ 10.2
Herbicide	44.5	22.5	76.6	46.0	+ 30.6*
Insecticide	17.2	22.5	110.8	151.9	− 41.1
Sample Size	314	183	314	183	

[a] * = significance at the 5% level.

To investigate input use by landholding size, we divided the sample again by the landholding size in Table 18. In the previous table, we found that urea is used more in non-DSR plots than in DSR plots. This remains so among small and medium landholders but not among large landholders. Among large landholders, there is no difference in the amounts of urea used in DSR and non-DSR plots. Among large landholders, the amount of urea used is 202 kg/ha in non-DSR plots and 198 kg/ha in DSR plots. Thus, the difference is only 4 kg/ha. However, the difference is about 20 kg/ha among small and medium landholders.

On the other hand, the use of DAP is larger in DSR plots than in non-DSR plots, and the difference is larger among small landholders than large landholders. Among the small landholders, the difference in DAP use is 22 kg/ha. The difference in urea is also 22 kg/ha among this group. Thus, small landholders use 22 kg less urea in DSR plots but use 22 kg more DAP in DSR plots. We also found a similar pattern among medium landholders.

Regarding herbicide use, we find that the average herbicide use per ha is lower among large landholders than small landholders. In particular, herbicide use in non-DSR plots decreases quickly as land size increases. Large landholders may use irrigation to prevent weeds from germinating or rely on manual weeding.

To be more specific, the average use of herbicide is about 78 kg/ha among small landholders, but it declines to 49 and 47 kg/ha among medium and large landholders, respectively. Herbicide use is larger in DSR plots than in non-DSR plots across all three groups, but the difference is largest among the large landholders. In non-DSR plots, large landholders use only 18 kg/ha of herbicide.

Regarding insecticide, we also find that the average use per ha declines as landholding size increases and that the average use is larger in DSR plots than in non-DSR plots. But, the observed differences are not statistically significant because of large variation in the data.

Table 18. Input application on DSR vs. Non-DSR plots by size of landholdings.

Inputs	All	Quantity used (kg)		
		DSR plots	Non-DSR plots	Difference[a]
Urea				
Small landholders	185.5	188.6	210.6	−22.0
Medium landholders	162.2	190.3	220.0	−29.7*
Large landholders	182.2	198.0	202.3	−4.3
DAP				
Small landholders	105.0	121.3	99.3	+22.0*
Medium landholders	89.0	116.3	99.5	+16.8
Large landholders	100.2	101.5	108.7	−7.2
Herbicide				
Small landholders	77.7	98.2	62.0	+36.2
Medium landholders	48.5	71.3	40.0	+31.3
Large landholders	46.9	64.9	17.6	+47.3**
Insecticide				
Small landholders	155.3	120.0	228.1	−108.1
Medium landholders	124.8	143.7	174.3	−30.6
Large landholders	30.9	47.5	2.3	+45.2

[a] * and ** indicate 10% and 5% significance level, respectively.

6.3. Labor use

Because direct seeding is implemented by machines, it does not require labor for transplanting rice from a nursery to rice fields. This reduction in labor of DSR is considered a major attraction for farmers to adopt DSR in eastern India, where wage rates for agricultural labor have increased recently.[3] In this subsection, we study labor use data from our sample of DSR and non-DSR plots and compare the labor use between them.

According to our data, we find that the total labor use, in person-days, in a DSR plot is about 50% less than in non-DSR plots. Table 19 shows that the total person-days required per hectare in a DRS plot is 60 as against 114 person-days per ha for a non-DSR plot. Thus, the total labor use is about 46 person-days lower in a DSR plot than in a non-DSR plot. Table 19 shows that a large share of this reduction in labor use comes from hired female workers. This is because, in eastern India, manual transplanting of rice is mostly conducted by hired female workers (Paris et al 2008, 2000). Table 19 shows that, in a non-DSR plot, hired female workers have worked about 50 days/ha on average, while they worked for only 23 days in a DSR plot. Thus, the difference is 27 days. As we can see in Table 20, this reduction comes mostly from reduced labor use in transplanting rice.

In a DSR plot, other workers also work less. Male and female family members work about 10 and 3.5 days less, respectively, in a DSR plot than in a non-DSR plot. Hired male workers also work slightly less in a DSR plot than in a non-DSR plot.

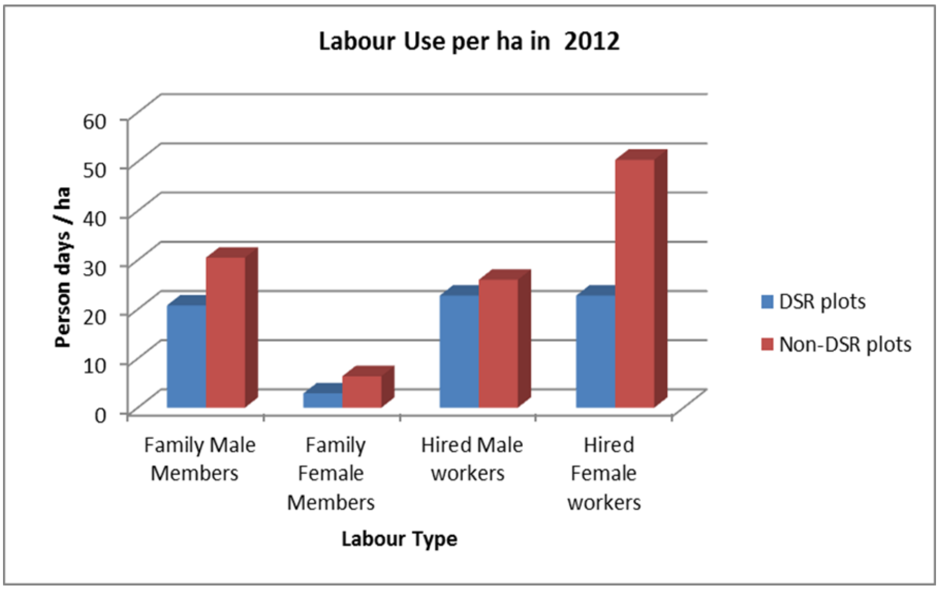

Figure 8: Labor Use per ha in 2012: DSR vs. Non-DSR plots

[3] (http://cacp.dacnet.nic.in/ Farm_Wages_in_Rural_India.pdf).

Table 19. Labor use (person-days/ha) in 2012: DSR vs. non-DSR plots.

	By DSR use		
Descriptors	DSR plots	Non-DSR plots	Difference[a]
Total labor	67.8	113.2	−45.5**
By labor type			
Family male members	20.8	30.5	−9.8*
Family female members	2.9	6.4	−3.5*
Hired male workers	22.8	26.0	−3.2
Hired female workers	22.8	50.4	−27.6**

[a] We apply t-tests: * indicates the 5% level; ** indicates the 1% level of significance.

As discussed above, total labor use decreases significantly as we move from non-DSR plots to DSR plots. Most of the reduction comes from transplanting. In contrast, in non-DSR plots, about 44 person-days of labor are required. This suggests that, for example, if a farmer hires 10 workers for transplanting, the farmer has to hire the 10 workers for more than 4 days for a plot of 1 hectare. In a DSR plot, the farmer also needs to use less labor in other activities such as seed and land preparation. This is because the farmer does not need to grow rice in nursery fields for DSR. Instead, the farmer needs to spend about 5 more days for direct seeding itself.

As discussed in Section 5, weeds are a major problem in DSR. Almost all surveyed farmers mentioned them as either a cause for not using DSR or a major problem that they face after using DSR. To overcome weed problems, DSR farmers need to control weeds.

An alternative way of dealing with weeds is to pull them out manually. Table 20, however, shows that the average amount of labor used in DSR plots is only slightly larger than in non-DSR plots: the average labor use in DSR plots is 37.7 days, while it is 34.4 days in non-DSR plots. The difference is only 3 days, and is not statistically significant. Thus, although weeds are a major problem for DSR farmers, they are not using more labor for weeding than non-DSR farmers.

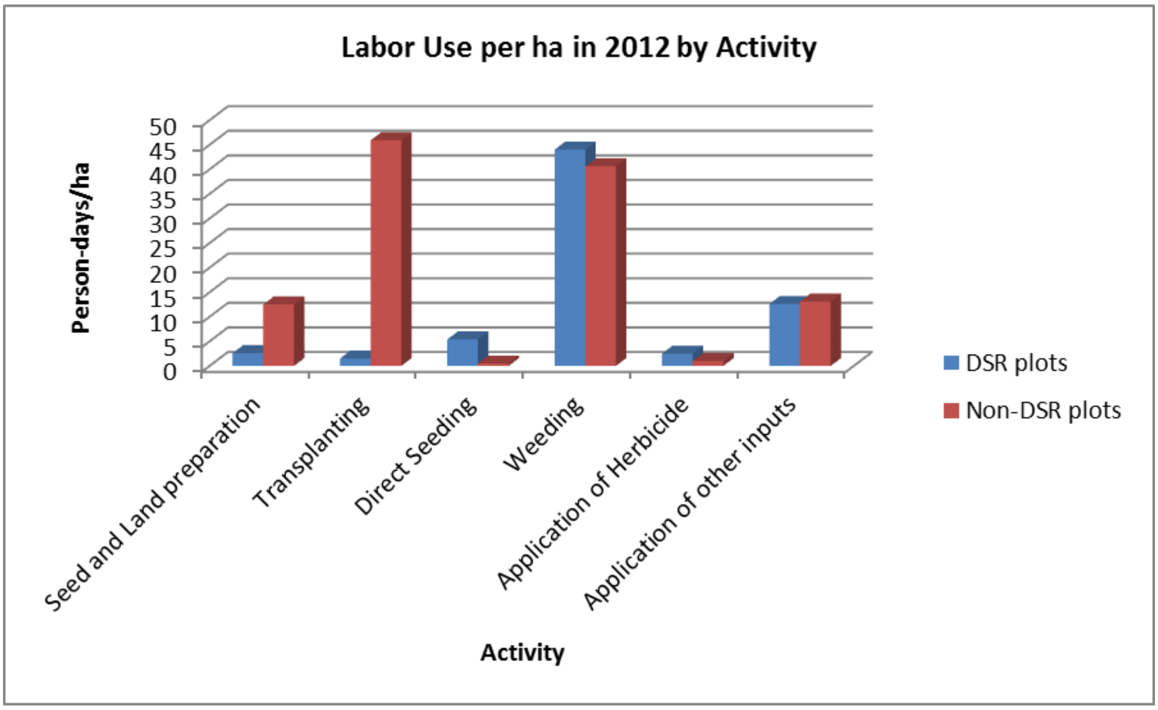

Figure 9: Labor Use per ha in 2012 by Activity: DSR vs. Non-DSR plots

Table 20. Labor use (person-days per ha) in 2012 by activity: DSR vs. non-DSR plots.

Unit: Person-days/ha

Descriptors	DSR plots	By DSR use in 2012 Non-DSR plots[a]	Difference
Total labor	67.8	113.2	−45.5**
By activity			
Seedbed and land preparation	2.6	12.5	−9.9**
Transplanting	1.5	45.9	−44.4**
Direct seeding	5.4	0.5	+4.9**
Weeding	44.0	40.6	+3.3
Application of herbicide	2.5	1.0	+1.5
Application of other inputs	12.6	13.1	−0.6

[a] 16 cases of broadcasting and 4 cases of machine transplanting are included with 117 cases of manual transplanting.

Finally, we analyze labor use across the predecided three groups of farmers by landholding size (Table 21). The results suggest that total labor use increases as the landholding size increases for DSR users: the total labor use is 62 person-days among small landholders but is 68 person-days among large landholders. On the other hand, total labor use decreases as the land size increases for non-DSR users: total labor use is 119 person-days among small landholders but is 94 person-days among large landholders among non-DSR users.

Another inference we draw from Table 21 is that small landholders can save more labor per day per ha by using DSR than larger farmers can. This may be because small farmers use labor for manual transplanting more intensively than large farmers do and by adopting DSR they can decrease labor more than large farmers. Moreover, the survey results also showed that small farmers save hired labor use more than large farmers. Regarding family labor use, we find that the difference in family labor use between DSR and non-DSR users is about the same across the three landholding groups.

Table 21. Labor use (person-days per ha) in 2012 by landholding size: DSR vs. non-DSR plots.

Descriptors	By DSR use in 2012 DSR plots	Non-DSR plots[a]	Difference
Total labor	67.8	113.2	−45.5**
By landholding size			
Small landholders	62.0	118.6	−56.6**
Medium landholders	66.7	113.9	−47.2**
Large landholders	68.2	94.1	−26.0*

[a] 16 cases of broadcasting and 4 cases of machine transplanting are included with 117 cases of manual transplanting. * and ** indicate the 5% and 1% significance level, respectively.

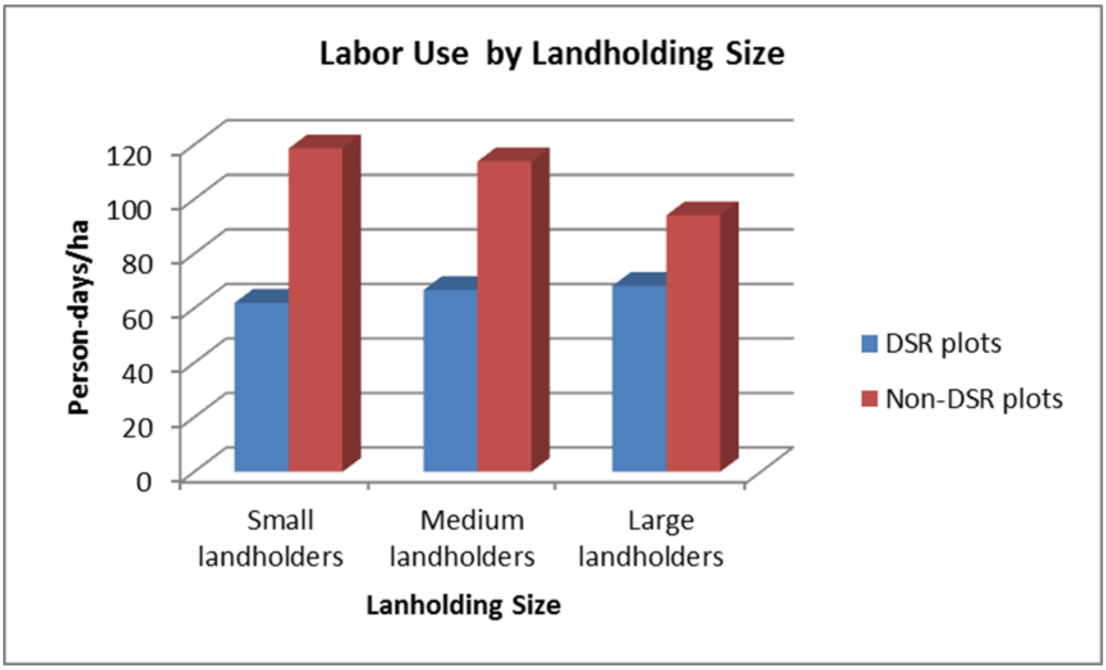

Figure 10: Labor Use per ha in 2012 by Landholding Size: DSR vs. Non-DSR plots

Finally, Table 22 shows the average daily wage rates for different labor activities for male and female hired workers. The data are obtained from our survey data. Female workers are hired mostly for transplanting and weeding and their wage rates are much lower than the wage rates for male workers for the same activities. For instance, the average wage rate for transplanting earned by males is Rs. 33 higher than that of females. For weeding, the difference is even more: Rs. 40. Male workers are hired for seed and land preparation, direct seeding, application of herbicide, and application of other inputs. For these activities, male workers are paid about Rs. 150/ha. We use these wage rates to calculate labor use costs and estimate profits in the next subsection.

Table 22. Daily labor wages (in Rs./ha) for male and female workers.

Activities	Male workers	Female workers
Seed and land preparation	152.1	
Transplanting	144.0	111.8
Direct seeding	151.9	
Weeding	123.5	83.4
Application of herbicide	144.4	
Application of other inputs	151.7	
Total	147.1	94.4

6.4. Revenue and cost calculation

In this subsection, we calculate profits for DSR and non-DSR plots. Before we present the results, we need to make some caveats. Although we use nonexperimental cross-sectional data obtained from farmers and are unable to estimate a causal impact of adopting DSR on farmers' profits, we still believe that the results in this subsection provide a reasonable proxy for the causal impact for the following reason. Our samples are taken from farmers who have adopted DSR at least once in the past 4 years. Thus, both DSR users and nonusers in 2012 have similar characteristics. Because of this sampling method, we can consider non-DSR users as a counterfactual group to DSR users. If we simply compare farmers randomly selected from target areas, we might be comparing DSR users with farmers who would never adopt DSR. But this is not what we present in the report.

In addition, to make the comparison more meaningful and precise, we decided to compare DSR with manually transplanted rice (TR). Thus, we excluded 20 farmers who used broadcasting and machine transplanting from the sample. We also excluded 75 farmers who cultivated hybrid rice because, as we have seen in Section 6.1, the average yield of hybrid rice was unusually low under DSR in 2012. By including hybrid rice in the sample, our conclusions could be biased. Thus, the results we present in this subsection are comparisons of DSR and TR of nonhybrid rice.

The results in Table 23 show that the average profit of DSR plots is higher than that of TR plots by Rs. 1,971/ha.[4] However, this difference is not statistically significant, suggesting that there is no difference in profits across DSR and TR plots. The average total cost of DSR plots is Rs. 15,629/ha and the average total cost of TR plots is Rs. 18,868/ha. The difference is Rs. 3,239/ha and it is statistically significant at the 5% level. Thus, we can say that the average total cost is lower in DSR plots than in manual transplanting plots. But, the revenue is lower in DSR plots. This is because the yield is slightly lower in DSR plots. The low revenue in DSR plots reduces their profit.

The low costs in DSR plots come from labor costs. The average hired labor cost is Rs. 5,114 in DSR plots and this is less than the average hired labor cost in TR plots by Rs. 3,157. The imputed family labor cost is also lower in DSR plots than in TR plots by Rs. 2,519. The seed cost is lower in DSR plots than in TR plots. However, the difference between the DSR and TR plots shrinks when we add the costs of inputs and service providers because these costs are higher in DSR plots than in TR plots.

[4] The exchange rate was Rs. 54.2 for US$1 in January 2013, a few months after the kharif 2012 harvest.

Table 23. Revenue and costs (Rs./ha): DSR and transplanted rice (TR) plots.

Variables	By DSR use in 2012		
	DSR plots	TR plots[a]	Difference
Total revenue	40,627	42,545	−1,918
Total paid costs	15,629	18,868	−3,239*
Profit	25,648	23,677	+1,971
Breakdown of paid-out costs			
DSR service providers	1,932	-	+1,932
Seeds	861	1,318	−457**
Inputs	4,934	4,068	+866
Hired labor	5,114	8,271	−3,157**
Family labor	2,691	5,210	−2,519**

[a] From the transplanted rice (TR) plots, we excluded 75 plots of hybrid rice, 16 plots of broadcast rice, and 4 plots of machine-transplanted rice to make the comparison of DSR and TR in the table. The exchange rate was US$1 = Rs. 54.2 in January 2013.

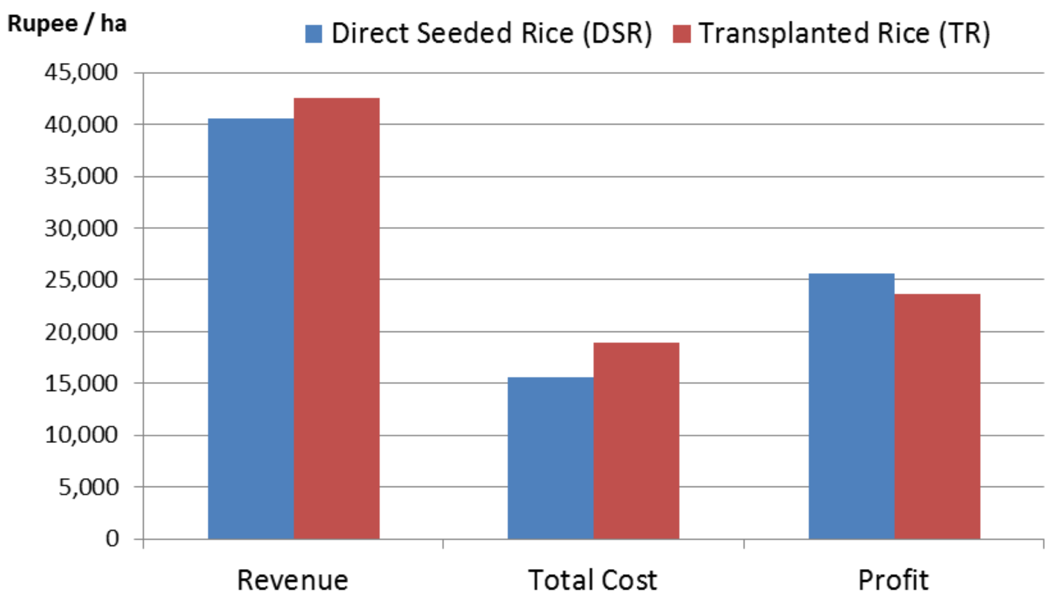

Figure 11. Per ha Revenue, Total Cost, and Profit between DSR and TR Plots in 2012

Table 24. Profit per ha (Rs./ha) in 2012 by landholding size: DSR vs. TR plots.[a]

Unit: Rupee/ha

Landholding size	By DSR use in 2012 DSR plots	TR plots	Difference
Small landholders	28,816	27,712	+1,104
Medium landholders	24,832	23,711	+1,121
Large landholders	23,982	18,789	+5,193

[a] The exchange rate was US$1 = Rs. 54.2 in January 2013. * and ** indicate the 5% and 1% significance level, respectively.

Finally, we compare profits between DSR and TR plots across three landholding groups. Table 24 shows that the difference in the average profit per ha is larger among the large farmers than among small and medium farmers. This is because the average profit is low among large farmers who use TR. It seems that large farmers produce rice less intensively when they employ TR. Therefore, it seems that DSR benefits large farmers more than small and medium farmers, but the differences in profits are not statistically significant. Thus, we cannot make any definitive conclusion from the table.

In summary, we find that the average total cost is lower in DSR plots than in TR plots by more than Rs. 3,200/ha. However, because the average yield is lower in DSR plots than in TR plots, the average revenue is lower. As a result, we do not find a significant difference in the average profit per ha between DSR and TR plots. Even when we compare the results across three different groups of farmers, the conclusion remains the same. Thus, with respect to profits, we cannot say that DSR is more profitable than manually transplanted rice.

By adopting DSR, however, farmers can also reduce water use and protect the soil. What do farmers think about such benefits of DSR? What is their perception of DSR? Because the overall benefits of DSR cannot be captured by monetary compensation, we asked farmers about their perceptions of DSR. We present the survey results about their perceptions of DSR in the next section.

7. Perceptions of DSR

Men's perceptions about DSR

In this section, we examine perceptions of DSR among farmers. By using DSR, farmers not only save labor costs but also save water use and protect the soil (Kumar and Ladha 2011). Thus, we cannot capture the benefits of DSR only in terms of revenues and costs. To investigate how farmers consider the benefits of DSR, we asked farmers about their perceptions of DSR. The questions cover nonmonetary benefits of DSR.

In our survey, we asked farmers whether they agreed with 10 statements about DSR on a 5-point Likert scale. If they agreed with one statement strongly, we asked them to give a score of 5; if they strongly disagreed with the statement, they gave a score of 1. The 10 statements are grouped in three general categories. The first group consists of three statements about farmers' *general attitude toward DSR*: (1) I think DSR is a very good practice, (2) Other farmers think DSR as a good practice, and (3) It is easy to adopt DSR.

The second group of statements is about *resource conservation* of DSR and consists of another three statements: (4) DSR requires less labor, (5) DSR saves water, and (6) DSR protects the soil. The third group consists of other characteristics of DSR: (7) DSR requires my labor less, (8) DSR requires more weeding, (9) DSR allows early planting for rabi crops, and (10) DSR is risky (may suffer from a yield loss). Note that statement 4 considers hired labor whereas statement 7 considers respondents' own labor.

Table 25 presents the average scores for the 10 statements from DSR users and nonusers in 2012. As expected, we find that DSR users have higher scores on positive statements about DSR than non-DSR users. For both general attitude and resource conservation, DSR users agree with positive statements about DSR more that non-DSR users. This suggests that DSR users recognize that DSR is a good technology that can save resources, such as labor and water, and protect the soil. In addition, DSR users agree that other farmers, such as their neighbors and friends, also think DSR is a good technology and that it is easy to adopt DSR.

DSR users also agree with statement 7, which states that the technology saves the respondents' labor requirement. This is probably because DSR users do not need to engage in seed preparation and transplanting. They also agree that DSR allows them to plant rabi crops early.

Statement 9 is about weeding. Because weed problems are listed as major constraints by respondents, we had expected that DSR users would agree more with the statement indicating that DSR requires more weeding. However, we found no difference in the response to this statement between DSR users and nonusers. In Section 6, we also found little difference in labor use in weeding between DSR users and nonusers. Thus, although DSR users consider weeds a problem, in terms of using labor in weeding, they do not think

DSR requires more labor for weeding. Probably, they think that they need to deal with weed problems with herbicide.

Because under DSR seeds are directly planted, there is a risk that the planted seeds fail to germinate, especially if rain fails during the initial production stage. Thus, some farmers are concerned about the failure. In Section 2, we found that some farmers decided not to apply DSR because of water scarcity, and their concern is mostly about water scarcity soon after planting seeds. In Table 25, however, we found that both DSR users and nonusers do not consider DSR to be a risky technology: the average scores are close to 3.0, and the score of 3.0 suggests neither agree nor disagree with the statement.

Table 25. DSR perceptions among male farmers on a 5-point Likert scale.[a]

Perception statement	DSR users	Non-DSR users	Difference A − B
	(A)	(B)	(C)
General attitude toward DSR			
(1) I think DSR is a very good technology (practice).	4.29	4.03	+0.26
(2) Other men (women) think DSR is a good practice.	3.97	3.67	+0.30
(3) It is easy to adopt DSR.	4.34	4.08	+0.26
Resource conservation			
(4) DSR requires less labor.	4.26	4.09	+0.17
(5) DSR saves water.	4.07	3.86	+0.21
(6) DSR protects the soil.	4.04	3.80	+0.24
Other characteristics			
(7) DSR requires my labor less.	4.20	3.95	+0.25
(8) DSR allows early planting for rabi crops.	3.82	3.69	+0.13
(9) DSR requires more weeding.	3.99	4.03	−0.04
(10) DSR is risky (may suffer from a yield loss).	3.04	3.03	+0.01
Average scores on positive statements (1) – (8)	4.12	3.90	+0.22
Factor analysis			
DSR perception index based on (1) – (10)	0.225	−0.259	+0.474**
Number of observations	164	162	

[a]1 = strongly disagree, 2 = disagree, 3 = neither, 4 = agree, 5 = strongly agree.

One statement for which DSR users have a lower score than non-DSR users is statement 9. This statement is a negative statement about DSR; thus, it is understandable that DSR users have a lower score than nonusers. Statement 10 is another negative statement about DSR, but we do not have any difference between DSR users and nonusers about this statement.

The average score for eight positive statements is 4.12 for DSR users and 3.90 for non-DSR users. Thus, we can easily show that DSR users have a higher score than non-DSR users.

The results in Table 25 are informative, but analyzing scores on 10 statements on a 5-point Likert scale makes it difficult for us to conduct further analysis. Thus, we constructed an index to capture farmers' perceptions about DSR in a single index by conducting a factor analysis. Factor analysis is an interdependence technique, whose primary purpose is to define the underlining structure among the variables in the analysis. Hair et al (2010) suggested that, if the constructs or factors are likely to be correlated with each other, it is necessary to use oblique rotation for the factor solution and interpretation of the factors and also create indices. Factor loading highlights the dimensionality, as it indicates that, the higher the load, the more relevant in defining the factor's dimensionality. The factor load has been estimated for the various indicators in each construct. We have followed the Kaiser criterion to retain those factors with eigenvalues equal to or higher than 1 and also measured total variance accounted for by each factor. Indices for farmers' psychological constructs have been predicted by estimating the individual scores through the regression coefficients from the factor model. The mean value for the constructed indices is set to zero.

By applying factor analysis, we generated a DSR perception index (detailed information about the factor analysis is provided in the Appendix). Note that factor analysis uses information from both positive and negative statements about DSR. Thus, to construct the index, we used all 10 statements. The average scores of the DSR perception index are presented in Table 26. The average score is 0.225 for DSR users and −0.259 for non-DSR users. Thus, the difference is 0.484 and it indicates that DSR users have better perceptions about DSR than non-DSR users, as expected.

Table 26. DSR perception index among male farmers by different factors.[a]

Factors	All	DSR users	Non-DSR users	Difference (B – C)
	(A)	(B)	(C)	(D)
By landholding size				
Small landholders	0.106	0.352	−0.110	+0.462
Medium landholders	−0.073	0.150	−0.301	+0.451
Large landholders	−0.052	0.222	−0.427	+0.649
By reason not using DSR among nonusers in 2012				
Weed problems			−0.562	
Water scarcity			−0.230	
Unavailability of service providers			−0.112	
By most severe problem for DSR among users in 2012				
Weed problems		0.129		
Water scarcity		0.313		
Unavailability of service providers		0.582		

[a] 1 = strongly disagree, 2 = disagree, 3 = neither, 4 = agree, 5 = strongly agree.

Using the index, we further investigated the perceptions of DSR across different farmer groups (Table 26). First, we compared the average index scores across three landholder groups and found that small landholders had the highest index score. The average index score was 0.106 for small landholders, but it was −0.073 and −0.052 for medium and large landholders, respectively. Among DSR users in 2012, the average index score of small landholders was high at 0.352.

The high score among small landholders could be surprising at first because DSR is considered a good practice for large landholders. However, as we found in Table 20, the reduction in labor per ha is large among small landholders probably because they use hired labor for manual transplanting intensively. Thus, small landholders may find it cost-effective to use DSR to save hired labor costs.

In Section 5, we show that weeds, water scarcity, and unavailability of service providers are major reasons for not adopting DSR and the most severe problems occurring with DSR users. Depending on the nature of the problems, farmers may have different perceptions toward DSR. For instance, farmers' perceptions of DSR might be high but they are unable to use DSR because of the lack of availability of service providers. In this case, they may adopt DSR as soon as service providers become available. On the other hand, if farmers think that water scarcity is severe and beyond their capacity, their perceptions of DSR could be low.

Table 26 shows that farmers who listed weed problems as the main reason for not using DSR have the lowest index score at −0.562. It seems that it would be difficult to convince them to use DSR unless they were provided with means to overcome weed problems. Farmers who listed water scarcity as the main reason for not using DSR have the second lowest score. Under the category of water scarcity, many farmers specified delayed monsoon as the major reason for not using DSR. This suggests that, if monsoon were not delayed, they might have used DSR. The better DSR index score may reflect this possibility.

Farmers who listed unavailability of service providers have the best index score among nonusers. This suggests that they have relatively good perceptions about DSR and would use DSR if service providers became available. Thus, it seems that they could be a good target for promoting DSR among nonusers.

Among DSR users, we find the same pattern: the DSR users who listed weed problems as the most severe problem occurring during their DSR production have the lowest perception score, while farmers who listed unavailability of service providers have the highest index score.

The results in Table 26 indicate that weeds are the most serious problem for both farmers who use DSR and those who consider using DSR.

Women's perceptions about DSR

In addition to male farmers' perceptions about DSR, we also asked about their wives' perceptions about DSR in our survey. The results appear in Table 27. We need to note that the wives of our sample farmers, who are relatively better-off farmers, do not work in the rice fields much, as we found in Table 19. Thus, their labor may not decrease by adopting DSR. The results in this section might be different if we had specifically asked the questions to wives of poorer farming families (small landholding size and lower caste households) who transplant rice seedlings.

Table 27 shows that women have lower scores on DSR than men in general. For instance, although the average scores are around 4.0 among DSR users among men, the scores are about 3.8 among women. The average score of statements 1 to 8 is 3.75 among women who use DSR, while it is 4.12 among men who use DSR. Thus, it seems that women are less likely to give higher scores than men.

Table 27. DSR perception among female farmers on a 5-point Likert scale.[a]

Perception statements	DSR users	Non-DSR Users	Difference (A – B)
	(A)	(B)	(C)
General attitude toward DSR			
(1) I think DSR is a very good technology (practice).	3.84	3.62	+0.22
(2) Other men (women) think DSR is a good practice.	3.41	3.17	+0.24
(3) It is easy to adopt DSR.	3.99	3.81	+0.18
Resource conservation			
(4) DSR requires less labor.	3.94	3.73	+0.21
(5) DSR saves water.	3.86	3.75	+0.11
(6) DSR protects the soil.	3.54	3.46	+0.08
Other characteristics			
(7) DSR requires my labor less.	3.80	3.61	+0.19
(8) DSR allows early planting for rabi crops.	3.60	3.44	+0.16
(9) DSR requires more weeding.	3.83	3.71	+0.12
(10) DSR is risky (may suffer from a yield loss).	3.01	2.99	+0.02
(11) DSR makes me better off.	3.55	3.20	+0.35
Average scores on positive statements (1) – (8)	3.75	3.57	+0.17
Factor analysis			
DSR perception index based on (1) – (11)	0.178	−0.202	+0.380**
Number of observations	155	138	

[a] 1 = strongly disagree, 2 = disagree, 3 = neither, 4 = agree, 5 = strongly agree.

Nonetheless, as we found among men, we found that women of DSR-using households have better scores than women from other households. The differences in the 5-point scale scores are about 0.2 and are similar to the differences found among men. The differences are large for the general statements about DSR: statements 1 to 3.

To women, we asked one question that we did not ask men: statement 11. This statement asks women if they think that DSR made them better off. Women of DSR households agree with this statement more than women of non-DSR households. The difference is large at 0.35. Therefore, it seems that DSR brings benefits to women in some ways. In statement 7, we ask them about DSR's benefit in reducing demand for their labor. Although women of DSR households agree with this statement more than women of non-DSR households, the difference is small. Thus, it seems that there are benefits in areas other than labor, but we do not know exactly how DSR makes women better off.

To conduct further analysis, we generated an index by again using factor analysis. The average score of the index is 0.178 among women of DSR households and −0.202 among women of non-DSR households. The difference is large. The index score of women is positively correlated with the index score of men, with a coefficient of 0.52. But, this level of correlation suggests that men and women may not completely agree on DSR.

Furthermore, we compare the average index score among women across different landholdings. Table 28 shows that women of small landholdings have a higher score than women of larger landholdings. We believe that this is because women of small landholdings have to work in the rice fields for transplanting rice and weeding. But surprisingly, women of large landholdings also have a high score, unlike men of large landholdings, as shown in Table 26.

Table 28. DSR perception index among female farmers by landholding size.

Landholding size	All	DSR users	Non-DSR users	Difference (B – C)
	(A)	(B)	(C)	(D)
By landholdings				
Small landholders	0.094	0.222	−0.043	+0.265
Medium landholders	−0.068	0.127	−0.283	+0.410
Large landholders	0.036	0.264	−0.301	+0.565

8. Conclusions

In this report, we examined the continuous use of direct-seeded rice (DSR). To identify farmers for this study, we collected lists of farmers who participated in DSR training conducted by CSISA in the 4-year period from 2008 to 2012 and farmers who received DSR services from CSISA-assisted DSR service providers in the same period. The aggregated list consists of 2,386 farmers. From the list, we randomly selected 360 farmers by stratifying them by district and the year that they were listed.

Because we chose sample farmers from the list of known DSR users, this study should not be considered as an adoption study of DSR among representative farmers of the target areas. Instead, the study should be considered as a dis-adoption study among known DSR users. By taking this approach, the adoption study has several advantages. First, we have an adequate number of DSR users in our sample. If we had employed a normal adoption study, we would have found an inadequate number of DSR users in our study areas because the DSR adoption rate is low. Second, by sampling farmers who adopted DSR at least once in the past, we can investigate the reasons for dis-adopting DSR. Farmers who used DSR in the past can provide useful information to identify constraints to adopting DSR. Third, a comparison of DSR users and one-time users in 2012 can provide us with a reliable estimate of the impact of DSR on input use, production, and profit because the non-DSR users in 2012 are realistic counterfactuals for the current DSR users. In the absence of randomized control trials among farmers or panel data, we think this is a reasonable approach.

In this study, we found the following:

(1) All of our sample farmers used DSR at least once from 2009 to 2012. About one-quarter of them never attended any DSR training. Among those who attended DSR training, about 75% of them attended CSISA-organized DSR training.

(2) About 57% of our sample farmers used DSR in 2012. The major reasons for not using DSR in 2012 were water scarcity (65%), weed problems (23%), and unavailability of service providers (11%).

(3) Among small farmers, whose landholding size is less than 0.5 ha, unavailability of service providers was one of the major reasons for not using DSR in 2012, while it was not a major problem for medium and large farmers.

(4) We found no difference in the average rice yields of DSR and non-DSR plots, except for hybrid rice. However, we found about a 40% reduction in labor use when farmers used DSR. The reduction in labor mainly comes from transplanting rice, which is conducted mostly by hired female workers.

(5) We found no significant difference in profit between DSR and manually transplanted rice (TR) plots. Although the average total cost is lower in DSR than in TR plots by more than Rs.

3,200/ha, the low average yield in DSR plots reduces the difference in the average profits of DSR and TR plots.

(6) Among men, DSR users in 2012 had a better perception of DSR than nonusers. They think DSR is a very good practice and saves labor and water. The perception of DSR is better among small farmers than among large farmers.

(7) Perceptions of DSR among female farmers show patterns similar to those of men. The perception index of women is positively correlated with that of men.

These findings suggest several policy recommendations and recommendations for CSISA hub activities:

(1) Small farmers need assistance in receiving DSR service from service providers. Small farmers listed unavailability of service providers as one major reason for not using DSR. However, medium and large farmers who live in the same areas do not list this as a major constraint. This suggests that service providers exist in the area, but they may consider providing services to small farmers not economical because of the large transaction costs. Thus, it is important to reduce the transaction costs to serve small farmers by, for instance, aggregating demand of small farmers. As we find in Section 7, small farmers have a good perception of DSR and they can decrease labor more per ha than large farmers because they use labor more intensively than large farmers. We find that the average profit per ha of DSR is higher for small farmers than for large farmers.

(2) We find a very low rice yield of hybrid rice in DSR plots. Because hybrid rice needs to be cultivated in controlled production environments, some abiotic stresses or mismanagement might have caused the loss. Cultivating hybrid rice in DSR plots appears to be riskier than cultivating high-yielding varieties in DSR plots.

(3) As we find in farmers' perceptions, farmers recognize that DSR saves labor and water and protects the soil. Some of the benefits of conserving resources are not captured by the economic factors, but the knowledge of such benefits of DSR should be disseminated to farmers.

Numerous studies have been conducted on DSR by crop and soil scientists in agricultural experimental fields. However, not many studies have been conducted by social scientists, through interviewing farmers. Thus, this study adds to the small list of socioeconomic studies of DSR. As DSR becomes popular among farmers, there should be more socioeconomic studies to identify the constraints to adopting DSR and evaluate the benefits of the technology, particularly among small and medium farmers.

References

Hair JF, Black WC, Babin BJ, Anderson RE. 2010. Multivariate data analysis: a global perspective. Seventh Edition. Delhi: Pearson.

Kumar V, Ladha JK. 2011. Direct seeding of rice: recent developments and future research needs. Adv. Agron. 111:297-413.

Neeraja et al 2007

Paris T, Cueno AD, Singh A. 2008. Characterizing and understanding the socioeconomic conditions of farming households in rainfed rice environments: a case in eastern Uttar Pradesh, India. In: Improving productivity and livelihood for fragile environments. IRRI Technical Bulletin No. 13. Los Baños (Philippines): International Rice Research Institute. p 36-54.

Paris TR, Singh A, Hossain M, Luis J. 2000. Using gender analysis in characterizing and understanding rainfed lowland rice environments. In: Tuong TP, Kam SP, Wade L, Pandey S, Bouman BAM, Hardy B, editors. Characterizing and understanding rainfed environments. Proceedings of the International Workshop on Characterizing and Understanding Rainfed Environments, 5-9 Dec. 1999, Bali, Indonesia. Los Baños (Philippines): International Rice Research Institute. p 339-370.

Rao AN, et al. 2007. Weed management in direct seeded rice. Adv. Agron. 93:153-255.

Sankar et al 2006

Septiningsih et al 2009

Singh VP, et al. 2008. Direct seeding and weed management in the irrigated rice-wheat production system. In: Singh Y, et al, editors. Direct seeding and weed management in the irrigated rice-wheat cropping system of the Indo-Gangetic Plains. Los Baños (Philippines): International Rice Research Institute.

Timsina J, Connor DJ. 2001. The productivity and management of rice-wheat cropping systems: issues and challenges. Field Crops Res. 69:93-132.

Appendix

Table A1. Rice yield by variety.

Variety name	Variety type	All (number & %)	Rice yield by DSR use		
			All	DSR plots (t/ha)	Non-DSR plots
Samba Mahsori	HYV	71 (23.5)	4.46	4.21	4.72
Swarna	HYV	50 (16.6)	4.58	4.91	4.05
Arize 6444	Hybrid	33 (10.9)	3.21	3.28	-
Swarna-Sub1	Submergence	24 (8.0)	4.56	4.51	4.63
Sarju-52	HYV	21 (7.0)	3.92	- [a]	4.00
Rajendra Mahsori	HYV	16 (5.3)	4.09	-	-
PHB 71	Hybrid	9 (3.0)	-	-	-
Dhaani	Hybrid	6 (2.0)	-	-	-
Arize 6129	Hybrid	4 (1.3)	-	-	-
Others		68 (22.5)	3.77	3.61	4.04
All		302 (100)	4.09	3.88	4.36

[a] Yields based on less than 10 cases are not reported in the table.