Determinants of Conservation Agriculture in the Indo-Gangetic Plains

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Abstract

This paper assesses the major determinants of conservation agriculture (CA) in the Indo-Gangetic Plains (IGP), using data from Nepal, India and Bangladesh. In order to analyze this, combinations of parametric and non-parametric methods are used. The analysis shows that households that operate large farms are more likely to adopt CA, implying that resource endowment matters for technology adoption. Likewise, farmers are more likely to adopt CA in irrigated land, indicating land quality as a major determinant to CA adoption. This might have implication in cost reduction or profit maximization with CA adoption. Results indicate that households in which women make decision regarding the adoption of farm technologies, often prefer CA as compared to their male counterparts. We also found significant differences between the countries in the IGP with regard to the adoption of CA.

JEL classifications: O13, O33, Q16, Q18

Keywords: Conservation agriculture, Indo-Gangetic Plains, Nepal, India, Bangladesh

1. Introduction

Increasing climate variability, growing population, and the problem of food security have threatened the sustainability of agriculture in south Asia (Sivakumar and Stefanski 2011), where more than one fifth of the world's population reside . Furthermore, majority of the population in this region rely heavily on the agricultural sector for their livelihood. The major question now is whether traditional agricultural practices can meet the increasing demand for food without deteriorating the environment. The challenge of agricultural sustainability is further aggravated by recent climate change, water scarcity and degradation of ecosystem services (Aggarwal and Sivakumar 2011). Given that agriculture is one of the major contributors to green house gases leading to climate change, adopting climate-smart farming practices such as conservation agriculture (CA) can help both mitigate and adapt to climate change (Hobbs et al. 2008; Lal 2006; Lal 2011). CA leads to better use of agricultural resources through an integrated management of land, water and other biological resources and can enhance food security and simultaneously mitigate the climate related risks in agriculture (FAO). Furthermore, conservation agriculture is important in view of rapid degradation of natural resources and the need to reduce the cost of production in agriculture. Major CA principles, i.e., reduced tillage, land laser levelling, the retention year-round ground cover and crop rotation, help reduce water and nutrient losses in farming, increase crop yields and also, significantly help farmers cope with greater climatic variability. Despite these benefits, the adoption of CA has been relatively slow in many regions (FAO). Therefore understanding the factors that determine farm households' decision to adopt CA is crucial in designing appropriate agricultural policy for achieving food security (Hobbs 2007; Nyanga et al. 2011). This is what this study looks for.

This study focuses on part of the Indo-Gangetic Plain (IGP), including villages in India, Nepal and Bangladesh. The IGP, which is the major cereal basket of South Asia, covers about one-fifth of the total geographical area in India, Nepal, Bangladesh and Pakistan (Panigrahy et al. 2009). Fertile soils, favourable climatic condition and abundant supply of water in IGP made it favourable region for rice and wheat production (Aggarwal et al. 2004). However, major concerns now are that rice-wheat cropping rotation in the IGP is approaching its productivity limits, and the resource base is under threat due to various degradation processes such as decreasing soil organic matter, receding ground water and increasing salinity (Rao et. al. 1998). These resource degradation problems are largely due to the intensive conventional production systems (Gupta and Sayre 2007; Hobbs and Gupta 2000; Sharma and De Datta 1985). At present, the challenge is to produce enough food from the same land and water resources, besides sustaining soil and environmental quality. On this backdrop, agriculture systems need to adopt new technologies that are able to enhance productivity and promote sustainability of agriculture (Jat et al. 2009). This calls for the adoption of conservation agriculture.

A recent review of farmers' adopting conservation agriculture in several countries (Knowler and Bradshaw 2007) exhibit that we need further studies to dig out the factors that determine the adoption decision. Previous studies examining the factors affecting technology adoption are mostly country specific even though the impacts of adoption or non-adoption are in many cases regional. This paper tries to fill in the gap by studying CA adoption decision among the farmers in the Indo-Gangetic Plains and thus providing new insights on the topic.

Another important issue in the case of developing countries is that farm households in the rural areas of these countries operate under multiple market imperfections (Sadoulet and Janvry 1995; Aryal and Holden 2012). Under such a situation, households' decision regarding efficiency enhancing technology adoption is affected by its asset ownership (Pender and Kerr 1998; Holden et al., 2001; Sadoulet and Janvry 1995). For instance, as land is the main asset for the household in rural areas, size of land holding can affect the decision to adopt technology through its effect on access to credit market and also its impact on farm household's risk bearing capacity. In general, under credit market imperfections large farmers can take more risk as compared to small farmers and usually do not face liquidity constraints. As most of the farmers in south Asia are small holders, there is no alternative to increase farm productivity rather than using farm intensively in order to achieve food security. Further we also need to focus on risk and households attitude towards risk as CA is sometimes considered as not appropriate for small farmers because they cannot bear the risk of yield reductions during the initial stage of its adoption (Nkala et al. 2011). As we do not have data on risk and its impact on households' decision to adopt technology, we tried to control this by including several socio-economic variables that shape households' risk bearing capacity (Holden et al., 1998).

The major contributions of the paper are as the followings. This is a paper which uses primary data from three countries in the Indo-Gangetic plains and provides a cross-country analysis on the determinants of conservation agriculture.

2. Review of literature

Studies show that multiple factors affect farm households' decision to adopt technology and thus, there is no straight forward answer to the question: What determines technology adoption in general and the adoption of CA technology in particular? In many cases, technology adoption decision is location- and household specific. Imperfect information (Foster and Rosenzweig 1995), risk and uncertainty(Shively 1997) , institutional constraints and institutional support (Tiwari et al. 2008) , availability of inputs, cost saving (Erenstein et al. 2012), human capital (Asfaw and Admassie 2004) and affordability (Nkala et al. 2011) are considered to be the major factors for technology adoption (Feder et al. 1985; Foster and Rosenzweig 1995; Kohli and Singh 1997). Kohli and Singh (1997) indicate that the rapid adoption of high yielding varieties (HYV) in the Indian state of Punjab is associated with the availability of inputs through government supplies, while McGuirk and Mundlak (1991) found the adoption of HYVs is largely determined by the availability of fertilizer and irrigation facilities because the success of HYVs is mainly depend on these inputs.

Social networks and learning also play major role in technology adoption. In India, Besley and Case (1993) found that once farmers know that the new technology is more profitable in comparison to what they are using currently, they are more likely to adopt it. (Foster and Rosenzweig 1995) found similar results in India while examining the adoption of high yielding varieties. They reported that farmers initially may not adopt a new technology due to imperfect knowledge about it however; they adopt it when they experience the technology by themselves or through their neighbours. A recent study (Erenstein et al. 2012) shows that farmers in south Asia are increasingly adopting conservation agriculture (in this case, zero-tillage wheat) mainly because that reduces production cost substantially. Recent study in Zambia by Nyanga et al., (2011) indicated that adaptation to climate change such as CA is determined not only by technical factors, but to a large extent by the social factors like farmers' perceptions towards it. Another study in Nepal (Raut et al. 2011) show that irrigation, land holding size and the net income from adopted technology as the major factors influencing farmers' decision to adopt technology. A recent study in Bangladesh reported that educational level and income are positively associated with the adoption of technology (in this case, adoption of power tillers) (Quayam and Ali 2012). In the Philippines, Shively (1997) found that the likelihood to adopt soil conservation technology decreases with a rise in consumption risk.

The level of access to information system outside the farm community is also an important factor determining the outcome of the technology adoption decision. Weak links to outside information system as well as markets, both input and output markets, can explain why farmers in a closed community continue using traditional practices (Wall, 2007). Therefore, small farmers with limited access to capital and credit market might face more difficulty in adopting new technology as these factors restrict their capacity to get access to non-traditional inputs. In Laos, Lestrelin et al. (2011) found that CA is not necessarily incompatible with small holder farming, but while we require complex crop associations and rotations in CA for integrated weed control and reduced chemical use , a broader transformation of the agricultural industry and the current market demand are essential for the better diffusion of CA technologies. In their study of the rice-wheat systems in south Asia, Hobbs et al. (2008) stated that CA (no-tillage) is mainly spreading in the irrigated RW regions. They also reported that rapid expansion of CA in the recent years can be attributed to the application of farmer participatory approaches which allows farmers to experiment with the technology in their own farm plots and the promotion of equipment required for CA such as no-till drillers at the local level.

Overall, the review indicates that there is still a need to inquire why some technologies are adopted and other just die out after projects stop supporting them. Alternatively, what makes certain technologies to go beyond the stage of the project and to spread across other scales?

3. Conceptual Framework

Like most developing country households in rural areas, farm households in Indo-Gangetic Plain operate under multiple market imperfections and production uncertainties including credit and insurance market imperfections and labour and land rental market imperfections. Under such imperfections, farm households' decisions regarding farm production and consumption becomes inseparable (Holden et al. 2001). Consequently, farm households' decisions to invest in or adopt farm technology depend on their access to and ownership of productive resources such as land and off-farm income. Moreover, production as well as consumption risks affect farm households' decision to adopt technology. Farmers now face a situation of increasing climate risk. Production risk may be associated with climate risk, but for simplicity let us assume that distribution of production risk is exogenous to farmers' activities and thus, considered as purely random. Likewise, this study does not focus on the effect of consumption risk on technology adoption (for details on this see Shively, 1997).

Under such a situation, choice of technology adoption is related to its expectation regarding technology i.e., whether the new technology increases the farm income as compared to the existing (traditional) technology or not. In addition, we need to consider the fact that farmers in developing countries are both consumer and producer of their farm products and under the condition of market imperfections, production and consumption decisions of the farm households are not separable. Let us consider the following production function:

1) $q_{it} = g(\boldsymbol{X}; u_{it})$

where q_{it} denote the level of output, $\boldsymbol{X}$ is a vector of inputs, and u_{it} refers to stochastic disturbance term. Given this, assume that a farm household maximizes expected utility which is the function of discounted profit overtime.

2) $Max\ E[U] = E\left[\int_t^T U\ dt\right] = E\left[\sum_{t=0}^{T} \frac{1}{1+\rho} \pi_t\right];\ \varphi(.)$

where $E[U]$ is expected utility, ρ is the discount factor, π_t is the farm profit and $\varphi(.)$ is the stochastic disturbance function. While considering conservation investment as also a function of land size (A) and other household specific variables ($\boldsymbol{Z}$), the profit equation becomes as follows.

3) $\pi_t = p^e q_t - \omega \boldsymbol{X} - \boldsymbol{i}\boldsymbol{X_c}(A; \boldsymbol{Z})$

Where p^e is the expected price of agricultural produce, ω is the price of inputs, i refers to the per unit cost of practicing conservation agriculture (CA), $\boldsymbol{X_c}$ input required per unit of land for CA. However, equation 3 can be simplified by assuming a constant cost of investment for conservation agriculture (in this case, the last part of equation 3 vanishes while taking first order conditions). From equation 1-3, we get following first order condition:

4) $p^e \frac{\partial g(.)}{\partial X} = \omega + i \frac{\partial X_c(.)}{\partial X}$

When we assume market imperfections, the first order condition, in this case differs from the simple equality of marginal value product and price of the respective inputs. This is basically due to the assumption of nonlinearity in the cost of conservation agriculture, i.e., farmers with different asset position might face different cost of adopting conservation agriculture. Under such a case, the theoretical analysis alone cannot provide the exact direction on whether a farmer adopts or not, it remains an empirical question.

5) $p^e \frac{\partial g(.)}{\partial X} \geq \omega + i \frac{\partial X_c(.)}{\partial X}$

For simplicity in estimation, we now go for reduced form model. The probability of adoption of CA is thus given by:

$Prob(CA) = f(H^z, E, A^q)$

Where H^Z, E and A^q refer to household characteristics, household asset endowment, and land quality variables respectively. Therefore, household characteristics such as endowment of labor, education and trainings obtained by household members, along with endowments of the household such as land and the land quality variables can influence the decision to adopt farm technology such as CA.

We therefore, test the following hypotheses empirically.

H1: Households that operate large farms are more likely to adopt CA as they have capacity to invest in new technology.

H2: Land-poor households are less likely to adopt CA as they rely more on off-farm income

H3: Farmers are more likely to adopt CA in irrigated land as they can get the return from their investment soon.

H4: Education and access to information is associated positively with likelihood to adopt CA

4. Empirical methods

CA adoption decision is not a continuous random variable and thus we need to set it as a discrete choice decision problem of whether or not to adopt CA. We therefore, applied a probit model in order to examine the determinants of CA adoption. Of the main three binary limited dependent variable models, which can be applied in our case, linear probability model suffers from the problem of heteroscedasticity, normality and the limits of probability range and thus, using probit or logit model is a better alternative (Wooldridge 2002; Cameron and Trivedi 2009). The only difference between logit and probit models is the assumption about the distribution function. Therefore, we used probit model for the empirical estimation. The right hand side variables in the estimation of the model were chosen based on our theoretical framework and the review of previous literature. As a farm household can use more than one type of CA technology simultaneously, sample households are classified as CA adopters when they use at least one type of CA technology and non-adopters, otherwise. In this study, CA technologies refer to the use of laser land leveller, bed planting, zero tillage, Turbo happy seeder, rotavator and direct seeded rice.

Adoption or non-adoption of CA are mutually exclusive binary outcomes, and thus, we need to examine the determinant of the probability p, the adoption of CA, rather than an alternative outcome with probability of 1-p, i.e., non-adoption of CA. Using probit model, we measure how the probability of adoption, p varies across individual households as a function of regressors. Therefore, the conditional probability of adoption can be expressed as

$$p_i = pr(y_i = 1|\boldsymbol{X}) = \Phi(\boldsymbol{X}'\beta) = \int_{-\infty}^{X'\beta} \emptyset(z)dz$$

where $\Phi(.)$ is the standard normal cumulative distribution function and $\phi(.)$ is standard normal density function. The marginal effect of an individual regressor on the probability of adopting CA is given by:

$$\frac{\partial p}{\partial x_j} = \phi(\boldsymbol{X'\beta})\boldsymbol{\beta_j}$$

However, the cross sectional data, which only provides the snapshot at a point in time, is not enough to capture the possible dynamic nature of technology adoption decisions (Besley and Case 1993). Consequently, our analysis will only provide the insights into the farm and farmer characteristics that are associated with the final decision on adopting CA rather than exploring the process of adoption that emerges over time. Not having panel data, we also could not control for unobserved heterogeneity across households as household effects and state-dependence cannot be handled with cross sectional data (Wooldridge 2002; Besley and Case 1993).

In order to test the robustness of the results that we obtained from parametric regression analysis, we also estimated non-parametric regressions to look at the association between CA adoption decision and key variables such as land owned (as a proxy for capacity to invest), education (as a proxy for human capital), consumption expenditure (as a proxy for poverty) and share of irrigated land in total land (better land quality). In general, non-parametric regression methods fit a local relationship between the dependent variable, y and the regressor, x. The local relationship refers to the separate fitted relationships that are obtained at different values of x (Cameron and Trivedi 2009). Unlike parametric regressions, non-parametric regressions are free from the assumptions about population distribution.

Let us consider a local linear regression model: $y = m(x) + u$, where m(.) is the conditional mean function and x is a scalar. A local regression estimate of $m(x)$ at $x=x_0$ is a local weighted average of y_i , i=1, 2, ...,N, that places greater weight on observations while x_i is closer to x_0 and less weight on observations while x_i is far from x_0. This can be represented by:

$$\widehat{m}(x_0) = \sum_{i=1}^{N} w(x_i, x_0, h)\, y_i$$

where $w(x_i, x_0, h)$ represents the weight which decreases when the distance between x_i and x_0 increases. As the bandwidth parameter h increases, more weight is placed on observations for which x_i is close to x_0. The local linear estimator additionally includes a slope coefficient and at $x=x_0$ minimizes,

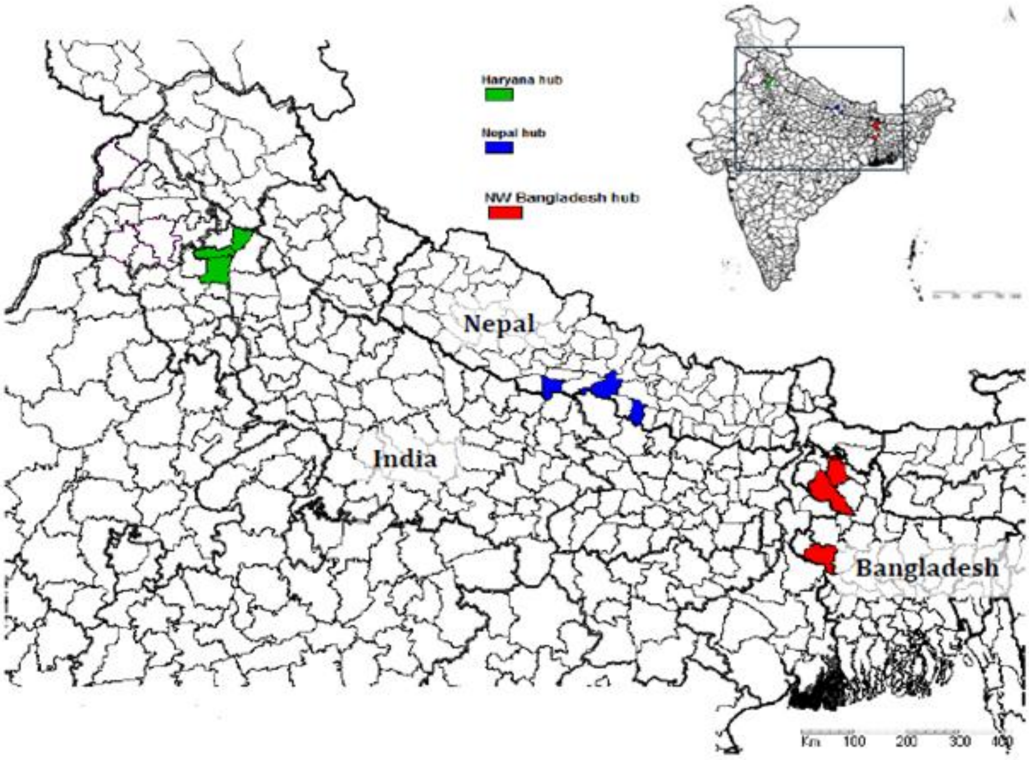
$$\sum_{i=1}^{N} K\left(\frac{x_i - x_0}{h}\right) \{y_i - \alpha_0 - \beta_0(x_i - x_0)\}^2$$

where $K(.)$ is a kernel function that places greater weights on points x_i is close to x_0. The local linear estimator with degree of polynomial (τ) greater or equal to 1 does much better than the preceding methods at estimating $m(x_0)$ at values of x_0 near the endpoints of the range of x, as it allows for any trends near the end points. Therefore, we used $\tau = 1$ in our estimation.

We also used the locally weighted scatter plot smoothing estimator (lowess), a variation of local linear regression. In the case of lowess, we use a variable bandwidth, a tri-cubic kernel and down-weights observations with large residuals. The bandwidth gives the fraction of the observations used to calculate $\widehat{m}(x_0)$ in the middle of the data, with a smaller fraction used towards the endpoints (for details, see Cameron and Trivedi, 2009).

5. Study area, data and descriptive statistics

The study area for present study consists of parts of Indo-Gangetic Plain (IGP) namely Haryana state of India, Terai region of Nepal and North West Bangladesh. The location of study area is presented in figure1. From which, it is clear that, Haryana lies in the western IGP, Nepal Terai is at Northern plain of the IGP and NW Bangladesh occupies eastern region of IGP.



Adopted from: Krishna et al, 2011

Figure 1: Map showing the study area

Rice-Wheat dominating cropping pattern is followed in the study area. In Haryana India, Rice-Wheat and Wheat- Sugarcane, in Nepal Terai, Rice-Wheat, Rice-Wheat-Maize, and Rice-Maize/Potato, and In NW Bangladesh, Rice-Maize and Rice-Rice are the major crop rotation being followed.

Because of cereal dominating cropping pattern in study area, our study focus on the adoption of conservation agriculture technology for cereal cultivation. Types of the CA technologies being adopted and number of the adopter are presented in table 1.

Table 1: Adoption of CA related technology

Technology	Haryana, India	Terai, Nepal	North West Bangladesh	Overall
	Adopter number	Adopter number	Adopter number	Adopter number

Laser land leveller	112.00	1.00	0.00	113.00
	(34.57)	(0.31)	(0.00)	(11.63)
Bed planting	61.00	75.00	2.00	138.00
	(18.83)	(23.15)	(0.62)	(14.20)
Zero tillage	117.00	31.00	5.00	153.00
	(36.11)	(9.57)	(1.54)	(15.74)
Turbo happy seeder	3.00	0.00	0.00	3.00
	(0.93)	(0.00)	(0.00)	(0.31)
Rotavator	161.00	12.00	86.00	259.00
	(49.69)	(3.70)	(26.54)	(26.65)
Direct seeded rice	4.00	66.00	5.00	75.00
	(1.23)	(20.37)	(1.54)	(7.72)
Total number of observations	324	324	324	972

Note: Figure in the parenthesis indicates percentage to total number of observations.

From Table 1, it can be depicted that, Rotavator, Laser Land Leveller (LLL) and Zero Tillage (ZT) are the most popular in Haryana. In case of Terai region of Nepal, Bed Planting and Direct Seeded Rice (DSR) are dominating CA technologies and these technologies are now becoming popular among the Nepalese farmers due to their multiple production advantages over the conventional alternatives (Ghimire et al. 2012). Rotavator is found more popular among farmers in Bangladesh. The adoption of the technologies is found to be site specific as LLL is adopted in Haryana, DSR is more popular in Nepal and Rotavator are being adopted in Bangladesh. Suitability of the land size and topography as well as farmers wealth status specifically, income generation from agriculture may have played the significant role in selection of the CA technologies. Share of different sources including crops and livestock in total income of farming household is shown in Table 2.

Table 2: Source of Income (%)

Income sources	Haryana, India	Terai, Nepal	NW Bangladesh	Overall
	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
Remittance	4.96	13.67	0.39	6.34
	(0.70)	(1.43)	(0.28)	(0.57)
Business	10.97	9.75	21.24	13.99
	(1.10)	(1.26)	(1.32)	(0.73)

Service	4.51	14.61	8.60	9.24
	(0.77)	(1.47)	(1.11)	(0.68)
Non-agricultural labour	3.08	18.21	13.37	11.55
	(0.67)	(1.30)	(1.10)	(0.64)
Other farm income	0.22	13.21	1.99	5.14
	(0.11)	(1.11)	(0.33)	(0.43)
Livestock	7.00	6.50	6.41	6.64
	(0.57)	(0.51)	(0.39)	(0.29)
Crops	69.25	24.04	47.99	47.09
	(1.51)	(1.39)	(1.27)	(1.00)

Note: Figure in the parenthesis indicates standard error

From the table 2, it can be inferred that, about 50 percent of the total household income is contributed by agriculture (crops and livestock) sector. Contribution of this sector is highest in Haryana, large size of land holding and availability of irrigation facility may be the reason behind more income from agriculture. In case of Bangladesh, agriculture is responsible for more than 50 per cent of total household income, Unlike Haryana, in Bangladesh farmers have no access to the irrigation facilities, but shallow pumps and diesel tubes are gaining popularity (Krishna et al., 2011). In Nepal, less than 31 per cent of total household income comes from crops and livestock. Services and remittance are the major source of income after agriculture in Nepal. Out-migration in search of better opportunity and jobs from Nepal, and soaring of industrial growth rate in neighbour country (Bihar of India), may be the reason for higher remittance income in Terai, Nepal.

Earlier studies (Dixon et al. 2006; Raut et al. 2011; Shively 1997) show that resource endowment or asset poverty is one of the major determinants of investment decision. Therefore, we need to look at the difference resource endowment of farm households across countries under study. Table 3 presents the inequality in land distribution and monthly expenditure among the farmers calculated using Gini concentration ratio.

Table 3: Inequality in land owned, land cultivated and monthly expenditure

	Gini Coefficients			
Variables	Haryana, India	Terai, Nepal	NW, Bangladesh	Overall
Land owned (in acres)	0.51	0.50	0.57	0.62
Land Cultivated (in acres)	0.51	0.47	0.52	0.61
Monthly expenditure (in US$)	0.40	0.29	0.20	0.41

The Table 3 shows that there is high inequality (i.e., 0.62) in the distribution of land owned as well as land cultivated land among the farm households in the Indo-Gangetic Plains . Of the three sample countries, the inequality in land distribution is highest in Bangladesh and is lowest in Nepal; the result is similar in both cases - land owned and land cultivated. But in the case of monthly expenditure, NW Bangladesh has more equal distribution among farmers, and Haryana has more unequal distribution.

5.1 Sampling procedure and data collection

Data for this study were obtained from the household survey conducted in 2010 by CIMMYT under the Cereal System Initiative for South Asia (CSISA) project. The household survey was carried out in the villages of Nepal, India and Bangladesh (as mentioned above) using a multi-stage random stratified sampling method. From Haryana, three district namely Karnal, Kurukshetra and Yamunanagar; Rupendehi, Bara and Chitwan districts from Nepal; and Dinajpur, Nilphamari and Rajshai districts from Bangladesh were purposively selected for the study because the districts represent the different cropping systems. From the selected districts, nine villages where CSISA activities were going on and nine non-CSISA villages were randomly selected. From each of the selected village, village census datasets were collected. This dataset was generated with the help of a few educated villagers. On the basis of the size of farm land owned by the households, the households were first sorted from smallest to the largest, and a systematic random sampling procedure was adopted to select households across the landholding categories for the data collection. From the each sampled village 18 sample household were selected, in this way from nine districts (3 districts from each country) total 972 households were selected for the study.

Primary data for this study were collected through personal interview method with the help of a comprehensive well-structured and pre-tested interview schedule with the help of trained enumerators who were familiar with the local socioeconomic environment between June and November 2010. The collected data were periodically examined by the economist in CIMMYT, South Asia, which ensures the quality of data.

6. Results and discussion

6.1 Descriptive statistics

In this study, we consider the farmers as adopters of CA if they have used at least one of the CA technologies; otherwise, they are considered as non-adopters. Table 4 presents the summary statistics and statistical significance tests for major socio-economic variables between adopters and non-adopters of CA. From Table 4, we see that 45% of farm households in the study area have adopted CA and there are significant differences between adopters and non-adopters with regard to main socio-economic variables included in the analysis. On average, adopters have 7.34 years of schooling while non-adopters have 5.62 years of schooling. A significant difference is observed between adopters (6.22 acre) and non-adopters (2.37 acre) in the case of operational land holding. Adopters are found to have higher access to information sources measured in terms of membership of institution, ownership of information and communication assets such as telephone and television.

Table 4: Socio-economic characteristics of sample farmers (mean & standard deviation)

Variable	Non-adopter	Adopter	Overall	Test statistics
Household head dummy (female:1) [a]	0.05 (0.22)	0.05 (0.21)	0.05 (0.22)	0.04
Age (in years)	46.56 (12.83)	46.40 (12.49)	46.48 (12.67)	0.19

Education	5.62	7.34	6.40	5.69***
	(4.79)	(4.55)	(4.76)	
Decision on farm technology dummy (female:1) [a]	0.29	0.34	0.31	3.27*
	(0.45)	(0.48)	(0.46)	
Family size	6.19	7.11	6.60	3.93***
	3.23)	(4.03)	(3.64)	
Adult share	30.56	32.69	31.52	1.31
	(27.14)	(22.80)	(25.29)	
Operational land (in Acre)	2.37	6.22	4.10	9.25***
	(3.53)	(8.80)	(6.74)	
Irrigation	0.73	0.90	0.81	10.98***
	(0.27)	(0.19)	(0.25)	
Household expenditure (in USD)	120.81	200.61	156.77	5.19***
	(86.49)	(342.34)	(241.72)	
Non-farm income	25.99	26.20	26.08	0.10
	(33.11)	(31.09)	(32.20)	
Credit use [a]	0.50	0.64	0.56	19.61***
	(0.50)	(0.48)	(0.50)	
Occupation dummy1(agriculture) [a]	0.52	0.80	0.65	22.80***
	(0.50)	(0.40)	(0.48)	
Occupation dummy2(labor) [a]	0.10	0.03	0.07	86.56***
	(0.31)	(0.18)	(0.26)	
Occupation dummy3 (service) [a]	0.30	0.15	0.23	17.72***
	(0.46)	(0.36)	(0.42)	
Occupation dymmy4[a]	0.30	0.15	0.24	30.57***
	(0.10)	(0.02)	(0.01)	
Telephone [a]	0.70	0.86	0.77	35.93***
	(0.46)	(0.35)	(0.42)	
Membership [a]	0.35	0.56	0.44	40.96***
	(0.48)	(0.50)	(0.50)	
Television [a]	0.59	0.76	0.67	30.55***
	(0.49)	(0.43)	(0.47)	
India [a]	0.18	0.53	0.33	131.95***
	(0.38)	(0.50)	(0.47)	
Nepal[a]	0.39	0.26	0.33	17.97***
	(0.02)	(0.02)	(0.13)	
Bangladesh [a]	0.43	0.21	0.33	52.53***
	(0.50)	(0.41)	(0.47)	
Total number of observation	438	534	972	

Notes: We used t-test for continuous variables and chi-square test for dummy variable

Level of significance: *: 10%, **: 5%, ***: 1%

6.2 Analysis of the determinants of CA adoption

Table 5 presents the results of analysis of the determinants of CA adoption. We estimated three separate models in order to test the robustness of our results and to see whether there are significant differences in adopting CA among the farmers' in three countries under study. Variables such as education of the household head (Dixon et al. 2006), share of adult members of the household working at farm (Shively 1997), operational land holding, share of irrigated land out of the total land operated, households with agriculture as a major occupation, and access to knowledge (both from institutional affiliation and education) (Foster and Rosenzweig 1995) are found to be significant in all model specifications, implying that these are the major variables that influence positively on farm households' likelihood to adopt CA. As other studies (Rahm and Huffman 1984; Raut et al. 2011), we found positive association between size of operated land and likelihood to adopt conservation agriculture. A recent study (Musara et al., 2012) puts forth the idea that large farmers have sufficient land to spare some part of land to try out for new practices at a lower risk. Similar to studies in other technology adoption such as land conservation investment (Shively 1997), we found that household with more endowment of family labor involved in agriculture is more likely to adopt CA. Institutional affiliation and education are found to have positive association with likelihood to adopt CA: this result is similar to many other studies examining factors affecting technology adoption such as (Feder and Slade 1984).

When we controlled for the regional difference by including the country dummy of the sample household, female headed households are found to have significant positive impact on the probability to adopt CA. This might be due to the variation in women's participation in decision making process within their household and we clearly see their major role in case of Nepal when compared to other countries under study. Similar effect is found in the case of share of non-farm income in total household income. Among the three sample countries, farmers in India and Bangladesh are more likely to use CA technologies as compared to Nepalese farmers. This might be due to better irrigation facility in India and Bangladesh as compared to Nepal. We examined the effect of gender on CA technology adoption in three ways: by including the dummy for sex of household head of the household, by including dummy for who decides on farm technology adoption and by including female and country interaction variable in the regression models.

Table 5: Determinants of conservation agriculture technology adoption in south Asia
(Coefficients of probit model with standard error)

Variable	Description	Model 1	Model 2	Model 3
Household/demographic characteristics				
HH head dummy	1: Female	0.166	0.398*	0.408*
		(0.21)	(0.21)	(0.22)
Log of age	Age of household head (inYrs)	-0.203	-0.234	-0.163
		(0.17)	(0.17)	(0.17)
Log of education	Education of household head (in Yrs of schooling)	0.123**	0.115**	0.114**
		(0.05)	(0.05)	(0.05)
Decision on farm technology dummy	1: Female is the decision maker	0.103	0.438***	-0.186
		(0.11)	(0.13)	(0.18)
Log of family size	Number of household members	-0.110	0.000	0.023
		(0.12)	(0.12)	(0.12)
Log of adult share	Share of adult hh members working at farm	0.061***	0.074***	0.069***
		(0.02)	(0.02)	(0.02)
Farm characteristics				
Log of operational land	Operated land (in Acres)	0.292***	0.294***	0.289***
		(0.05)	(0.06)	(0.06)
Log of irrigation	Share of cultivated land irrigated	0.359***	0.294***	0.282***
		(0.10)	(0.10)	(0.10)
Income characteristics				
Log of household expenditure	Excluding ceremonies, monthly in US $	0.047	-0.028	-0.054
		(0.10)	(0.11)	(0.11)
Non-farm income	Share of nonfarm income in total income	0.001	0.006***	0.005**
		(0.00)	(0.00)	(0.00)
Credit use dummy	1: Availed credit	0.068	-0.008	-0.002
		(0.10)	(0.10)	(0.10)
Occupation dummy1	1: Agriculture	0.641**	0.736***	0.738***
		(0.28)	(0.29)	(0.29)
Occupation dummy2	1: Other labour	0.034	0.263	0.299
		(0.32)	(0.33)	(0.33)
Occupation dummy3	1: Services	0.273	0.423	0.384
		(0.30)	(0.30)	(0.30)
Information characteristics				
Telephone	1: Uses phone	0.084	0.140	0.170
		(0.13)	(0.13)	(0.13)
Institutional Membership	1: Institutional affiliation	0.279***	0.297***	0.287***
		(0.09)	(0.10)	(0.10)
Television	1: Owns TV	-0.058	-0.145	-0.174
		(0.12)	(0.12)	(0.12)

Regional dummies				
India	Country dummy		0.814***	1.516***
			(0.18)	(0.24)
Bangladesh	Country dummy		0.814***	1.335***
			(0.21)	(0.25)
Interaction terms				
Female-Nepal interaction				1.342***
				(0.29)
Constant		-0.595	-1.195	-1.898**
		(0.77)	(0.82)	(0.85)
Number of observations			972	
Chi2 statistic		246.203	271.516	294.574
Prob > chi2		0.000	0.000	0.000
Pseudo R2		0.184	0.203	0.220

Note: Level of significance, *: 10%, **: 5%, ***: 1%

From the results in Table 5, it is clear that farm households in the study areas operate under factor market imperfections. This is because the ownership holding of assets such as land and labour do not affect the decision to invest in farm technology under the perfect market case. However, this is not the case under market imperfections. This also indicates that there is a need to set a policy in order to enhance farmers' capacity to adopt CA. Results show that likelihood to adopt CA increases with the increase in the share of off-farm income in the total household income while we control for sample countries. This indicates that the contribution of off-farm income in softening liquidity constraint of the household is larger than the labor that off-farm activities take out of agriculture. Alternatively, higher off-farm income may compensate for labor loss due to participation in off-farm activities and thus, contributing more in adopting conservation agriculture. This is similar to the claim made by (Reardon and Vosti 1995) that off-farm income provides cash required for the investment in new technology, especially in a situation when farm household needs to buy materials required. As CA requires suitable equipment for its proper application, non-farm income may add to the investment for purchasing equipment or renting services from others.

Results in Table 5 show a clear difference between the sample countries with regard to the adoption of CA. This is also supported by the fact we presented in Table 2, i.e., share of agricultural income in the total household income is lower in the case of Nepal as compared to India and Bangladesh. This may explain part of the differences in CA adoption between these countries. Furthermore, it is also in line with the concept that households that are more dependent on agricultural income may invest more on the technology that contribute to sustainability of agriculture. This is also evident from our result as the occupation dummy for agriculture is highly significant and positive, indicating that households with agriculture as a major occupation go for conservation agriculture. Interestingly, when we control for country the female headed households are found to be more likely to adopt CA as compared to their male counterparts. The results also show that female headed households in Nepal are more likely to adopt CA as compared to the similar households in India and Bangladesh.

In order to know the effect of major determinant of conservation agriculture, we ran some non-parametric regressions using land owned, education, share of irrigated land in total land used, and consumption expenditure of the sample hosuehold. The results of local linear regression and lowess are presented in figure 2.

Based on the figure 2, we observe that adoption of CA is positively associated with all the variables we estimated. In figure 2 (A), we see that size of land holding and adoption of CA have strong positive association, implying that capacity to invest in CA methods as one of the major determinants for its adoption. This may be one of the reasons why more farmers in India have adopted CA as compared to other countries in South Asia. The figure 2 (A) shows that probability to adopt CA increases sharply in the range when owned land reaches approximately up to 27 acres, while after that the probability of adoption remains more or less constant. Figure 2(B) exhibits that education is a major determinant of CA technology adoption. We found similar results while we run the non-parametric regressions between the proportions of irrigated land out of total land operated and the CA technology adoption as shown in figure 2(C), implying that expansion of irrigation contributes to CA technology adoption.

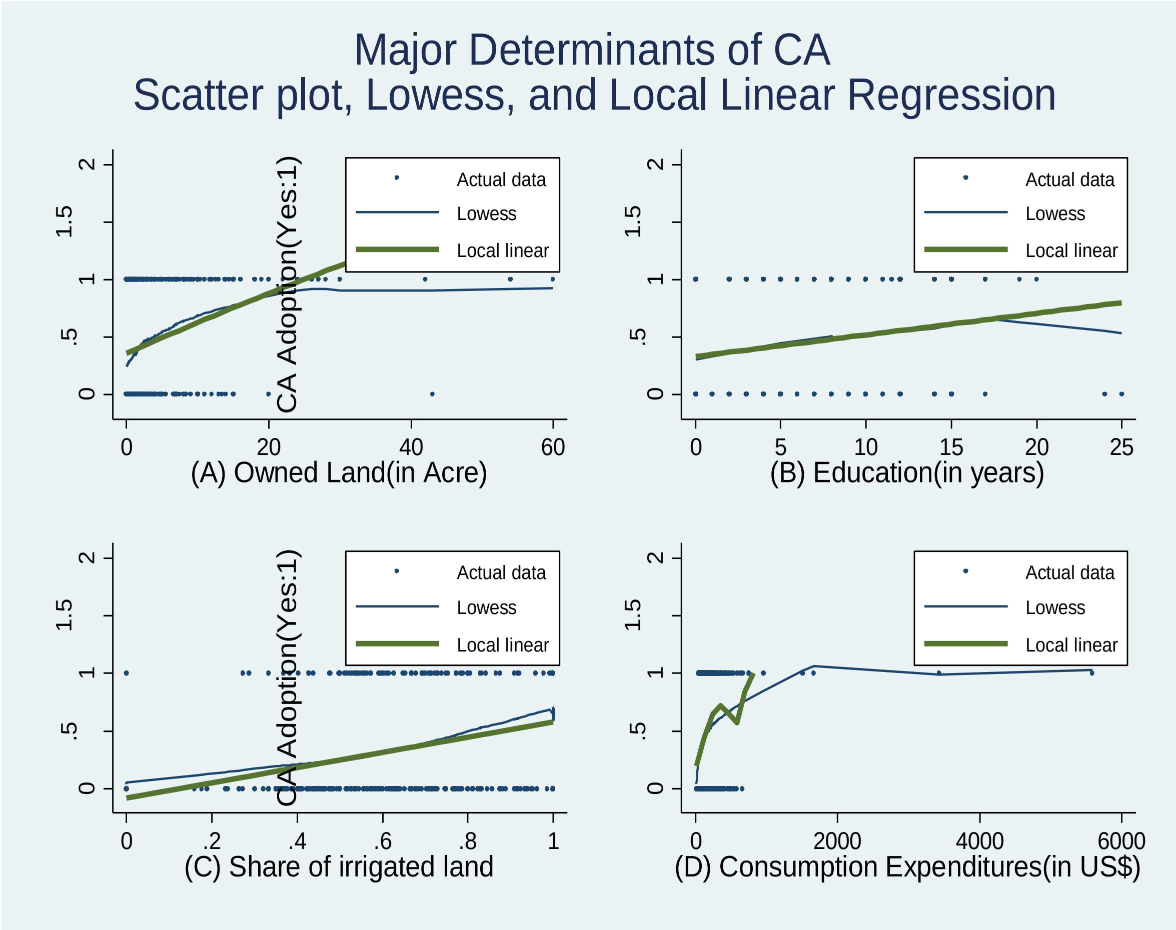


Figure 2: Non-parametric regressions

Unlike the case of parametric regression shown above, we found a clear positive relation between households' consumption expenditure and CA adoption in the non-parametric regressions shown in figure 2. From figure 2 (D), it is clear that probability of CA adoption increases sharply up to a certain level of consumption expenditure (about 1900 US$ in this case).

7. Conclusion

Both socio-economic and land specific factors are found to have affected CA technology adoption in south Asia. Large farmers are found to adopt CA as compared to small farmers, supporting the claim that CA is more appropriate for rich farmers. This has an important policy implication, especially on how to create economic incentives so that small farmer can also adopt CA. Appropriate use of CA requires proper equipment, which in many cases small farmers are not able to purchase. Therefore, promoting local manufacturer to produce those equipments at low-cost can be a major policy to enhance the adoption of CA by small farmers. Increasing irrigation facility is found to be one of the possible ways of promoting the adoption of CA as farmers with larger proportion of irrigated land out of the total land operated are found practicing CA[1]. This may also be due to the fact that the benefits of CA methods are very sensitive to water management and thus, it is easier as well as beneficial to adopt such technologies in irrigated farms. Increasing institutional support to farmers is a better method to increase the adoption of CA among rural farmers and thus, any policy to enhancing extension support and technological advices at village level are inevitable. Another important lesson is that increasing education among farm household and providing them training on conservation agriculture can be important to better adoption of conservation agriculture.

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[1] This is also reported by farmers in Karnal village, Haryana in several visits to the field by the first author.

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