

**Adoption of Water Conservation and Intensification Technologies in the Lowland Rice  
Production Systems of Northern Ghana**

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**Abstract**

This study identifies the socio-economic factors influencing the adoption decision of bunds and dibbling among small-scale lowland rice production in Northern Region of Ghana. The empirical application involved a cross-section sample of 342 lowland rice farmers in Ghana. The empirical evidence suggests that the adoption decision of bunds and dibbling are made jointly. The seemingly unrelated bivariate probit estimation on plot level indicates that access to credit, project involvement, family land/ labour ratio, age, reported good results, number of bikes, area under other crops and number of labour equivalents frequently ill, as well as soil type and retention capacity influence the adoption decision of bunds. Dibbling is determined by factors as access to credit, project involvement, family land / labour ratio, area under other crops, perception of dibbling and farmer's constraints and number of bulls. Also household heads are more likely to adopt dibbling. Plots characteristics are provision of LRDP bunds, soil quality and water retention capacity also influence the likelihood of adoption.

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## **1. Introduction**

Given the close link between poverty, population growth and environmental degradation, there is great need for agricultural growth and development to achieve food security, to conserve natural resources and to stimulate overall national economic growth through intersectoral linkages (e.g. Hazell and Hojjati, 1995). In Ghana, under the Vision 2020 programme, the agricultural sector is targeted to grow at annual growth rate of 5-6% to fuel an increase in Ghana's annual GDP growth rate to 8% in order to ensure food security and adequate nutrition for all Ghanaians and to stimulate national economic growth (MoFA 2004). Growth rate of rice and maize decreased in 1998-2003 compared to 1993-1998 from 5.0% to 1.8% and from 5.6% to 3.5% respectively. These growth rate can be attributed mainly to area expansion, while yield gains playing a minor role (MOFA 2004). Actual yield levels achieved lag behind potential yields with considerable variation in the actual yield levels achieved even under similar production systems. The gap reflects deficiencies arising primarily from inadequate crop, nutrient and water management practices. As these limitations in production are closely linked, integrated approaches have been gained in importance.

### **1.1. Background information**

Ghana is located on the west coast of Africa, about 750 km north of the equator. The population in 2006 is estimated at 22.409.572 million, with a population growth estimated at about 2.07% for 2006 (CIA 2006). The agricultural sector, which is basically rural, generates 36% of GDP in 2000 and employs around 70% of the labour force (MOFA 2001). Ghana is a low-income food-deficit country with food insecurity and poverty particular severe in the rural areas of northern Ghana (FAO 2002). Northern Ghana falls in the interior savannah agro-ecological zone characterized by mostly shallow soils of low fertility and a single cropping season beginning in April / May and ending in October with erratic rainfall and long periods (more than 10 days) of dry spells. Annual rainfall totals about 1100 mm and allows a length of 180-200 days of growing season. In the north of Ghana more than 75% of the population depends on smallholdings and livestock with the predominant production systems of cereals being the traditional subsistence type (FAO 2002).

## **1.2 Problem statement**

Rice is an important cereal to Ghana's economy and agriculture, accounting for nearly 15% of the agricultural Gross Domestic Product (Kranjac-Berislavjevic 2000). Ghana was found to have a comparative advantage in the production of paddy rice over the other countries in the sub-region (Asuming-Brempong 1998). Northern Region has a potential for rice production. In Northern Ghana, rice is the major cash crop. Northern Region was a main producer of paddy rice with a share of 60 percent of total rice production in the 1970ties (WARDA 1986), supplying the rest of the country and beyond mainly due to relatively high subsidies on agricultural inputs including machinery and equipment. As subsidies were gradually removed, rice profitability has shrunken, due to increasing prices of agricultural inputs relative to nominal prices of rice (Asuming-Brempong 1998). On the other hand, obtaining machinery at the right time became more and more difficult and expensive, which resulted in untimely preparation of rice fields and increasing risk of poor scheduling of synchronising cultivation practices with soil moisture levels (Dittoh, Yeboah and Kranjac-Berislavjevic 1997), Most rice production is still in the hand of small-scale farmers holding less than one hectare of land with low levels of technological knowledge and mechanization (Kranjac-Berislavjevic et al. 2003).

Rice consumption doubled up to 14.5 kg per capita per year in 2000 compared to the period 1982 to 1985 (WARDA 1986; MOFA 2004). It is predicted to increase further due to a high human population growth rate of 2.8% and a shifting demand to high value staples (MOFA 2001). On the supply side, the average annual production growth rate of rice decreased to 1.8% in 1998-2003 due to declining rice-fertilizer price ratio caused by the liberalization policy. The average yield of paddy rice under rain fed conditions was 2.0 Mt/ha in 2003 compared with average yields of 6.5 Mt/ha achievable under more effective extension and use of recommended technologies (MOFA 2004). As a result, rice imports have been increasing steadily since 1980 and are contributing more than 50% of all rice consumed in the country – at huge expenses in terms of hard currency (Bam et al. 1998).

## **1.3. New techniques in small-scale lowland rice production in Northern Ghana**

The Lowland Rice Development Project (LRDP) first introduced and disseminated construction of earthen bunds as water conservation method<sup>1</sup> and dibbling as yield increasing but labour-intensive planting method in lowland rice production in three valleys surrounding Tamale from 1999 to 2003. The aim of the LRDP was to develop a profitable and sustainable intensive rice production system focussing

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<sup>1</sup> It has been shown for inland valleys in West Africa that the 'period of positive water balance can be extended by about 20 days in wet years' in Bida, Nigeria or by about 50 days in both wet and dry years in Makeni, Sierra Leone by properly constructed bunds (Gunnneweg et al. 1986).

on small scale farmers. From 2003, the project collaborated with the Food Security and Rice Producers Organization Project (FSRPOP). The objective of FSRPOP is mainly to sustain the rice intensive cropping scheme by building the capacities of farmer based organizations to fulfill some of the tasks ensured previously by LRDP (organize access to inputs, credits, and tractor services, marketing of paddy, monitor cropping activities and manage & sustain collective structures as storage or water).

The LRDP itself developed 1040 ha of lowland area through provision of water harvesting structures in form of contour bunds<sup>2</sup>. Yields increased from 1 Mt/ha to 2.5 Mt/ha (LRDP 2004). Despite the yield increase through bund creation and the fact that the construction of intermediary bunds<sup>3</sup> was much encouraged during LRDP, it seemed at the end of the project, that the dissemination of dibbling was quite more successful than the dissemination of bund construction among the farmers (LRDP 2004). The reasons of the low adoption rate of bund construction are unclear so far (FSRPOP 2005).

#### 1.4 Objective of the study

The objective of the present study is to examine the determinants of the adoption decision of bunds constructed by the farmers and of dibbling in the lowland rice production among small-scale farmers in Northern Region of Ghana.

## 2. Theoretical model and empirical specification

Given the objective of the study, which is to examine bunds as a water conservation method and dibbling as a yield-increasing seeding method, we assume that farmers choose between construction of bunds or non-construction, and on the other hand between dibbling seed or not dibbling. Assuming that farmers are risk neutral, it may be assumed that in the decision making process whether to adopt or non-adopt the producer weighs up the expected utility of wealth from adoption represented as  $U_A^*(\pi)$  and the expected utility of wealth from non-adoption represented as  $U_N^*(\pi)$ , with profits  $(\pi)$  represent wealth. Adoption then occurs if  $U_A^*(\pi) > U_N^*(\pi)$ . Farmer's expected utility of adoption can be related to a set of explanatory variables ( $Z$ ) as follows:  $U_A^*(\pi) = \gamma'Z_i + \varepsilon_i$  with  $\gamma$  being a vector of parameters. The error term  $\varepsilon$  with mean zero and variance  $\sigma_\varepsilon^2$  captures

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<sup>2</sup> Contour bunds are big earth ridges constructed along contours. Since they are constructed against the direction of the water flow in the valley, bunds trap both surface run-off and precipitation thus improving infiltration into the soil and storage of the excess on the soil surface.

<sup>3</sup> Due to the tendency of water to pond in one section in between the contour bunds the construction of intermediary bunds is recommended to the farmers at intervals between the micro-catchments in between the two contour bunds. They have to be constructed every year by hoe after land preparation and roughly have a size of 30cm high, 15-20 cm crest width.

measurement errors and factors unobserved to the researcher but known to the farmer. Variables in  $Z$  include determinants of the adoption decision as plot characteristics, characteristics of the farm (e.g. farm size) as well as socio-economic characteristics of the farmer and the farm family such as education, age or household size. Policy variables and characteristics of the village may also be included in vector  $Z$ . The farmer's utility from choosing adoption is not observable but the choice of adoption or non-adoption:  $U(\pi) = 1$  if  $U_A^*(\pi) > U_N^*(\pi)$  and  $U(\pi) = 0$  if  $U_A^*(\pi) \leq U_N^*(\pi)$ . The probability of adoption may then be expressed as:

$\Pr(U = 1) = \Pr(U_A^*(\pi) > U_N^*(\pi)) = \Pr(\varepsilon_i > -\gamma'Z_i) = 1 - F(-\gamma'Z_i)$  where  $F$  is the cumulative distribution function for  $\varepsilon$ . Assumptions about the functional form of  $F$  result in different models. Here, the probit model will be employed, which assumes a normal distribution. A joint analysis of techniques might be needed for determining the total effect of simultaneous adoption, even when other technique decisions are made exogenously. This arises because the total effect of adopting several practices simultaneously does not necessarily equal the sum of the effects of adopting each practice separately (Wu and Babcock 1998). Therefore a seemingly unrelated bivariate probit model is estimated to identify the determining factors of adoption decisions of bunds and dibbling.

### **3. Data and variable definition**

#### **3.1 Study region**

The study is conducted in four neighbouring districts of Northern Region (Savelugu-Nantong district, Tamale Municipal district, Tolon-Kumbungu district, covering three river valleys (Kulda-Yarong valley, Zuwari valley and Sillum valley). Farmers in the study region are subsistence farmers and attempt to grow all the food staples needed by the household. Especially, self-sufficiency in maize as major food-staple is most important. In contrast to maize, rice was traditionally of minor importance but became the major cash crop nowadays (Katie Abu, 1992).

The basic unit of social organization is the (compound) household. Its nucleus is an elementary or polygynous family, to which may be attached the descendants of the head's grandfather. Food staples for the entire compound household are provided by the household head from the produce of the household farms which are under the authority of the household head as decision-maker. Farm produce of household farms is mainly consumed. The household head is himself one of the main

workers on the household farm, but dependent men<sup>4</sup> have absolute obligation to provide labour on the household farms for meeting the food security of the compound family, thus they are the backbone of the labour force for the household farms. Besides, dependent men and also the household head have their own individual plots under their own authority which produce is considered to be theirs, and thus they are free to dispose of it. For this reason, they tend to concentrate on cash crops (as rice) on these individual plots (Abu 1992). Besides these labour obligations within the compound family, there is also exchange of labour in form of communal labour and working groups, which are fixed groups of farmers who get together to take turns in doing a job as a group on each other's farms.

### **3.2 Sampling procedure and data collection**

In the present study cross-section data collected in October 2005 to April 2006 pertaining to 2005 cropping season was used. The data set was gathered in 24 communities located within a 60km radius around the regional capital Tamale. Selection of farmers was based on a multi-stage stratified sampling procedure. After purposive selection of communities with proportions of adopters and non-adopters, farmers were randomly selected. Both primary and secondary sources were used to identify villages suitable for the study. Structured questionnaires were used to collect village and compound-level data as well as detailed farmer information, comprising production system, input use, costs, nature and extent of adoption, adoption history, socio-economic characteristics of farmer and compound family, as well as plot level characteristics. Administration of questionnaires was carried out by trained and Dagbani speaking enumerators under the supervision of the author.

### **3.3. Variables**

In the adoption literature, there are three major groups of explanations: the innovation-diffusion paradigm, the resource-constraint paradigm and the adopters' perception paradigm. Derived from these theories, some groups of factors were found to be influencing determinants in previous studies: farm and farmers' attributes, external support systems, perception of or attributes associated with the technology and the farming objective. Specifically, agricultural adoption literature found variables as age, experience, gender and education of the decision maker, labour endowment farm size, information availability, access to credit, wealth, risk aversion, land tenure, transportation infrastructure,

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<sup>4</sup> Dependent men (married or unmarried) are not yet household heads, but live in the compound household under the household head (Katie Abu, 1992).

complementary input supply, perception of needs and of technology to be important variables for adoption decisions in developing countries (Feder and Umali 1993; Feder, Just and Zilberman 1985).

Detailed definition of the independent and dependent variables used in the empirical estimation is given in Table 1. The bivariate probit model specified for the study includes two dependent variables:  $y_B = 1$  if the farmer constructed any bunds and  $y_D = 1$  if the farmer dibbled at least some part of his lowland rice area.

It is hypothesised in the literature that higher education enhances acquiring of information and the evaluation and assessment of benefits and costs of the new technologies and the assessment of farm-level performance. Therefore, education should enhance farmers to make more efficient adoption decision (Huffman 2001).

As labour endowment is an important factor in traditional agricultural production household size as labour potential is included in the estimation. Also, the number of persons suffering from frequent illness (Malaria or other chronicle illnesses) of those who regularly help in the lowland rice production, are included as the labour constraint might become worse (e.g. Ersado et al. 2003). On the other hand, labour constraint might be alleviated with the possibility of getting communal labour help.

Cash availability and access to credit is often found to increase the probability of adoption of new technologies. Due to cash constraints the farmer might not afford necessary expensive inputs related to the new techniques, e.g. hiring labour for labour-intensive techniques or hiring tractors which make bund construction much easier, stable and durable. On the other hand, higher off-farm income might reflect higher opportunity costs of labour on the own farm and of adopting new techniques. Wealthier farmer are more likely to adopt because of better financial resources, higher education and better social networks. Social networks might alleviate labour constraints and increase information flow about new techniques and therefore influence adoption decision (Boahene et al. 1999). Similar, it is hypothesized that participation in projects, organizations and farmer groups increase the probability of adoption due to better information about the benefits of new technologies. The perception of attributes of new techniques is often found to be a significant factor of adoption (Adesina and Zinnah 1993; Negatu and Parikh 1999). In this study the perception of dibbling as yield increasing and bunds as highly effective are included. Additionally, the perception of constraints or needs of the farmer is included: CON\_L2 =1 if the farmer ranks labour first or seconds as most constraining for his lowland rice production, WEED\_R representing the rank of weeding as labour constraint in lowland rice production.

## **4. Empirical results**

### **4.1. Qualitative analysis**

An overview of selected descriptive statistics for the surveyed households is presented in Table 1. Furthermore, Table 2 and 3 present selected descriptive statistics and differences of adopters and non-adopters of both technologies.

The cross-section sample consists of 342 farmers operating 439 plots. At the time of the study, 166 adopted bund technology (48.53%), while 176 farmers did not use bunds (51.46%). A further look to the group of adopters show that 139 farmers of out of this group adopted bunds completely (83.73), while only 27 were partial adopters of bund technology (16.27%). Referring to dibbling, 232 farmers adopted dibbling (67.83%), while 110 farmers were non-users of dibbling (32.16%). Among the adopters of dibbling, nearly all of them were complete adopters (92.24%) and only 18 farmers were partial adopters of dibbling (7.76%).

On plot level, 205 out of 439 plots (46.70%) were provided with bunds in 2005, while 234 were not bunded (53.30%). On 295 out of 439 plots, in 2005 the seed was dibbled (67.20%). Farmers cultivate on average 4.25 plots in total (rice and other crops). The average number of cultivated rice plots is 1.28 plots, while the average number of LRPD rice plots is 0.41 plots. The average individual farm size is 7.35 acres, with an average size of area of lowland rice cultivated of 2.17 acres and an average area of other crops cultivated of 5.18 acres.

Due to the fact that very few rice farmer are female, there is only a small proportion of female farmer in the sample (4.97%). According to LRDP, in 2001 only 6.7% of LRDP project farmers were women, most of them owning plots for the first time (Jenin and Awuni 2001).

Households have an average size of 19 persons and farmers being on average 37 years old. 80% of the farmers in the sample have no formal school education; with 70% of all farmers being illiterate and 9.70% have some English or Dagbani literacy. The average number of years of schooling among those with formal schooling is 9.28 years.

Looking at the project participation, 162 farmers out of 342 participated in the LRDP project (47.37%). 81 farmers out of 342 indicated that they were supported by the FSRPOP project (23.68%), 64 farmers of them also indicating a former participation in the LRDP project. From LRDP project participants, 80% of farmers use dibbling as planting method and 61% construct bunds, compared to only 57% of farmers dibbling among non-participants and 37% of farmers creating bunds. LRDP participants have less educational background, only 25% being literate compared to 33% to non-

participants. Likewise, the average number of years of formal schooling is 1.26 years for LRDP participants compared with an average of 2.35 years for non-participants.

Dibbling is mostly spread among plots with LRDP and self constructed bunds: 89% of the plots are dibbled compared with 81% dibbled among plots equipped with only self constructed bunds. 79% of plots provided with only LRDP bunds are dibbled, but only 43% of plots without any kind of bund are dibbled. Out of LRDP bunded plots, 60% are also equipped with self constructed bunds, while only 40% of plots outside of LRDP bunds are provided with self constructed bunds.

#### **4.2. Econometric results**

The analysis was conducted on plot level to allow for farm differences in plot level characteristics. The results of the joint decision to adopt bunds and dibbling are presented in Table 4. The estimate of Rho ( $\rho$ ) (correlation between the errors) is 0.758 and is significantly greater than zero at the 1% level. This suggests that the random disturbances of the two equations are affected in the same direction by random shocks and that the adoption decision of bunds and dibbling are not statistically independent. Therefore, the adoption decision of both technologies should not be estimated independently with two univariate probit estimation. The log likelihood statistic for the bivariate probit estimation (-331.263) is significant at the 1% level, suggesting that the explanatory variables together influence the probability of adopting bunds and dibbling.

Adoption decision of bunds is found to be more likely with an increasing family land/labour ratio of the compound household (AV\_FSZ). The labour endowment of the compound household (GEQ\_HH) has the expected positive sign, but is not significant. This might be due to the strongly anchored communal labour systems which might alleviate labour constraints caused by lacking labour endowment of the household. However, a higher number of persons helping regularly in the lowland rice production of the farmer who are frequently ill (GEQ\_ILL) influence the probability of bund adoption negatively. This conforms to findings in the adoption literature (Ersado and Anmacher 2004). As constructing bunds manually is a relatively heavy physical work, illness is likely to reduce adoption probability. With higher age, farmers are less likely to adopt bunds, but reaching the age of 49.5 years they become more likely to adopt. Farmer with an higher status than average are more likely to adopt bunds. This might be due to the fact that they are more likely to participate in projects, get more information about new technologies and might have easier access to communal labour. Area cultivated with other crops has a significantly negative sign. This suggests that with increasing area and increasing importance of other crops the labour constraint at working peaks might become more crucial, thus resulting in decreasing adoption

probability. The educational level of the farmer as decision-maker is insignificant in contrast to other adoption studies. As the variation in the educational level in the sample is quite low, the information given by the coefficient might be negligible. Also, both technologies (bunds and dibbling) can be considered as not very knowledge intensive. Participation in the Food Security Rice Producer Program (FSRPOP) increases the farmer's probability to adopt bunds. Also, the involvement in any other project before LRDP, which is assumed to be an indicator of innovativeness of the farmer, is significantly positive. Access to credit influences the adoption decision positively significant, as expected by the adoption literature. The access to off-farm income of the respondent is insignificant (OFF\_R). In contrast to credits, off-farm activities available to the farmer might reflect high opportunity costs of farming and adoption of labour-intensive technologies. The number of bicycles increases the adoption probability of bunds significantly positive. This might show the importance of means of transport as the distance to plot and markets might be quite high (up to 2 hours by bike). Furthermore, the number of bikes might be an indicator of wealth. This finding then corresponds to the adoption literature, as wealthier farmers are often found to be more likely to adopt. The proportion of people in the direct environment of the farmer reporting good results to the farmer is highly significant (repsults). However, the perception of bunds as highly effective has a positive but insignificant sign.

Plot characteristics as very good water retention capacity of the plot (before construction of bunds) reduces the likelihood of bunds being adopted by the farmer. This is plausible, as the benefit of adoption is less for farmers having plots with already very good water retention. Loamy soil results in a lower probability of bund adoption, as this soil type makes bund construction with hoe more difficult than other soil types. Furthermore, results suggest that farmers in Kulda-Yarong valley are more likely to adopt bunds.

Referring to dibbling, the land/labour ratio of the compound household also increases the adoption probability. Age of the farmer here is insignificant, in contrast to the adoption decision estimation of bunds. Educational level of the respondent is significantly positive as expected by adoption literature. As mentioned above, due to limited variation in the educational level, this variable has to be handled with care. Again, access to credit increases the probability of adopting dibbling technology. Here, in contrast to the bund adoption equation, the off-farm income of the respondent is significantly negative. This suggests that with off-farm opportunities available the adoption of dibbling becomes unattractive. This might be due to the fact that dibbling requires more labour at one point of time (planting time being a crucial working peak in the cropping season), than the construction and maintenance of bunds. A strong perception of dibbling as yield increasing has a significantly positive coefficient. Again, farmers

participating in the FSRPOP are more likely to adopt dibbling. Participation in other groups or organizations related to crop production has also a positive sign, but is not significant. As there are different types of communal labour, the affiliation to such a fixed group might not be necessary to alleviate possible labour constraints. Household heads are more likely to adopt. For them, the labour constraint might be less crucial due to the labour obligations of dependent household members. Area cultivated with other crops influences the adoption probability of dibbling significantly negative, as the labour constraints might become worse during planting time. Number of bulls reduces the adoption probability. As there are very few bullocks in the study area, working as bullock operator on other farms might be more attractive than to invest time for dibbling on own rice fields. In addition, farmers perceiving weeding activity as the most constraining labour activity are more likely to adopt. As dibbling is labour saving in weeding activity, this seems to be plausible. In Kulda-Yarong valley and Zuwari valley the adoption rate of dibbling is significantly lower than for Sillum valley. This is surprising as the difference between the regions is not as distinctive for bund technology as for dibbling technology. Referring to plot characteristics, existence of LRDP bunds on a plot significantly increases the use of dibbling as planting method. Very good soil quality influences adoption decision significantly positive, as the benefit of dibbling might be higher on very good soils. On the other hand, very good water retention decreases the adoption probability of dibbling, as dibbling seed becomes impossible on flooded fields.

## **5. Concluding remarks**

The results suggest that different factors determine the adoption decision of bunds and dibbling. This underlines the necessity of technology and country related micro-economic adoption studies. However, some determining factors have become apparent: similar to the findings of other studies, access to credit seems to be a key factor for both the technologies of bunds and dibbling. Furthermore, involvement in projects and farmer groups seem to be important factors for the adoption decision of bunds and dibbling, due to the possibility of alleviation of information flow and forming of perceptions of the technology. This matching of perceptions with the needs of the farmer seems to be very crucial. This emphasizes the importance of farmer based organizations linked with access to credit in regard to adoption and dissemination of new technologies.

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Table 1: Variable definitions and descriptive statistics

Variable Name	Variable definition	Sample mean	Standard deviation
<i>Dependent variables</i>			
SELF_B	=1 if bund is constructed	0.47	0.50
DIB_D	=1 if plot is dibbled	0.67	0.47
<i>Independent Variables</i>			
GEQ_HH	Number of labour equivalents living in the compound household.	13.40	9.46
GEQ_ILL	Number of labour equivalents regularly helping in lowland rice production, suffering from frequent illness	2.07	2.80
AGE_R	Age of respondent in years	37.31	10.82
AV_FSZ	Family land in acres per labour equivalent of household <sup>5</sup>	1.28	1.01
CROP_SZ	Area cultivated by rice farmer under other crops (acre)	5.18	4.53
STATUS_HH	1 if farmer has higher status than average, 0 otherwise	0.25	0.43
INFS_R	Educational level of farmer: 0=none, 1=literate	0.29	0.46
CREDIT	Farmer obtained any credit: 0=no, 1=yes	0.40	0.49
OFF_R	Farmer has any off-farm income: 0=no, 1=yes	0.36	0.48
FSRPOP	Farmer participates in FSRPOP: 0=no, 1=yes	0.24	0.43
PROJ	Farmer participated in any other project before LRDP: 0=no, 1=yes	0.21	0.41
B_EFF	1 if farmer perceives bunds as highly effective, 0 otherwise	0.52	0.50
reperesults	Percent of good results reported to the farmer by his environment: 1=0-25%, 2=25-50%, 3=50-75%, 4=75-100%	2.61	1.01
KY	District dummy: 1=farmer is located in Kulda-Yarong valley, 0=otherwise	0.12	0.33
ZUWARI	District dummy: 1=farmer is located in Zuwari valley, 0=otherwise	0.11	0.32
bike	Number of bicycles owned by the farmer	1.03	0.53
HEAD	Farmer is head of the household: 0=no, 1=yes	0.42	0.49
CON_L2	1 if labour is ranked first or second as most constraining for lowland rice production	0.31	0.46
DIB_Y	1 if farmer perceives dibbling as highly yield increasing, 0 otherwise	0.61	0.49
CGROUP2	Farmer is in any organization related to crop production (other than FSRPOP)	0.38	0.49
BULL	Number of bullocks (pair) owned by the farmer	0.15	0.40
weed_r	Rank of weeding as labour constraint in lowland rice production	1.55	0.76
LOAM	1 if the plot has loamy soil, 0 otherwise	0.18	0.38
VGOOD_RET	1 if the plot had very good water retention without bunds, 0 otherwise	0.52	0.50
VGOOD_SOIL	1 if plot has very good soil, 0 otherwise	0.51	0.50
LRDP_BUND	1 if plot has a LRDP project bund, 0 otherwise	0.32	0.47

<sup>5</sup> Labour equivalents are calculated with following factors: men (14-60)=1; women (14-60)=0.75; elderly / children=0.5

Table 2: Characteristics of adopter and non-adopter of bunds

Variable Name	Adopter		Non-adopter	
	Sample mean	Standard deviation	Sample mean	Standard deviation
AGE_R	36.81	11.14	37.78	10.52
INFS_R	0.31	0.46	0.28	0.45
R_SZ	2.26	1.47	2.09	1.27
CROP_SZ	5.21	5.03	5.15	4.01
FSZ	7.47	5.83	7.24	4.73
Number of total rice plots	1.40	0.52	1.17	0.41
Number of LRDP plots	0.55	0.52	0.27	0.46
GEQ_HH	14.30	10.33	12.54	8.49
GEQ_ILL	1.74	2.18	2.39	3.25
FSRPOP	0.34	0.48	0.14	0.34
LRDP	0.60	0.49	0.36	0.48
PROJ	0.25	0.44	0.16	0.37
CREDIT	0.53	0.50	0.28	0.45
B_EFF	0.59	0.49	0.45	0.50
Reresults	2.73	1.03	2.48	0.96
Adopter of dibbling	0.86	0.35	0.51	0.50

Table 3: Characteristics of adopter and non-adopter of dibbling

Variable Name	Adopter		Non-adopter	
	Sample mean	Standard deviation	Sample mean	Standard deviation
AGE_R	37.31	10.47	37.32	11.57
INFS_R	0.33	0.47	0.22	0.42
R_SZ	2.03	1.21	2.45	1.63
CROP_SZ	5.08	4.60	5.39	4.40
FSZ	7.12	5.26	7.84	5.35
Number of total rice plots	1.35	0.51	1.14	0.37
Number of LRDP plots	0.51	0.53	0.19	0.39
GEQ_HH	13.62	9.92	12.92	8.41
GEQ_ILL	1.99	2.86	2.25	2.66
BULL	0.15	0.40	0.14	0.39
FSRPOP	0.30	0.46	0.11	0.31
LRDP	0.56	0.50	0.30	0.46
PROJ	0.25	0.43	0.11	0.32
CREDIT	0.48	0.50	0.25	0.43
CGROUP2	0.39	0.49	0.36	0.48
B_EFF	0.53	0.50	0.48	0.50
Reresults	2.79	1.01	2.24	0.89
Weed_r	1.62	0.76	1.40	0.74
CON_L2	0.31	0.46	0.33	0.47
Adopter of bunds	0.61	0.49	0.22	0.41

Table 4: Results of seemingly unrelated bivariate probit of adoption decision of bund and dibbling

	Adoption of bunds			Adoption of dibbling		
	Coefficients	t-value	Marginal probability	Coefficients	t-value	Marginal probability
CONS	0.271	0.35		-0.658	-1.27	
GEQ_HH	0.014	1.61	0.005	0.010	0.90	0.003
GEQ_ILL	-0.044*	-1.72	-0.018			
AGE_R	-0.076**	-2.04	-0.030	-0.007	-0.63	-0.002
AGE2	0.001*	1.73	0.000			
STATUS_HH	0.332	1.63	0.132			
AV_FSZ	0.223**	2.30	0.089	0.339**	2.69	0.114
CROP_SZ	-0.050**	-2.46	-0.020	-0.053**	-2.01	-0.018
INFS_R	-0.069	-0.41	-0.028	0.406**	2.06	0.129
CREDIT	0.403**	2.29	0.160	0.496**	2.44	0.165
OFF_R	-0.040	-0.24	-0.016	-0.930***	-4.50	-0.329
FSRPOP	0.350*	1.81	0.137	0.592**	2.33	0.182
PROJ	0.359*	1.81	0.142			
HEAD				0.587**	2.53	0.191
B_EFF	0.224	1.57	0.089			
resresults	0.255**	3.14	0.101			
KY	0.446*	1.78	0.175	-2.391***	-6.65	-0.747
ZUWARI	0.002	0.01	0.001	-0.470*	-1.78	-0.171
bike	0.244*	1.80	0.097			
CON_L2				-0.593**	-3.03	-0.207
DIB_Y				0.510**	2.93	0.175
CGROUP2				0.233	1.24	0.077
BULL				-0.380**	-1.94	-0.128
weed_r				0.371***	3.29	0.124
LOAM	-0.365**	-2.00	-0.143			
VGOOD_RET	-0.329**	-2.21	-0.130	-0.381**	-1.99	-0.127
VGOOD_SOIL				0.662***	3.64	0.221
LRDP_BUND				0.827***	3.77	0.248
Log-Likelihood	-331.263					
Rho	0.758					

Note: Coefficients followed by \*, \*\* and \*\*\* indicate significance at the 10%, 5% and 1% level, respectively.