What Determines Farmers' Decision to Own Water Extracting Devices in Water Abundant Regions? A Study of Groundwater Markets in Assam

JituTamuli*
Mrinal Kanti Dutta**
Payel Priya Kashyap***

Abstract:

Development of groundwater based irrigation has resulted in emergence groundwater markets or water markets in many parts of India. The size and growth of the market depend upon the status of agricultural development, agro-climatic conditions, and level of groundwater development and power policy of the state concerned. Unlike other parts of India, Assam in eastern India has abundant groundwater reserves with heavy monsoon precipitation facilitating easy replenishment. With the proliferation of groundwater-based irrigation since 1980's, groundwater markets have emerged in some pockets of the state mostly driven by capital scarcity of participating farmers.This paper examines the functioning of the market in a water abundant state i.e. Assam and the determinants of ownership of Water Extracting Devices (WEDs) using farm-level data collected from 198 farm households in two districts viz. Nagaon and Morigaon. The results have shown that own farm size, access to formal sources of credit, availability of off-farm income sources, education and age of the head of the household have significant and positive influence on the probability of a farmer's decision to own tubewells.

1. Introduction

Groundwater market, popularly known as water market, is a localised informal institutional arrangement where a farmer owning a Water Extracting Device (WED) (e.g. pump sets or tube wells)sells excess of the groundwater extracted from beneath his land to the willing buyers in the neighbourhood of the owner's plots (Shah, 1991, 1993; Pant, 1992; Zhang, 2006). Development of this market, in general can be attributed to the expansion of groundwater based irrigation in agriculture in Asian countries. The market has its significant presence in India especially in states like

* The author is an Assistant Professor, Dept. of Economics, Tyagbir Hem Baruah College, Jamugurihat, Sonitpur.The author can be reached at jitutamuli@gmail.com

** The author is Professor (Economics), Dept. of Humanities and Social Sciences, IIT Guwahati,The author can be reached at mkdutta@iitg.ernet.in

*** The author is independent Researcher, located at BiswanathChariali, Assam. The author can be reached at kashyappayel@gmail.con

Gujarat, Maharashtra, Haryana, Andhra Pradesh, Tamil Nadu, Western Uttar Pradesh, Punjab and West Bengal. Other Asian countries such as Pakistan, Bangladesh, (Rinaudo and Stosser, 1997; Meinzen-Dick, 1998; Shah, 1991, 1993; Saleth, 1996, 1998), Indonesia, Jordan (Meinzen-Dick and Mendoza, 1996) and China (Zhang, 2006), and countries like Mexico (Thobani, 1997; World Bank, 1999), etc. have also seen pervasive presence of water markets in irrigation based agriculture.

The development of the market is not uniform across regions in India. The size and rate of proliferation of the market and its inherent issues depend upon the status of agricultural development, agro-climatic conditions and level of groundwater reserves and state of groundwater development (Shah, 1993; Saleth, 1997). While water markets in India display a wide variation in terms of organisational features and behavioural pattern (Saleth, 1998), researchers also note that these differences are obvious as groundwater markets are village level localised institutions (Pant, 1991; Shah, 1993; Joshi, 2005; Zhang, 2006). Water markets in water abundant regions present issues which may be in quite contrast to the water scarce regions. Noting the presence of such differences, Dubash (2000) points out that instead of looking at how the markets work or do not work, it is important to look at how and why they work differently in different locations, under different social and hydrological circumstances and with what effects. Shah (1991) also observes that water abundant regions offer a major scope for development as water markets can transform the stagnant agriculture to a booming economy. The question in abundant region, as Shah has pointed out, is how to speed up the development of water markets and saturate the available potential. When one can easily come by plethora of studies on water market from water scarce regions of any country, more so in India, the studies from water abundant regions are fairly scarce.

Assam in eastern India has abundant groundwater reserves with heavy monsoon precipitation facilitating easy replenishment. However, in view of a very limited use of ground water for agricultural purposes, development of groundwater based irrigation has been promoted since 1980’s. Out of the ground water based irrigation structures, tube well based irrigation constitutes more than 80 percent of the total groundwater structures and shallow tube well constitutes 87.28 percent of the total tube wells in the state (Govt. of Assam, 2011a, 2011b). One of the striking features of minor irrigation development in Assam is that these shallow tube wells are installed under private/ individual ownership. As per the Minor Irrigation Census 2000-01 of Government of India, about 98 percent of the total STWs in Assam are under individual ownership. As installation of shallow tube wells requires relatively large investments which a resource poor marginal and small farmer finds difficult to afford, water transaction takes place between owners of WED and the non-owners. As a result, groundwater market has emerged in the state as an alternative institutional arrangement facilitating the access of groundwater to small and marginal farmers as well (Dutta, 2011, 2012).

In the present paper, an attempt has been made to examine the functioning of the market and especially the factors that affect ownership of WEDs in groundwater markets in Assam, a groundwater endowed state in the eastern part of India. The rest of the paper is organised under six sections. Section 2 deals with the data source and type of data used in the study. While section 3 discusses the methods for examining the determinants of WED ownership, section 4 presents a discussion on the structure of the market and interface of groundwater market with other rural markets. Section five includes a discussion of the factors affecting the water buying decision of farmers based on theoretical and empirical findings. The estimated results of the logit regression model are discussed in section six. Section seven provides a conclusion to the paper.

2. Data source and methodology

Groundwater has been an abundant resource in Assam especially more in the low lying areas. As per available estimates of the Central Groundwater Board (CGWB), out of total available replenishable amount of groundwater, only 22 percent of it has been developed so far (Govt. of India, 2006). With the development of groundwater based irrigation, some drastic changes in cropping pattern of the state has been noticed, for e.g. there has been a gradual shift from winter rice cultivation to summer rice cultivation in some districts of the state. The cultivation of summer rice in the state is undertaken solely based on groundwater irrigation during November to April in any agricultural year. The study area has been chosen from the areas where the cultivation of summer rice is carried out and where farmers recourse to groundwater transaction.

2.1. Study area

The study was carried out in the Central Brahmaputra Valley Zone (CBVZ) of the state. The districts of Nagaon and Morigaon had been purposively selected for the study. The selection is guided by the fact that the presence of groundwater markets is quite widespread in the low lying pockets of the two districts especially in the cultivation of summer rice. For inclusion of farmers in the sample, initially the locations where the market has widespread presence were identified. In the next stage, a few villages from those locations were randomly selected and finally information on various issues of ground water market and agricultural practices were collected from a few randomly selected farm households from each of these villages. Since market practices are found to be similar in a particular village or in the same crop field, emphasis was on including farmers from more number of villages, so that spatial/regional variations on market practices market could be captured.

Figure 1 : Land use map of Nagaon and Morigaon District

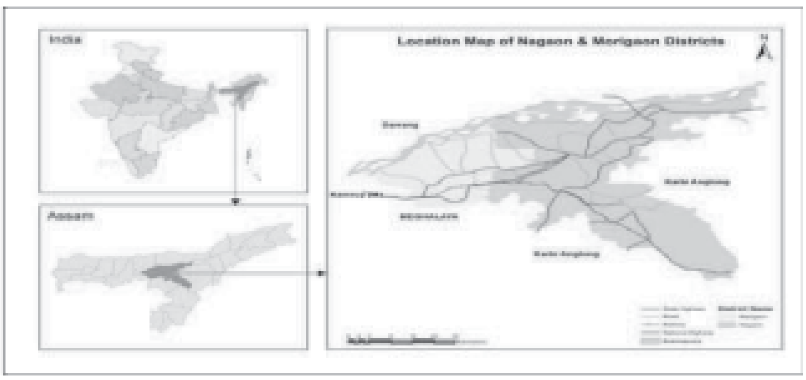
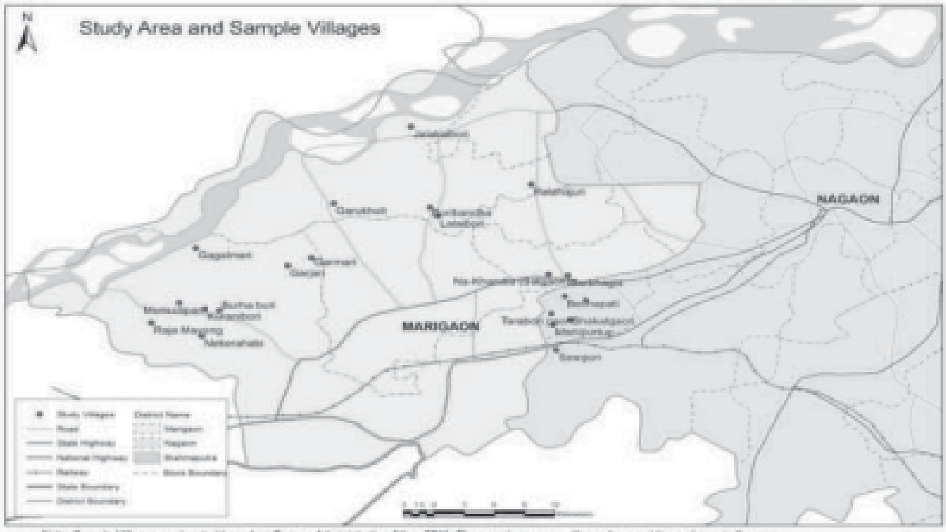


Figure 2 : Study Area



Note: Sample Villages are located based on Census Administrative Atlas, 2011. The sample revenue villages have not been shown in the map

2.2. Data base and sample

The total number of farmers included in the sample was 198 who are engaged in the cultivation of summer rice with sole reliance on virtually unrestricted access to groundwater. A specially structured and pre-tested questionnaire had been administered to collect data on various aspects of production and groundwater markets for the agricultural year 2011-12. Data was collected mostly on farm and non-farm activities, demographic and locational characteristics. While the data on farm activities include number of irrigation, labour, wages, farm size, crop output and prices, capital assets, costs of cultivation, fertiliser application, etc., the data on the market related issues include the size of the market, mode of transaction, non-market factors and the issue of reliability. After selecting the sample, they were categorised into seven different types[1]: Self-users (SU), Self-users + sellers (SU+S), Self-users+ sellers + buyers (SU+S+B), Self-users + buyers (SU+B), Buyers (B), and Owners+sellers (OS).

[1] Self-users+sellers: Farmers with independent or joint ownership (or both) of tube wells, use water for cultivating their own plots as well as selling water to needy farmers in the vicinity of the tube well after meeting their own requirement. Buyers: The farmers who buy water from the nearest tube wells usually adjacent to their agricultural plots. However, there is the possibility of water purchase from any distant source when there is facility for water conveyance. Self-users+sellers+buyers: The owner of tube wells who cultivate their agricultural plots with water from own tube wells, sell water to willing buyers after meeting their own requirement and buy water from other tube wells in another location, when their cultivable land is fragmented. Self-users+buyers: the farmers with independent ownership or joint ownership of tube wells use water from their own tube wells for own use in one plot and buy water from other tube wells in another plots. Owner+sellers: refers to a situation in which some farmers have invested on tubewells, not to meet their own irrigation requirement, but for using it primarily for selling water to other farmers. Self-users: Farmers with individual or joint ownership of tubewells and use it for cultivation on own plots.

2.3. Methods

The ownership of a tube well of a farmer is a binary or dichotomous-response variable taking on the values "0" or "1". Therefore, in order to identify the factors and their relative role in influencing the response variable in probabilistic sense, the logit model based on cumulative logistic distribution function was found to be suitable (Maddala, 1983; Aldrich and Nelson, 1984; Cramer, 2003; Gujarati, 2004; Gujarati and Sangeetha, 2007; Hill et al., 2011). The logit model used in the study was formulated as follows.

The logit model postulates that P_i, the probability that i^{th} farmer owns a tubewellis a function of an index variable $Z_i$summarising a set of explanatory variablesX_{ki}. That is,

$$P_i = f(Z_i) = f\left(\alpha + \sum \beta_k X_{ki}\right) = \frac{1}{1+e^{-z_i}} = \frac{1}{1+e^{-\alpha+\sum \beta_k X_{ki}}}$$

Where,

Z_i =An underlying and unobserved index for the i^{th}farmer (when Z exceeds some threshold Z*, the farmer is observed to be ownerotherwise non-owner.

X_{ki} = The k^{th}explanatory variable for the i^{th} farmer that may affect his decision to own tubewells.

i=1,2...N; where, N is the total number of sample farmers included in the study

k= 1, 2 …M; where M is the total number of explanatory variables.

α = Constant

β = Vector of coefficients

e = Base of the natural logarithm and approximately equals to 2.718.

Now, in the estimation context $Z_i$can be estimated as, $\log(\frac{P_i}{1-P_i}) = z_i = \alpha + \sum \beta_k X_{ki}$. Thus, Z_i is a linear function of a host of explanatory variables. In fact Z_i[2]is equal to the natural logarithm of the odd ratio[3], i.e. the ratio of probability that the farmer has owned a tube well to the probability that the farmer does not. The goodness of fit of the model has been checked using the Log-likelihood Ratio tests and a few pseudo coefficients of determination. In order to assess the effect of each selected explanatory variable on the probability of ownership decision, the marginal effects and elasticity coefficients are estimated. Marginal effects of the explanatory variables are the partial derivatives of probabilities with respect to the vector of explanatory variables and are computed at the mean of the explanatory variables. The value of the coefficient of marginal effects indicates the changes in decision of a farmer to buy water which is caused by a one unit change in the independent variable, *ceteris paribus*. The elasticity coefficient

[2] Z_i the natural logarithm of the odd ratio is referred to as logit. It is also called logit transformation as it transform Y which is restricted in the range of [0,1] to a range of [-", + "].

[3] A odds ratio is the ratio of odds of success for one group divided by odds of success for another group

indicates that 1 percent change in the explanatory variable will change the probability of farmers' decision to buy water equal to the respective percentage of the elasticity coefficient (Khair et al. 2012).

3. Groundwater markets in the study area

3.1. Market Arrangement

The distribution of the sample farmers participating in groundwater markets according to their size of operational holding is presented in Table1.A large majority of the sample farmers, (about 90.90 percent) are engaged in water transaction. The "buyers" alone constitute the largest segment (39.90 percent) followed by "self-users+sellers" (38.38 percent), "self-users" (9.09 percent), "self-users+sellers+buyers" (7.07 percent), "owner+sellers" (3.54 percent) and "self-users + buyers" (2.02 percent). The majority of the buyers are found to be marginal (56.82 percent) and small farmers (41.54 percent). It implies that about 98.36 percent of the buyers are in the category of small and marginal farmers. Buyers in the semi-medium category are only 5.13 percent. With relatively larger farm size, the number of buyers is very less (5.13 percent of the total sample farms). Thus buyers in the groundwater markets are usually small and marginal farmers and the finding is similar to the results of Fujita and Hossain (1995) in Bangladesh; Meinzen-Dick (1997) in Punjab province of Pakistan; Zhang et al. (2007) in China; Bhandari and Pandey (2006) in Nepal; and a couple of studies such as Deepak et al. (2005), Sharma and Sharma (2006), Khanna (2006), Singh and Singh (2006), Manjunatha et al. (2011a), Dutta (2012), Manonmani and Malathi (2012), etc. in India.

Table 1: The Distribution of Sample Farmers According to the Structure of the Groundwater Market

Size class of operational land holding (in hectare)	Category of participants in the water market						Total
	Self-users	Self-users + sellers	Self -users+ sellers + buyers	Self-users + buyers	Buyers	Owner+ sellers	
Marginal	5(5.68)	25(28.41)	2(2.27)	-	50 (56.82)	6(6.82)	88 (100)
Small	5(7.69)	25(38.46)	5(7.69)	2(3.08)	27(41.54)	1(1.54)	65(100)
Semi-medium	8 (20.51)	22(56.41)	6 (15.38)	1 (2.56)	2(5.13)	0	39(100)
Medium	0	4(66.67)	1(16.67)	1(16.67)	0	0	6 (100)
Total	18(9.09)	76(38.38)	14(7.07)	4(2.02)	79(39.90)	7(3.54)	198 (100)

Note: Figures in parentheses indicate percentage of the row total.

Out of the total sample "self-users+sellers", about 65.78 percent are marginal and small farmers. Taking all the categories together, the total number of sellers in one or other form of selling activities is 97 out of which 65.98 percent are marginal farmers (34.02 percent) and small farmers (31.96 percent). But against this, about 28.86 percent are in semi-medium and 5.15 percent in medium farm holding categories.

The size of operational holdings of the farmers under different categories of groundwater users show that the average size of operational holdings of the buyers is 0.9 hectares while the minimum and maximum size of operational holdings are 0.20 hectares and 3.08 hectares respectively (Table:2). But the average size of operational holdings of the sellers in all categories (except the "owner+sellers"), remains higher than the average size of operational holdings (1.35 hectare) for all the market participants. It implies that, on the average, the size of operational holdings of the water sellers is comparatively larger than the buyers. However, there is an exception to this trend. It was observed that a few members of the group "owners+sellers", though do not hold any cultivable land are in the possession of shallow tube wells and engage in water selling. This category of water sellers owns the tube well primarily for selling water to other farmers and to their tenants. The finding includes a new dimension in water market while explaining the conditions for the existence of groundwater market. Thus, on the seller's side, it shows that the market has helped some of the tube well owners to sell water not only in excess of their own use on self-operated area but also taking groundwater pumping as an additional source of income. It also suggests that the market is not residual to the buyers in all cases.

Table 2: Size of the Operational Holdings of Different Categories of Groundwater Users

Categories of water users	No. of Farms	Minimum (in hectare)	Maximum (in hectare)	Average (in hectare)	Standard Deviation
Self-users	18(09.09)	0.40	3.34	1.68	0.99
Self-users+sellers	76(38.38)	0.27	4.95	1.64	1.05
Self-users+sellers+buyers	14 (07.07)	0.27	4.41	2.09	1.24
Self-users+buyers	4(02.02)	1.07	4.01	2.58	1.59
Buyers	79 (39.90)	0.20	3.08	0.90	0.55
Owner+sellers	7 (03.54)	0.00	1.74	0.29	0.65
Total	198	0.00	4.95	1.35	1.00

Notes: Figures in parentheses indicate percentage of the column total.

3.2. Interface of the groundwater market with non-market factors

Palmer-Jones (1994), Meinzen-Dick (2000) and Dubash (2002) have outlined the complexity in the nature of water contracts which is mostly governed by the social processes. As discussed above, the water charge is not fixed by any formal written agreement between the buyers and the sellers. At the same time, it has been observed that the sample buyers' choices of water sellers are also restricted due to lower tube well density in the crop fields, and limited availability of conveyance facilities if buyers' plots are located in a distant plot (Hussain et al. 2005). This lends the water sellers some market power to charge different prices from different buyers (Shah, 1993; Wood, 1995; Shah and Ballabh, 1997; Pant, 2003; Jacoby et al., 2004). Though, sample sellers' were not found to have charged different water charges from different buyers, some of them have been found to have given concession on water charges to some of their buyers. This finding is similar to the results of Shah (1993) who has found that transaction between water buying and water selling farm households were personal in a few cases depending on personal relation. However, this finding is not similar to the results of Zhang (2006) who has found that in Northern China groundwater markers are almost fully impersonal. The extent of this price concession in the study area varies from 10.00 percent (1.49 quintal per hectare) to23.3 percent (5.97 quintal per hectare). In majority of the cases, about 2.98 quintals per hectare concession is given. While the brothers of the water sellers have enjoyed either 5.97 quintal per hectare concession from the water sellers or full concession (conditioned by serious illness), the relatives of the water sellers have enjoyed a concession of 2.98 quintal per hectare.

The studies on water market report that there always remains an overdue in the payment of water charge by the water buyers (Khanna, 2006). In the present study, a few buyers have been found to be defaulters in making payment of water in time. Out of a total of 97 water sellers, about 55.67 percent have reported that there remains an overdue in the payment of water charge. Out of the total sample buyers, the relatives of the sample water sellers, are the highest defaulters (about 44.45 percent of the total defaulters). This is followed by buyers (37.04 percent of the defaulters) who are neither the relatives nor the tenants of the water sellers. Compared to these two groups, the number of tenants who failed to make payment on time is less (9.26 percent of the total defaulters). A few buyers, who are tenants and relatives of the water sellers, have also been found to be defaulting on payment of water charge. Though a majority of buyers have remained defaulter for a year, out of the total defaulters, about 38.88 percent are permanent defaulters. Among the permanent defaulters, about 57.14 percent are relatives of the sample water sellers. Thus, it is clear that brothers and close relatives of the sample water sellers are the defaulters in the payment of water charges. Thus, there are free riders in water market. It raises a serious question why the sellers have not retaliated to punish these permanent free riders? When institutional economics dealing with resource management suggests that free riders are usually punished –sometimes, severely (Ostrom, 1990;Baland and Plateu, 1996) the study results here suggests that if the free riders are the sellers' relatives, they are allowed to continue with default which may render it unsustainable in future.

The nature and mode of operation of the village level groundwater market also show that the price does not always guarantee access to water (Wood, 1995). In addition to water charge, some of the buyers are required to render some other services to the water sellers like operating the pump and irrigating the well owner's field (Janakarajan, 1993, 1994). In the present study too, about 35.05 percent of the buyers are found to provide some sort of free services to their respective water sellers in addition to the water charge paid. The buyers are required to provide these services in order to maintain a cordial relationship with the sellers, so that they are provided with timely supply of water at the time of requirement. A few sample buyers(8.82 percent) providing other services refused to render these free services but were denied water by the sellers leading to giving up of cultivation by the farmers. There is also a preferential treatment of the buyers by the sellers. Normally, siblings and close relatives are provided with high preference in providing water by the sellers. The presence of this type of preferential treatment has also been reported by Narayanamoorthy (1991) in a study on water markets in Puddukkottai district of Tamil Nadu. Thus market practices are not purely based on conventional economic model which is endogenous to the water market. Instead, the water sellers exercise some monopoly power, though not reflected in the water charges, through some other means which are exogenous to the market system. Similar type of practice was also reported by Ray (1998) in the operation of rural credit market. In the light of these findings, a comparison with a few aspects of water market reported by existing studies on water market can be made. *Firstly*, the market in the study area is like the market in Gujarat (Shah, 1993) and Tamil Nadu (Janakarajan, 1994) where the market is found to have more oligopolistic and monopolistic in nature; *Secondly*, it resembles the observation made by Saleth (1998) that "…in a market where the buyers and sellers have about the same sized farms and share a common socio-economic background is likely to be more equitable and less exploitative". *Thirdly*, the market in the study area is less exploitative like the same in case of Madhya Pradesh where in a study Kajisa and Sakurai (2003) have found that the sellers' behaviour is not exploitative.

4. Factors influencing ownership of WEDs

To understand the factors influencing ownership of water supply resources, a binary logit model has been used and the sample farmers have been categorised into two classes, viz., tube well owner and non-owners. The total number of sample farmers included in the analysis is 198. The typology of the farmers according to their ownership of tube well is presented in Table 3.

Table 3: Typology of Sample Farmers According to Their Decision to Own a Tubewell

Category of Farmers	Ownership of tubewell		Total
	Non-Owners	Owners	
Self-users	0	18	18 (9.09)
Self-users +sellers	0	76	76 (38.38)
Self-users+sellers+buyers	0	14	14 (7.07)
Self-users+buyers	0	4	4 (2.02)
Buyers	79	0	79 (39.89)
Owner+sellers	0	7	7 (3.53)
Total	79	119	198 (100)

Notes: Figures in parentheses represent percentages to column total

The available theoretical and empirical literature reflects a number of factors that determine the decision of a farmer to own a tube well (Bhandari and Pandey, 2006). However, subject to the availability of data and their relevance in the context of the present study, a few factors have been identified so as to capture their possible influences on tube well ownership decision of a farmer. The description of the explanatory variables, the theoretical justification for the inclusion of them and the nature of their likely impact on the probability ownership decision are given in appendix A.2. The definition of the explanatory variables and expected signs of the coefficients of the variables are summarised in Table 4.

Table 4: Definition of the Explanatory Variables and their Likely Impact on Farmers' Decision to Own a Tubewell

Sl. No.	Variable	Definition	Expected the coefficients
1	*WFS*	Own farm size (area in hectare)	+
2	*TOHL*	Total operational holding (area in hectare)	+
3	*AULC*	Area under the largest compact plots (in hectare)	+
4	*ACIC*	Access to institutional credit (1 = Yes; 0, otherwise)	+
5	*SSI*	Subsidiary source of income in the farm household (1 = Yes; 0, otherwise)	+
6	*AGE*	Age of the head of the farm household (in years)	+
7	*EDN*	Education of the head of the farm household (in years)	+
8	*NFPT*	Nos. of fragmented plots	-
9	*CSTE*	Caste of the farm household (1 = General caste; 0, otherwise)	+
10	*AVLE*	Availability of electricity facility (1 = Yes; 0 = No)	+
11	*SCES*	Score of the extensions services (in number)	+

The descriptive statistics of the explanatory variables considered in the model are presented in Appendix A-2.

5. Results and discussion

The maximum likelihood estimates (MLEs) of the coefficients of logit regression model, marginal effects and elasticity are presented in Table 5.

Table 5: Logit Estimates for the Likelihood of Tube well Ownership Decision of the Sample Farmers

Variables/Particulars	MLEs		Marginal Effects		Elasticity
	Coefficient	Standard Error	dy/dx	Standard Error	
CONSANT	-5.2814***	1.332549			
OFS	1.209369***	0.358655	0.228348	0.05379	0.419718
TOHL	0.049986	0.350906	0.009438	0.06632	0.016894
AULC	1.059901*	0.645966	0.200126	0.12307	0.21462
ACIC	1.045966**	0.47818	0.170697	0.06753	0.064063
SSI	-0.2173	0.381554	-0.04117	0.07265	-0.02551
AGE	0.045399**	0.018547	0.008572	0.00353	0.543313
EDN	0.125517**	0.049673	0.0237	0.00913	0.165603
NFPT	-0.17756*	0.223077	-0.03353	0.04226	-0.06956
CSTE	0.413706	0.436251	0.076431	0.07876	0.041703
AVLE	0.481328	0.468672	0.090882	0.08898	0.152928
SCES	0.13174**	0.065304	0.024875	0.01269	0.084553
Log-likelihood of full model					-92.433
Log-likelihood of null model					-133.87
LR Chi^2					81.48*
Overall pseudo R^2					0.305
Degrees of freedom					11
Nos. of observation					198

, ** and * represent significance at 10 percent, 5 percent and 1 percent levels. For a dummy variable, dy/dx is the discrete change of dummy from 0 to 1.*

The estimated model gives a good fit indicated by the significant Likelihood Ratio Test (L-R Chi^2) keeping in view the cross section data set used. The model has provided correct prediction to the extent of 77.78 percent of the dependent variable. The Variance Inflation Factor (VIF) values used to check multi-collinearity (Appendix-3) have shown absence of multi-collinearity problem in the model. As evident from Table 5, the pseudo R^2 has turned out to be 0.305. Though a high value of pseudo R^2 is desirable, in logit model they are not always considered at par with the adjusted R^2 like in OLS.

The coefficient of "*OFS*" is found to be significant and positive, which implies that when own farm size increases, farmers' probability of tube well ownership increases. In other words, with large own farm size a farmer decides to own a WED. Thus, own farm size has a positive and significant influence on ownership of WED. The partial probability of own farm size is estimated to be 0.228. It implies that other things remaining the same, one unit increase in own farm size will increase the probability of ownership by 0.228 points. Similarly, the elasticity coefficient which is estimated to be 0.419, implies that one percent change in the own farm size increases the probability of tubewell ownership by 41 percent, *ceteris paribus*.

The coefficient of "*AUL*" has been found to be positive and fairly significant which shows that the area under the largest compact plots induces a farmer to own a pump set rather than resorting to buy water. The possible explanation for this could be the advantages enjoyed by a farmer with relatively larger plot in terms of scale of operation. The partial probability of the variable was found to be 0.200 which shows that when the area under the largest compact plots increases by one hectare, the probability of owning a tube well increase by 0.214 points, other things remaining the same. The elasticity coefficient of the variable implies that one percent increase in the compact plots the probability to own a tube well will increase by 21 percent, *ceteris paribus.*

Initial investment on tube wells requires a large capital outlay in buying the pump sets, equipments and installation of the boring. Though a financially capable and large farmer can invest on a tube well, it has been found that the provision of formal credit may enable farmers to own a WED as the coefficient of the variable "*ACIC*" is found to be significant and positive. The elasticity coefficient implies that when the farmer has an access to formal credit, the probability of owning a tube well increases by 6 percent, other things remaining the same.

The coefficient of "*EDN*" has been found to be positive and significant and with education, the farmer may see the benefits of ownership of WED in terms of cost and reliability in supplying water to the field during its requirement at different stages. The available literature on water markets also points to the positive impact of education on water ownership decision of the farmers (Bhandari and Pandey, 2006). The partial probability is estimated to be 0.023 which indicates that when education of the farmer increases by one year of formal schooling, the probability of the farmer to own a tube well will increase by 0.023 points. The elasticity coefficient of 0.165 of the variable implies that when education of the farmer increased by one year of formal schooling, the probability of tube well ownership increases by 16 percent.

The coefficient of "*AGE*" is also found to be significant and positive. When a farmer becomes more and more experienced from the point of view of better farming, he is more likely to own a WED. The partial probability of the variable is found to be 0.008 which implies that, other things being equal, one year increase in age of the farmer/ farm household will increase the probability of tube well ownership by 0.008 points. The elasticity coefficient of the variable implies that when age of the farmer increases by one percent, the probability of tube well ownership, *ceteris paribus,* will increase by 54 percent.

In order to explore the likely impact of number of fragmented plots on farmers' decision to own a WED, the variable "*NFPT*" was considered in the study. The coefficient of the variable is found to be significant and negative. This implies that when the number of fragmented plots increases, the probability of farmers' tube well ownership decreases. The partial probability of the variable is found to be (-) 0.03. It implies that when the number of fragmented plots increases, the farmer's probability to own a tube well decrease by 0.03 points, other things remaining the same. The elasticity coefficient of the variable shows that, *ceteris paribus,* a one percent increase in number of fragmented plots will increase the probability of tube well ownership of a farmer by 6 percent.

The coefficient of "*ACES"* is found to be positive and highly significant. Thus when a farmer receives better extension services in the form of information on farming practices, the farmer is more likely to own a tube well. The observation in the field also confirms that farmers with better contact with agricultural extension workers are in a better position to avail different facilities given by the government under its different schemes. The partial probability of the variable which is found to be 0.024 implies that when the farmer's scores on extension services increases by one point, *ceteris paribus*, the probability of tube well ownership will increase by 0.024 points. The partial elasticity coefficient shows that one percent increase in farmer's scores increases the probability of tube well ownership by 8 percent, other things remaining the same.

Though the coefficients of "*TOHL"* and "*SSI"* are found to be statistically insignificant in the context of the present study but their signs are positive as expected. Similarly, the "*AVLE"* is not a significant determinant of ownership of tube well. But the variable bears a positive sign as expected. In addition, "CSTE" is also not a significant determinant of ownership of tube well by a farmer.

6. Conclusion:

The results of the logit analysis of the determinants of tube well ownership have shown that tube well ownership is skewed towards the larger farm holdings. Own farm size, land fragmentation, education and age of the head of the household, access to credit and availability of off-farm income sources have been found to be significant determinants of tube well ownership.

Though groundwater based irrigation has been promoted in the state for furthering agricultural development as the state is endowed with abundant replenishable groundwater reserves, it has been found that the cost of pumping is high due to the dependence on diesel operated tube wells. This has resulted in decline in the absolute number of groundwater buyers over the years. Although electricity operated tube wells entail lower cost per unit of water supplied, absence of electricity connections (in a few places) and low voltage, irregular supply with several power cuts (where electricity connections are available) are some of the major obstacles felt by both water sellers and water buyers. Thus, the investments in rural electrification are necessary pre condition so that the farmers can tap the ground water resource. In the similar line, it can be mentioned that fragmentation of land holdings has been found to have negative impact on ownership decision of tube well. Therefore, in order to enable marginal and small farmers to own a tube well, consolidation of land holdings and joint ownership of tube well may be promoted under suitable policy.

Though groundwater markets have facilitated access to groundwater among small and marginal farmers, the study finds that the small farmers may not be able to buy the pumpset as it involves relatively large capital outlay. This is further constrained by farmers' inability to access formal credit sources. While provisioning of subsidized credit facility can help the farmers to own a tube well it is also likely to bring down cost of cultivation in the long run.

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Appendix:

A.1: Empirical model for determinants of WED ownership:

Incorporating the explanatory variables shown in Table 7, the functional form of the model specified above can be formulated for estimating the parameters affecting WED ownership decision of the relevant sample farmers as where $\log(\frac{P_i}{1-P_i}) = z_i$ where P_i is the probability to own a tubewell.

$$Z_i = \alpha + \beta_1(WFS) + \beta_2(TOHL) + \beta_3(AULC) + \beta_4(ACIC) + \beta_5(SSI) + \beta_6(AGE) + \beta_7(EDN) + \beta_8(NFPT) + \beta_9(CSTE) + \beta_{10}(AVLE) + \beta_{11}(SCES) + U_i$$

U_i is the error term.

A.2: The description of the explanatory variables:

***Own Farm** Size (OFS):* Own farm size, measured in hectare, is the total cultivated area owned by a sample farmer. Existing empirical literature (Pant, 1992; Shah, 1993; Bhandari and Pandey, 2006, etc) points out that: OFS of a farmer is positively related to the probability of owning tubewell.

Size of Operational Holdings (**TOHL**):

In most instances though own farm size of a farmer is low, if the farmer has the possibility to lease in land, the farmer may choose to own a tubewell. The size of total operational holdings measured in hectare is important to consider as a factor that influences tube well ownership decision of a farmer. Thus, larger is the size of operational holdings greater may be the possibility to on tube well.

Fragmentation of Land Holdings (NFPT):

The fragmentation of land has been captured as the number of fragmented plots where summer rice is cultivated. When farmers' cultivable plots are dispersed in many plots, it is quite unlikely that with single water extracting device a farmer will be able to irrigate all his land. Besides, moving pumps around frequently may also cause early break-down which may entail more cost. Therefore, when degree of fragmentation is high and fragmented plots are smaller in size: a farmer may not own a pumpset or a farmer with pump set may not be willing to own more than one pump set. Thus larger the number of fragmented plots, lesser is the probability to own a tube well.

Area under the Largest Compact Plots:

Even though a farmer might have many fragmented plots, if the dispersed plots are large in size, the farmer is more likely to own a WED. It can be hypothesized that when area under largest compact plots increases the farmer is more likely to own a WED. Therefore, area under largest compact plot (denoted in short as *AULP)* is positively related with ownership of tube well by a farmer.

***Subsidiary Occupation (SSI)**:*

Since, a farm family with stable subsidiary source of income may enjoy capacity to invest on pump sets, a farmer with subsidiary sources of family income find it easier to own a tube well, such a farmer might have less concentration on farming and might not invest heavily in agriculture. The income from the subsidiary sources may also not be sufficient to own a tube well. Therefore, a farmer with subsidiary source of income may or may not turn out to be an owner. The role of this variable on the probability of tube well ownership could be captured by constructing the dummy variable whether the farmer family has subsidiary income sources or not.

Education (EDN):It is captured as the number of formal years of schooling attended by a farmer. It's a proxy variable for know-how of information regarding improved farm practices, managerial skills, etc. are important for effective farming. Since, education reflects possible effect of human capital (Bhandari and Pandey, 2006) and managerial ability (Singh and Singh, 2006) it may enhance farmer's understanding to capture the chance to sell water as a viable economic opportunity and own a tube well.

Age (AGE):Age of the water sellers measured in terms of years. Its proxy for experience of farmer in farming that helps in effective farming. Experience may encourage the farmer to own a tube well to ensure adequacy in applying irrigation in undertaking summer rice cultivation which is a water intensive crop and based primarily on groundwater irrigation. Besides, an experienced farmer may also take an initiative to own a WED jointly in order to minimise its own share in initial investment required to buy a pump set.

Access to Institutional Credit (ATIC):

Initial investment on tube well requires a large capital outlay in buying the pump set, equipments and installation of the boring which a large farmer is capable of buying a WED through his own savings. But most of the poor farmers cannot afford to install a WED in particular and other agricultural inputs in general. The provision of formal credit may enable farmers to own a WED. Thus, access to credit from formal sources is expected to affect ownership of tube well of the farmer and is positively related to the tube well ownership decision of a farmer. A dummy variable has been constructed to capture the effect of farmers' access to institutional credit assuming the value "1" if the farm household has an access to institutional credit and "0" otherwise.

***Caste*:**

A few available literatures also conclude that ownership of tube well is skewed towards higher caste. It is expected that farmer who belong to upper caste may have access to financial resources, etc. and thus be able to own a tube well. Therefore, in the context of the present study, the variable is considered to examine how caste as a variable affects tube well ownership. The probable impact of this variable can be captured as a dummy assigning the value "1" if the farmer belongs to the general caste, "0', otherwise.

Electricity Availability:

The STWs are operated with electricity or diesel. Though, in the present study, the concentration of diesel operated tubewells is more than the electricity operated tube wells, capital outlay, operation and maintenance expenditure is substantially lower in case of electric tube wells (Shah, 1993; Bhandari and Pandey, 2006; observation of the researcher). Because of low operational cost buyers prefer to buy water from the electric tube well than the diesel operated tube wells. Therefore, it may be hypothesised that the availability of electricity enables a farmer to own electric tube well and attract more buyers. The role of this variable on the probability of tube well ownership has been captured building a dummy variable (denoted in short as *AVLE*) assigning he value "1" is if electricity facility is available or "0" otherwise.

Table A.1: Descriptive Statistics of the Explanatory Variables that Influence Farmers' Decision to Own a Tubewell

Sl. No.	Variable Name	Variable Definition	Minimum	Maximum	Mean/ Mode	Std. Deviation
1	*WFS*	Own farm size (area in hectare)	0.00	12.04	1.37	1.58
2	*TOHL*	Total operational holdings (area in hectare)0.00	4.95	1.34	0.99	
3	*AULC*	Area under the largest compact plots (in hectare)	0.13	2.01	0.80	0.45
4	*AGE*	Age of the head of the farm household (in years)	22.00	77.00	47.37	11.79
5	*EDN*	Education of the head of the farm household (in years)	0.00	15.00	5.22	4.91
6	*NFPT*	Nos. of fragmented plots	1.00	5.00	1.55	0.79
7	*CSTE*	Caste of the farm household (1 = General caste; 0, Otherwise)	0	1	0.40	0.491
8	*AVLE*	Availability of electricity facility (1 = Yes; 0 = No)	0	1	0.74	0.438
9	*SCES*	Score of the extensions services	0	9	1.67	2.017
10	*ACIC*	Access to institutional credit (1 = Yes; or 0, Otherwise)	0	1	0.24	0.430
11	*SSI*	Subsidiary source of income in the farm household(1 = Yes; 0 = No)	0	1	0.46	0.500

Appendix A.3: Collinearity diagnostics for independent variables influencing WED ownership decisions of a farmer

Table A.3: Collinearity Diagnostics for independent variables influencing water buying decision of a farmer

Variable	VIF	SRT VIF	Tolerance	R-Squared
OFS	1.71	1.31	0.58	0.42
TOHL	1.49	1.22	0.67	0.33
PAUB	1.28	1.13	0.78	0.22
NFPT	1.04	1.02	0.97	0.03
DFNSI	1.16	1.08	0.86	0.14
AGE	1.28	1.13	0.78	0.22
EDN	1.41	1.19	0.71	0.29
SSI	1.14	1.07	0.87	0.13
ACIC	1.13	1.06	0.89	0.11
SCES	1.17	1.08	0.85	0.15
PSNR	1.40	1.19	0.71	0.29
CSTE	1.35	1.16	0.74	0.26
TNCY	1.25	1.12	0.80	0.20
Mean VIF	1.29			

Note: There are many recommendations for acceptable levels of VIF. While the most commonly suggested maximum level of VIF is 10 (Kennedy, 1992), a recommended maximum VIF value of 5 and even 4 have also been found in the literature. Considering the most commonly used VIF value of 10, the presence of collinearity in preferred model has been checked.