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Groundwater market in water-abundant regions: determinants of farmers' decision to buy irrigation water in Assam in North-East India

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ABSTRACT

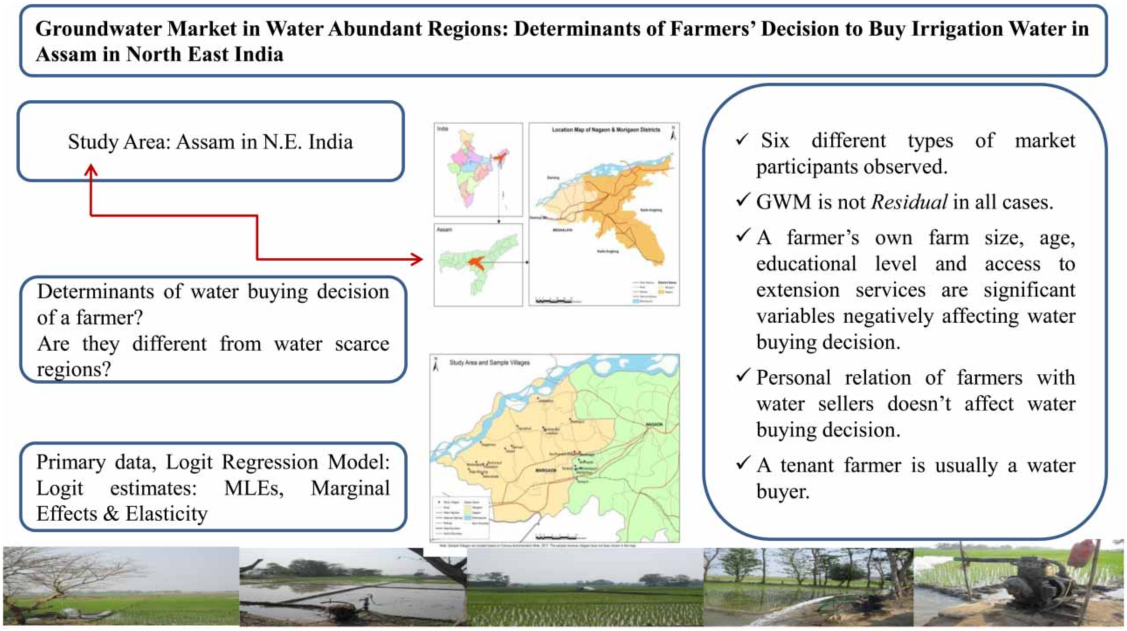
In response to the development of groundwater-based irrigation technology, institutions such as groundwater markets have emerged in many parts of India. While the farmers' decision to buy water is shaped by issues such as capital scarcity, size of operational holdings, number of fragmented plots, farmers' access to institutional credit, etc., there are spatial variations of factors affecting farmers' participation in the market due to its localised nature. In view of the fact that the number of studies on water markets from water-abundant regions of India is very limited, the present study was carried out to unearth the factors influencing the water-buying decisions of farmers in the groundwater market in Assam in the eastern part of India. Using field data from two districts of the state, viz. Nagaon and Morigaon and with the help of logit regression, this study examines the determinants of water-buying decisions of farmers in Assam. The results of the logit analysis show that own farm size, farmer's access to institutional credit, age, education, and better contact with extension agencies reduce the probability of water-buying decision for a buyer. For a tenant farmer, the probability of buying water is found to be higher.

Key words: Assam, Farm size, Groundwater market, Logit regression, Water-buying

HIGHLIGHTS

- It is an original research work on the groundwater market or water market in the water-abundant region.
- The study specifically looks at the nature and structure of the market and the determinants of water-buying decisions in water-abundant regions.
- This study is a deviation from the existing works on the water market, mostly from the water-scarce regions of India or Asian countries.

GRAPHICAL ABSTRACT



1. INTRODUCTION

The emergence of water institutions, such as groundwater markets (also popularly known as water markets), has helped resource-poor farmers of many developing countries overcome the problem of lack of access to irrigation water thereby enabling them to meet their food requirements. These markets, which are widespread in some Asian countries such as Pakistan, India, Bangladesh Indonesia, Jordan, and China (Shah, 1991, 1993; Saleth, 1994, 1996, 1998, 2006; Rinaudo & Strosser, 1997; Meinzen-Dick & Mendoza, 1996; Meinzen-Dick 1998; Zhang *et al*., 2006), have also helped better management of precious groundwater resources in different countries. As opposed to the formal water markets in developed countries, water markets in developing countries are informal in nature, where farmers owning tubewells sell groundwater to willing buyers in the neighbourhood without recourse to any legal sanction (Shah, 1991, 1993; Pant, 1992, 2004, 2005; Zhang *et al*., 2006, Tamuli, 2014). The market is usually considered a 'residual market' as the sellers sell water only after meeting their own requirements (Shah, 1993; Meinzen-Dick 1998; Khair *et al.* 2012). Both sellers and buyers of water have their own significance in such markets and the participation of farmers in these markets is conditional upon a number of factors. Buyers usually resort to water purchases when they are starved of capital to own water-extracting devices (WEDs). Additionally, as Pant (1992) has emphasized, buyers decide to purchase water when they perceive irrigation through the purchase of groundwater to be the most agreeable alternative compared to other sources of irrigation. Also, the buyers of water should be able to physically gain access to the source of water. Studies carried out in this field have identified various factors influencing farmers' decisions to participate in water markets, such as the size of the operational holdings, number of fragmented plots of the cultivator, farmers' access to institutional credit, etc. (Sharma & Sharma, 2006; Singh & Singh, 2006; Khair *et al*., 2012). However, since the groundwater market is localised in nature, the factors affecting farmers' participation in such markets is bound to exhibit some spatial variation.

Water markets are considered to be widespread in India. However, the spread of the market in the country seems to be varying considerably based on agro-climatic conditions and many other socio-economic parameters. Availability of water resources is one such important factor in determining the pace of growth of water markets. Normally in regions where the supply of water is high, the pace of development of water market is considered to be rapid (Dutta & Tamuli, 2022). However, contrary to this assertion, in the eastern Indian states of Orissa, Bihar, and West Bengal, groundwater markets are stated to be highly underdeveloped, in spite of the abundance of easily accessible groundwater reserve (Shah, 1993). Assam is another state in eastern India where the spread of groundwater market is found to be relatively slow in spite of having an abundance in groundwater reserve. One precondition for the emergence of water markets is the availability of willing buyers in the vicinity of WEDs.

In light of the above data, the present study has been taken up to unearth the factors influencing water-buying decisions of farmers in groundwater markets in Assam. While examining the issue, the paper also looks into the operational features of the groundwater market which might have a bearing on the decision of farmers to buy water.

Assam in the Eastern part of India has abundant groundwater reserves with heavy monsoon precipitation facilitating easy replenishment. According to the Central Groundwater Board (CGWB) of India, the net availability of annual replenishable groundwater in the state is 21.43 bcm, out of which 11.25% are extracted for all purposes (industrial, domestic, and agriculture) (Government of India, 2020). With a view to tapping the availability of groundwater for agricultural use in the state, there were initiatives through government agencies for rapid growth of groundwater-based minor irrigation schemes in the late nineties of the previous century. [For instance, the compound annual growth rates (CAGRs) of total minor irrigation structures in the state was 11.40% during 1986–87 to 1993–1994, which increased to 16.08% during 1993–1994 to 2000–2001 while the same for India was 6.99% during 1993–1994 to 2000–2001 (MoWR, 2005).] Among the groundwater structures, shallow tube wells (STWs) have recorded phenomenal growth outstripping surface irrigation schemes (surface flow and surface lift) in the state. Significantly, these tubewells have been installed under private and single ownership. As per the Minor Irrigation Census 2000–2001 of Government of India, about 98% of the total STWs in Assam have been under individual ownership. Tamuli *et al.* (2021) noted that the STW-based irrigation drew a huge response from the farmers in the state. With this development some changes in the cropping pattern of the state have also been noticed, e.g. there has been a gradual shift from autumn rice cultivation to summer rice (locally known as *boro* rice) cultivation in some districts of the state. Summer rice in the state is normally sown in the dry months of December and January when there is hardly any rainfall, and as such, it is almost impossible to raise the crop without irrigation. Most of the owners of the WEDs with excess capacity of their tubewells engage themselves in water transactions with the neighbouring farmers who do not own WEDs (on their own) for market and non-market reasons (Dutta, 2011, 2012; Tamuli, 2014). This has resulted in the emergence of groundwater markets in some locations of the state.

The rest of the paper is organised under four 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 the water-buying decision of the farmers and descriptions of potential variables influencing the decision, section 4 presents a discussion on descriptive and logit results. Section 5 finally sums up the whole discussion of the paper.

2. EMPIRICAL CONTEXT: DESCRIPTION OF STUDY AREA AND DATA SOURCES

The study is carried out in the Central Brahmaputra Valley Zone (CBVZ) of the state[1] which constitutes about 72% of the total geographical area and about 92% of population in the state. The selection of the Brahmaputra

[1] The State of Assam is divided into three broad physiographical units: The Brahmaputra Valley in the north, the Central Hilly Regions of Karbi-Anglong and North Cachar and the Barak Valley in the south.

Valley is guided by the fact that the valley constitutes more than 99% of the STWs installed in the state from 1,980 till 2010 (MoWR, 2005; Government of Assam, 2011). Among the four Brahmaputra Valley Agricultural Zones (viz. the North Bank Plain, the Upper Brahmaputra Valley, the Central Brahmaputra Valley and the Lower Brahmaputra Valley), the Central Brahmaputra Valley Agricultural Zone comprising two districts, viz. Nagaon and Morigaon districts, was selected for the study. The selection of the districts is guided by the fact that these districts have a better concentration of groundwater market activities in the cultivation of summer rice, especially in the low lying pockets of the districts (pilot survey by the first author). However, the incidence and variability are relatively high in a few locations. While almost all parts of Morigaon district are characterized by this groundwater market practice, in Nagaon district the markets concentrate only in a few places. Wherever the market operation takes place, the activities are found to be very intensive. It is found that Nagaon and Morigaon districts represent the area in which cultivation of summer rice is growing faster than the other districts in the state (Talukdar & Beka, 2005). Together, these two districts account for about 37% of the total area under summer rice cultivation in the state (Government of Assam, 2013). At the same time, the Nagaon district has nearly 23,482 numbers of STWs and 602 numbers of Low Lift Pumpsets (LLPs). Similarly, Morigaon district also has 11,103 number of STWs and 334 numbers of LLPs in the district having about 98% of the STWs under private ownership (Government of Assam, 2013).

The study has adopted multistage sampling. In the first stage, three Community Development Blocks (CDBs) from the Morigaon district and two CDBs from the Nagaon district were identified based on incidence of market practices based on the pilot study. The sample includes 125 farm households from the Morigaon district and 73 farm households from Nagaon district. The samples from Morigaon district have been randomly selected from 21 villages from three CDBs, viz. Mayang, Kapili and Laharighat. While Mayang comprises about 48.80% of the total sample farms, Kapili and Laharighat account for the rest 51.20%. The 73 farm households of Nagaon district have been randomly selected from 11 villages from two CDBs, viz. Kapili Pt. and Raha. While about 71.23% of the total sample farms in the Nagaon district are from Kapili Pt. CDB, about 28.77% are from Raha CDB. From each village, finally about 10–15% of the irrigated farm households were selected at random as the ultimate sample units for detailed investigation. Accordingly, 198 farm households selected in this manner from the selected villages, constituted the whole sample of the field study. The locational map of the study area is presented in Figure 1.

3. METHODOLOGY

The total number of farmers included in the sample is 198. As already mentioned, these sample farmers are engaged in the cultivation of summer rice with sole reliance on virtually unrestricted access to groundwater. A specially structured and pre-tested questionnaire has been administered in the field to collect data during the agricultural year 2011–2012. Data are collected mostly on farm and non-farm activities, demographic and locational characteristics. While the data on farm activities include the number of irrigation, labour, wages, farm size, crop output, and prices, capital assets, costs of cultivation, fertilizer 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. The nature and structure of the market have been examined using simple descriptive statistics such as percentage, ratio, average, etc. The determinants of the water-buying decision have been examined using a logit regression model.

3.1. The logit regression model for examining factors influencing water-buying decision

The decision to buy water from a farmer is a binary or dichotomous-response variable taking on the values ‘1’ or ‘0’. In such circumstances, in order to identify the factors and their relative role in influencing such dichotomous-response variables in probabilistic sense, logit or probit model is used (Maddala, 1983; Gujarati & Sangeetha,

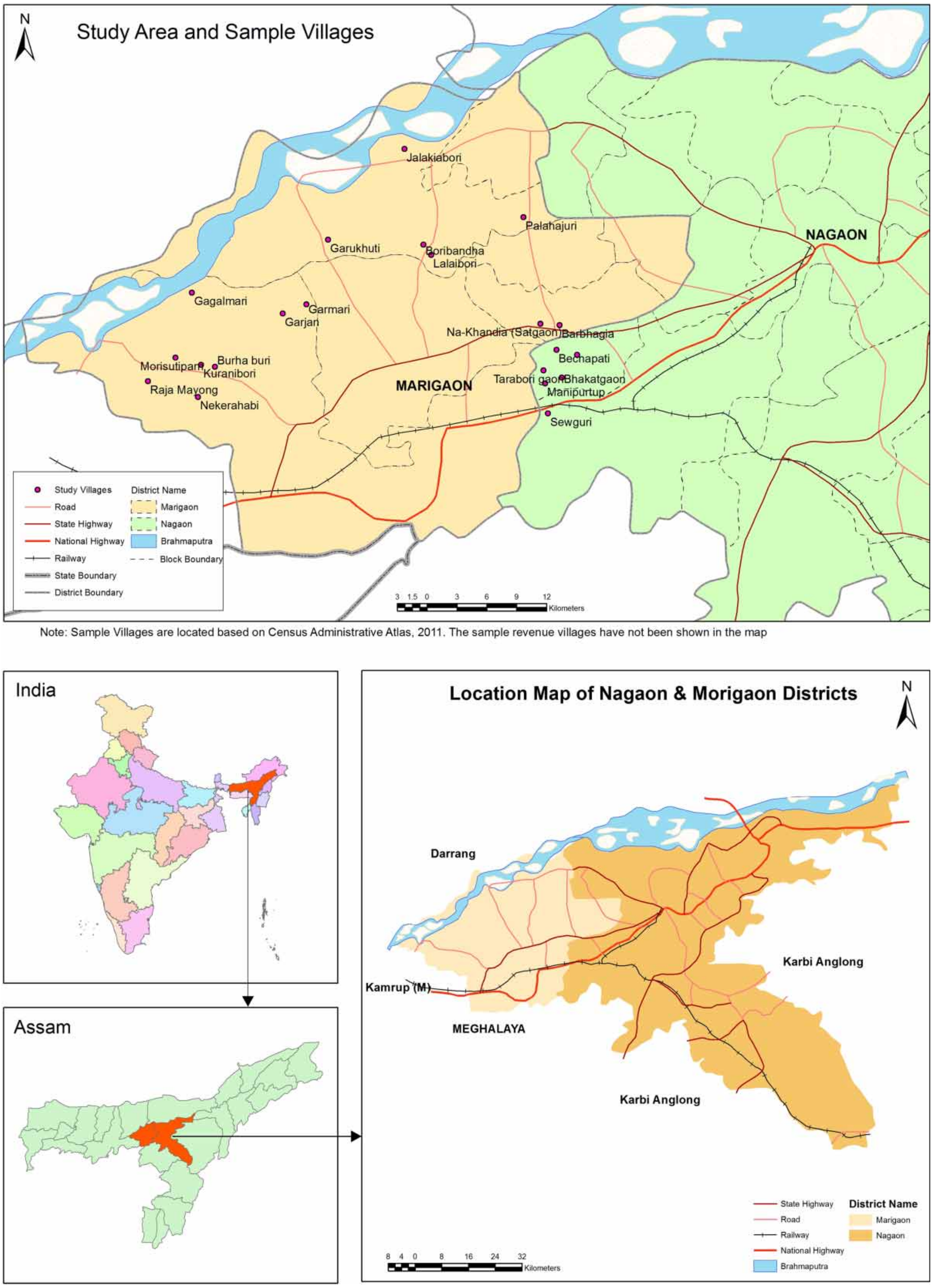


Fig. 1 | Location map of the study area.

2007; Hill *et al*., 2011). However, there is little theoretical justification for choosing between probit and logit models as they often produce similar results (Greene, 2003). In a number of empirical studies on water markets, the logit model has usually been preferred to identify the factors determining tubewell ownership, water selling, and water-buying decisions of farmers. In this context, mention may be made of Saleth (1996) who has used the logit model to explain the determinants of buying decisions of water. Singh & Singh (2006), Sharma & Sharma (2006), and Khair *et al*. (2012) in their empirical studies have applied a logit regression model to identify the factors influencing both buying and selling decisions of groundwater based on household-level primary data. In this study, the logit model is used to identify the factors that influence farmers' decision to buy water. The model is formulated as follows.

The logit model postulates that P_i, the probability that ith farmer buys groundwater, is a function of an index variable Z_i summarising a set of explanatory variables X_{ki}. That is,

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

where Z_i indicates an underlying and unobserved index for the ith farmer (when Z exceeds some threshold Z^*, the farmer is observed to be buyer; otherwise non-buyer). X_{ki} is the kth explanatory variables for the ith farmer that may affect the farmer's decision to buy groundwater. $i = 1, 2, \ldots, N$; where, N is the total number of sample farmers included in the study. $k = 1, 2, \ldots, M$; where M is the total number of explanatory variables. α is the constant; β is the vector of coefficients; e is the base of the natural logarithm and approximately equals to 2.718.

Now, Z_i is estimated as follows:

$$\log\left(\frac{P_i}{1-P_i}\right) = z_i = \alpha + \sum \beta_k X_{ki} \tag{2}$$

Thus, Z_i (in Equation (2)), is a linear function of a host of explanatory variables. In fact, Z_i is equal to the natural logarithm of the odd ratio, i.e. the ratio of the probability that the farmer has purchased groundwater to the probability that the farmer has not.

The goodness of fit of the model has been checked using the log-likelihood ratio tests and a few pseudo coefficients of determination (pseudo R^2). In order to assess the effect of each selected explanatory variable on the probability of water-buying decision of a farmer, 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 the decision of a farmer to buy water which is caused by a one unit change in the independent variable, *ceteris paribus*. The elasticity coefficient indicates that 1% 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).

3.2. Factor affecting water-buying decision

The buyers of groundwater are primarily the farmers who do not own tubewell but undertake cultivation of summer rice by purchasing water usually from the nearest owner-cum-water sellers though a few sellers are also found to be water buyers on fragmented plots. The sample farmers are categorised into two classes, viz. water buyers and non-buyers. Non-buyers include 'self-users' and 'self-users + sellers'. Other categories of participants of water markets like 'self-users + buyers' and 'self-users + sellers + buyers' are excluded from the analysis to maintain mutual exclusiveness. Thus, as evident from Table 1, the total number of sample farmers considered for the analysis is 180. For the farmers who resort to water purchase, the dependent variable is assigned the value '1' and for the farmers who are non-buyers the value of the dependent variable is taken to be '0'.

The available theoretical and empirical literature reflects on a number of factors that determine the water-buying decision of a farmer. However, subject to the availability of data and their relevance in the context of the present study, a number of factors have been identified. The definition and descriptive statistics of the variables are presented in Table 2. A description of the variables and the nature of their likely impact (the expected sign of independent variables) on the probability of water-buying decision are presented in Table 3.

Table 1 | Typology of sample farmers according to their decision to buy groundwater.

	Decision to buy water		
Category of farmers	**No**	**Yes**	**Total**
Self-users	18	00	18 (10.00)
Self-users + sellers	76	00	76 (42.22)
Buyers	00	79	79 (43.89)
Owner + sellers	7	00	07 (3.89)
Total	101	79	180 (100)

Note: Figures in parentheses represent the percentage of column total.

Table 2 | Definition and descriptive statistics of the variables included in the logit regression model.

Variable	Description	Expected sign	Minimum	Maximum	Mean	Std. deviation
OFS	Own farm size (area in hectare)	–	0	12.04	1.34	1.51
TOHL	Total operational holding (area in hectare)	–	0	4.95	1.29	0.97
PAUB	Percentage of area under summer rice (in percent)	–	0	100.00	71.50	30.19
NFPT	Number of fragmented plots	–	1	5.00	1.52	0.75
DFNSI	Distance from the nearest source of irrigation (in meter)	–/+	20	700.00	155.84	96.97
AGE	Age of the head of the farm household (in years)	–	22	77.00	46.86	11.63
EDN	Education of the head of the farm household (in number of years completed)	–	0	15.00	5.39	4.95
SSI	Subsidiary source of income in the farm household (1 = yes; 0, otherwise)	+				
ACIC	Access to institutional credit (1 = yes; 0, otherwise)	–				
SCES	Score of the extensions services (in number)	–				
PSNR	Personal relation with buyers and sellers (1 = yes, 2 = no)	–				
CSTE	Caste of the farm household (1 = general caste; 0, otherwise)	+				
TNCY	Tenancy among the farmers (1 = if the farmer is tenant; 0 otherwise)	–				

Table 3 | Description of variables and their likely impact on the probability of water-buying decision.

Variables	Definition and description
OFS	Own farm size, measured in hectare, is the total cultivated area owned by the water buyer. This is a significant determinant of a farmer's decision to sell or buy groundwater. Existing literature points out that own farm size and the ownership of tubewells are directly related with each other (Bhandari & Pandey 2006; Pant, 1992; Shah, 1993, etc). Since the farmer owning WEDs are potential sellers, the apriori assumption is that the own firm size of a farmer is inversely related to the probability of buying water.
TOHL	In most instances, though own farm size of a farmer is low if the farmer has the scope to lease in land usually attached to his own plot, the total operational holdings of the farmer's increases. Under such circumstance, the farmer may choose to own a tubewell. Hence, the size of total operational holdings measured in hectare is important to consider as a factor that influences water-buying decision of a farmer. Thus, larger is the size of operational holdings lower may be the possibility to buy water.
PAUB	Like the size of operational holding, the percentage of total operational holdings brought under summer rice cultivation, in the present study, is also an important factor that may affect water purchase decision of a sample farmer. In the context of the present study, it is assumed that when percentage of area under summer rice cultivation increases the farmer is more inclined to owning a tubewell than resorting to buy water. Thus, this variable has a negative impact on water purchase decision of the farmer.
FPLT	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 WED a farmer will be able to irrigate all his plots. Besides, moving pumps/WED 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 pumpset may not be willing to own more than one pumpset rather he may prefer to buy water on fragmented plots. Hence, with more number of fragmented plots, the possibility of water purchase of a farmer increases.
SSI	A farm family with stable subsidiary source of income may have higher capacity to invest in farming technologies. Therefore, a farmer with subsidiary source/s of income may own STWs and may not be engaged in water purchase. At the same time 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 tubewell. Therefore, a farmer with subsidiary source of income may or may not turn out to be an owner. Therefore, the probable effect of this variable on water-buying decision is not conclusive. The role of this variable on the probability of buying water is captured by constructing a dummy variable whether the farmer family has subsidiary income sources or not. Value '1' is assigned for having subsidiary source of income in the family, '0' otherwise.
EDN	The level of education of a farmer is measured by the number of formal years of schooling completed by him/her. It is used as a proxy variable for know-how of information regarding improved farm practices, managerial skills, etc. which are important for effective farming. Since, education reflects possible effect of human capital (Bhandari & Pandey, 2006) and managerial ability (Singh & Singh, 2006), it may enhance farmer's understanding to own a tubewell to ensure assured irrigation. If a farmer owns a tubewell he is less likely to buy water. Thus, higher level of education of a farmer may increase his probability to own a tubewell resulting in lower probability of buying water.
AGE	Age of the water sellers is measured in terms of years. It is a proxy for experience of farmer in farming that helps in effective farming. With experience farmers may be tempted to own a tubewell to ensure adequate irrigation water in the field. In the present case, summer rice is a water intensive crop and is 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 pumpset.
ATIC	Installation of a tubewell requires a large initial investment in the form of buying the pumpset, equipments and installation of the boring which a financially capable and large farmer only is capable of doing through own savings. But most of the poor farmers cannot afford to install a WED in particular and purchase other agricultural inputs in general. The provision of formal credit may enable farmers to own a WED. Thus, access to

(*Continued.*)

Table 3 | Continued

Variables	Definition and description
	credit from formal sources is expected to affect ownership of tubewell of the farmer and is negatively related to the water-buying decision of a farmer. The impact of the variable is captured by constructing a dummy variable. The variable assumes the value '1' if the farm household has an access to institutional credit and '0' otherwise.
DFNSI	Distance of the sample buyers' plots from the nearest WED is measured in terms of meter. It has been found that farmers generally do not prefer buying water from distant sources of tubewell which is constrained by non-availability of conveyance facilities. Thus the a priori assumption is that nearer the source of irrigation water, greater is the possibility that a farmer buys water.
SCES	Nine questions related to farmers' interaction with government extension agency have been included in the schedule. Farmers' responses to these queries were codified into scores. The total scores on these queries could vary from 0 to 9 depending on the level of the farmers' interaction with the extension workers. A farmer's scores on these questions have been used as the measure of his access to extension service. Thus, a higher score of extension service implies that the farmer has better contact with the extension worker and is deriving benefits of the services. A farmer benefited by better extension services is expected to have availed facilities under different schemes (especially provision of subsidy in the installation of STWs) enabling the farmer to own a tubewell thereby reducing his probability to buy water.
CSTE	A few available literatures also conclude that ownership of tubewell is skewed towards upper caste. It is expected that farmer belonging to upper caste may have better access to financial resources and thus be able to own a tubewell. However, in the field, no such division like upper and lower caste is observed. Rather, caste as a variable is captured in the field either as general caste or other backward caste or scheduled caste or scheduled tribe. Since presence of inequalities among the farmers by their caste cannot be ruled out, this variable is included in the study to check whether there is any difference in the probability of buying water based on caste. The possible effect of this variable can be captured as a dummy assigning the value '1' if the farmer belongs to the general category, '0', otherwise.
PSNR	Water market in general is also found to be influenced by the social process. In our study, some of the buyers and sellers in water market have been found to be relatives of one another. Thus, the role of kinship in influencing water purchase decision cannot be ruled out. As found in the study, one of the reasons for buying water is that the buyers enjoy some concession when they have kinship relationship with the seller. On the other hand, a seller can also expect other services over and above the payment for water. This variable is captured by a dummy taking on the value '1' if the buyer has a personal relationship with the seller and '0' otherwise.
TNCY	Tenancy as a variable influencing water purchase decision assumes significance in the present study. Tenancy is intertwined with the operation of water market. Therefore, it is assumed that a buyer, who is also a tenant of the water seller, is more likely to enter into water-buying contract with the seller. This variable is captured by a dummy taking on the value '1' if the farmer is a tenant and '0' otherwise.

Incorporating the explanatory variables shown in Table 2, the functional form of the model specified in Equation (1) can be formulated for estimating the parameters affecting buying decision of the relevant sample farmers in the following manner:

$$\log\left(\frac{P_i}{1-P_i}\right) = z_i,$$

where P_i is the probability of buying water.

$$Z_i = \alpha + \beta_1(OFS) + \beta_2(TOHL) + \beta_3(PAUB) + \beta_4(ACIC) + \beta_5(SSI) + \beta_6(AGE) + \beta_7(EDN) + \beta_8(NFPT) + \beta_9(CSTE) + \beta_{10}(DFNSI) + \beta_{11}(SCES) + \beta_{12}(PSNR) + \beta_{13}(TNCY) + U_i$$

here U_i is the error term.

4. RESULTS AND DISCUSSION

4.1. Descriptive results

There are six alternative market participants[2] in the field, viz. 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). The distribution of the sample farmers under these six different structures of groundwater markets according to their size of operational holding is presented in Table 4.

It is clear from Table 4 that about 90.91% of the sample farmers are engaged in water transactions while the rest (9.09%) are self-users. The 'buyers' alone constitute the largest segment (39.90%) followed by 'self-users + sellers' (38.38%), 'self-users' (9.09%), 'self-users + sellers + buyers' (7.07%), 'owner + sellers' (3.54%) and 'self-users + buyers' (2.02%). The majority of the sample buyers are found to be small (41.54%) and marginal farmers (56.82%). Buyers in the semi-medium category are only 5.13%. Distribution of the sample buyers according to the size of their operational holding explicitly shows that when the farm size increases, the number of buyers has decreased correspondingly. It supports the established theory of the market that buyers in the groundwater markets are usually small and marginal farmers. This finding is similar to the results of Fujita & Hossain (1995) in Bangladesh; Meinzen-Dick (1998) in the Punjab province of Pakistan; Zhang (2007) in China; Bhandari & Pandey (2006) in Nepal; and a couple of studies such as Deepak *et al*. (2005), Sharma & Sharma (2006),

Table 4 | The distribution of sample farmers according to the nature of participation of the groundwater market.

Size class of operational holding (in hectare)	Category of participants in the water market: Self-users	Self-users + sellers	Self-users + sellers + buyers	Self-users + buyers	Buyers	Owner + sellers	Total
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.

[2] Self-users + sellers: Farmers with independent or joint ownership (or both) of tubewells use water for cultivating their own plots as well as selling water to needy farmers in the vicinity of the tubewell, usually after meeting their own requirements.

Buyers: The farmers who buy water from the nearest single or multiple tubewells usually adjacent to their agricultural plots. However, the possibility of water purchase from any distant source cannot be ruled out when there is suitable arrangement for water conveyance.

Self-users + sellers + buyers: The owner of tubewells who cultivate their agricultural plots with water from own tubewells, sell water to willing buyers after meeting their own requirement and buy water from other tubewells in another location, especially when their cultivable land is fragmented in two or more than two plots.

Self-users + buyers: The farmers with independent ownership or joint ownership of a tubewell or tubewells use water from their own tubewells for own use in one plot and buy water from other tubewells in another plots.

Owner + sellers: Refers to a situation in which some farmers have invested in tubewells not to meet their own irrigation requirements 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.

Khanna (2006), Singh & Singh (2006), Manjunatha *et al*. (2011a), Dutta (2012), Manonmani & Malathi (2012), etc. in India.

In the case of sellers, out of the total sample of 'self-users + sellers', about 65.78% are small and marginal farmers. The number of 'self-user + sellers' in semi-medium and medium categories of farm holdings constitute about 28.94 and 5.26%, respectively. That the majority of the water sellers are concentrated in the category of small and marginal farmers, is in contrast with the established theory of the existing literature on groundwater markets which have reported that the water sellers are usually the large farmers whereas the buyers are small farmers (Saleth 1998). The evidence of small and marginal farmers selling water has also been reported by studies like Dubash (2000, 2002) and Manjunatha *et al*. (2011a, 2011b) but the share of these farmers in the total water sellers has been not that high unlike one reported by this study. This study thus marks a deviation from the established theory in the literature of the water market that sellers are always large scale farmers. Furthermore, as clear from Table 1, a few members of the group 'owners + sellers', though do not hold any cultivable land are in the possession of shallow tubewells and engage in water selling. This dimension of the market has even not been mentioned by Pant (1992) while explaining the conditions for the existence of groundwater markets. Thus, on the seller's side, it shows that the market has helped some of the tubewell owners to sell water not only in excess of their own use in self-operated areas 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 against the popular belief that groundwater market is residual.

4.2. Regression results

The results of the logit model used to identify factors influencing water-buying decisions in terms of MLE estimates, marginal effects and elasticity coefficients are presented in Table 5.

It is clear from Table 5 that the model gives a good fit as the Likelihood Ratio Test (L-R χ^2) is found to be significant. The Variance Inflation Factor (VIF) values used to check multi-collinearity problem (shown in Supplementary Material, Table A.1 of Annexure-A.1) have shown an absence of multi-collinearity problem in the model. The model has provided correct prediction to the extent of 72% of the dependent variable. The overall pseudo R^2 has turned out to be 0.337. Though a high value of pseudo R^2 is desirable, it is not always considered at par with the adjusted R^2 like in ordinary least square (OLS). The significance of the explanatory variables, direction of change in the dependent variable with respect to each explanatory variable, marginal effects and the elasticity coefficients are discussed below.

The coefficient of the variable 'OFS' is found to be highly significant and negative, which implies that with increase in own farm size, the probability of water-buying decision of a farmer decreases. It is due to the fact that when farmers' farm size increases, they are more likely to own tubewell (Tamuli *et al*., 2018). Thus, it is appropriate that own farm size has negative and significant influence on the decision to purchase water. The partial probability of own farm size is estimated to be (–) 0.267. It implies that other things remaining the same, one unit increase in own farm size of the farmer, will reduce the probability of water buying by 0.267 points. Similarly, the elasticity coefficient which is estimated to be (–) 0.97, implies that a 1% increase in the 'own farm size', leads to the probability of water purchase decreasing by 97%, *ceteris paribus*.

Tenancy as a variable is statistically significant and its coefficient is found to be positive. It implies that if a farmer is a tenant he or she is more likely to be a buyer of water. Tenancy being a significant determinant of water purchase decision indicates the presence of a strong interlinkage between the operation of the water market and the land tenure system prevalent in the study area. The partial probability of tenancy is estimated to be 0.207. It implies that other things remain the same, when a farmer becomes a tenant the probability of water buying increases by 0.207 points. Similarly, the elasticity coefficient which is estimated to be 0.18 implies

Table 5 | Logit estimates for the likelihood of water-buying decision of the sample farmers.

	MLEs		Marginal effects		Elasticity
Variables/Particulars	Coefficient	Std. error	*dy/dx*	Std. Err.	*ey/ex*
CONSTANT	3.1774**	1.4285			
OFS	−1.1502***	0.3494	−0.2675	0.0758	−0.9717
TOHL	0.2946	0.3652	0.0685	0.0842	0.2408
PAUB	0.0090	0.0075	0.0021	0.0017	0.4046
NFPT	0.2447	0.2739	0.0569	0.0639	0.2353
DFNSI	−0.0037*	0.0023	−0.0008	0.0005	−0.3598
AGE	−0.0401**	0.0192	−0.0093	0.0045	−1.1867
EDN	−0.0757	0.0483	−0.0176	0.0112	−0.2577
SSI	0.4416	0.4161	0.1028	0.0969	0.1289
ACIC	0.1854	0.4593	0.0435	0.1090	0.0331
SCES	−0.1854***	0.0702	−0.0431	0.0163	−0.3132
PSNR	−1.7627***	0.4716	−0.3722	0.0876	−0.4419
CSTE	−0.2063	0.4732	−0.0476	0.1085	−0.0503
TNCY	0.8748*	0.5046	0.2072	0.1201	0.1893
Log-likelihood of full model:				− 83.946	
Log-likelihood of null model				− 126.657	
L-R χ^2				85.423*	
Over all pseudo R^2				0.337	
McFadden's Adj. R^2:				0.227	
Correct prediction (in %)				72	
Degrees of freedom				13	
Total observation				180	

Note: Dependent variable: decision to buy water. For a dummy variable, d*y*/d*x* is the discrete change of dummy from 0 to 1.
*, ** and *** represent significance at 10, 5 and 1% levels, respectively.

that when the buyer turns out to be a tenant, the probability of water purchase will increase by 18%, *ceteris paribus*.

The coefficient of 'DFNSI' is also found to be negative and significant. It indicates that when the distance from the nearest source of irrigation/tubewell increases farmers are less likely to be turned out as a buyer. The partial probability of the variable is found to be (–) 0.0008 which implies that when a farmer's plots from the nearest source of irrigation increase by 1 m, the likelihood of the farmer's decision to buy water will decrease by 0.0008 points. The elasticity coefficient which is estimated to be (–) 0.35, implies that when the distance of buyer's plots from the nearest source of tubewell increase by 1%, the probability of water purchase will decrease by 35%, *ceteris paribus*.

The coefficient of 'AGE' is found to be negative and significant. It implies that when the age of the farmer/farm household increases, it is more likely that he does not buy water. When experience increases the farmer may find it better to own WED than buying water as water purchase is also beset with the question of reliability due to residual nature of the market. The partial probability value of (–) 0.009 of the variables indicates that when the age of the farmer/farm household increases by 1 year, the probability of the farmer's decision to buy water will decrease by 0.009 points. The elasticity coefficient which is estimated to be (–) 1.18, implies that a 1% increase in age of the farmer the probability of water purchase will decrease by 118%, *ceteris paribus*.

The available literature on the water market reports that the operation of the water market is influenced by the presence of personal relationship between buyers and sellers apart from the market factors. However, in the present study, the coefficient of 'PSNR' between the buyers and sellers as a determinant of water-buying decision is found to be significant but negative. It implies that the personal relationship of a farmer with the water seller does not push him to buy water and discards the role of personal relationship in the development of water market in water-abundant regions. The elasticity coefficient of the variable implies that *ceteris paribus,* when a buyer has a personal relationship with the seller, the probability of a water-buying decision goes down by 44%.

The coefficient of 'SCES' is found to be negative and highly significant indicating that when a farmer avails more extension services provided by the government the farmer is less likely to purchase water. The partial probability of access to extension services is found to be (–) 0.043. It implies that *ceteris paribus*, one point increase in scores of extension services will decrease the probability of water buying by 0.043 points. Similarly, the elasticity coefficient which is estimated to be 0.31 implies that a 1% increase in the scores of extension services obtained by the farmer will increase the probability of water purchase by 31%, *ceteris paribus*. The negative impact of better extension services on the decision to purchase water by a farmer is supported by the findings in the field. It is found that when a farmer receives better extension services in the form of information on farming practices, available government schemes especially regarding the provision of government subsidy for installation of STWs, etc. the farmer is more likely to own WEDs with the help of available government schemes.

In one of our studies based on the same data set, the coefficient of the variable 'farmer's access to extension services', used to examine its impact on STW ownership through logit regression, has been found to be positive and highly significant with partial probability 0.024 (Tamuli *et al*., 2018). The partial elasticity coefficient of the variable also shows that a 1% increase in farmer's scores in extension services increases the probability of tubewell ownership by 8%, other things remaining constant. At the same time, for an owner of the tubewell with excess capacity, the likelihood of selling water increases though the farmer may purchase water for a distant plot. This is also established by our study, Tamuli *et al*. (2021) based on the same data set, that when an owner enjoys excess capacity, he is a potential seller of groundwater. The logit coefficient of the variable 'Excess Capacity', used to examine the relationship between the excess capacity of WEDs and water selling decision of the farmer, has been found to be positive and highly significant. While the partial probability of excess capacity is found to be 0.00956, the elasticity coefficient of the variable is found to be 0.169.

The variable 'NFT' though not significant the sign of it has been found to be positive as expected implying that a farmer with many fragmented plots is a potential buyer in the market.

5. CONCLUSION

It is clear from the above discussion that the groundwater market in the water-abundant state of Assam displays some characteristics which are in contrast to the ones found in water-scarce regions. Out of the six alternative forms of market arrangement for groundwater, about 5.88% of the sample tubewell owners have been found possessing tubewells only for selling groundwater. Thus, on the seller's side, it shows that the market has helped some of the tubewell 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 all buyers discarding the established theory that 'water market is residual'. This aspect of water market was not considered by Pant (1992) while discussing the conditions for the existence of the market. Thus, the present study suggests the need for revisiting the conditions for existence of water market particularly in water-abundant regions.

The results of the logit analysis on the determinants of water-buying decision of the farmers have shown that farmers' own farm size, education, age, and distance of farmer's plots from the nearest source of irrigation have exerted significant influence on water-buying decision of the farmers. The negative impact of the farm size on the probability of water buying and positive role of fragmentation of land holdings have also been identified by Singh & Singh (2003) and Sharma & Sharma (2006). Thus, regarding determinants of the water-buying decisions, the study validates some of the major findings of earlier studies. The fact that tenants are mostly water buyers prominently establishes the fact that the market is intertwined with the land tenancy. The study notes that farmers' better contact with the extension workers reduces the probability of a farmer's water-buying decision indicating that the government's support in farming helps farmers to gain more control over irrigation water. The discussion on the determinants of water-buying decision indicates that the water-buying decision of farmers is a combined effect of a number of farm-specific, farmer-specific and non-market factors.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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