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Factors Determining Farmers' Decision for Buying Irrigation Water: Study of Groundwater Markets in Rajasthan

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Abstract

The emergence of groundwater markets has helped in mitigating inequality in physical access to the groundwater resources, on the one hand, but on the other hand, it may lead to exploitation of the buyers of water, i.e. resource-poor, small farmers. For the sellers of water, it is becoming a remunerative business economically, leading to serious environmental as well as social concerns. The present study conducted in the arid and semi-arid zones of Rajasthan has addressed these issues. The study has shown that prevailing terms of water transactions, particularly 'in-kind' terms, lead to the over-exploitation of groundwater resources. The credit policies and the power pricing policies of the government also help in the unsustainable and inequitable use of this resource. Water policy ensuring mandatory recharging of the abandoned wells mainly for the sellers of water is the need of hour for the efficient and sustainable use of this scarce natural resource. The analysis of farmers' decision to participate in water markets employing logit regression has suggested that the farmers having higher fragmented landholdings have higher probability of buying groundwater. Joint ownership of wells is negatively associated with the farmers' probability of buying groundwater. This implies that the consolidation of holdings or installing cooperative wells may economize the irrigation investment and lead to efficient management of resources of the farmers and sustainable utilization of water. In the national and state water policies as well as in the Model Bill to regulate and control the groundwater resources, this aspect has not been given any emphasis.

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Introduction

The phenomenon of groundwater trade among farmers is though localized, fragmented, and in the process of evolution as informal market institution, it does have substantial equity and efficiency implications for the utilization of groundwater resources and irrigation assets. Impressed by these positive effects, many researchers have projected groundwater markets as an institutional option for the efficient and equitable use of groundwater and irrigation assets (Shah, 1993; Shah and Raju, 1988; Kolavalli and Chicoine, 1989; Saleth, 1992).

The groundwater is highly scarce in the Rajasthan state and is depleting fast. It is a major factor of production in the agrarian economy of Rajasthan. The state is mostly covered by the arid (57.31% of total geographical area) and semi-arid (31.35%) regions, and it receives less than 500 mm rainfall annually and that too is erratic. The groundwater draft in the state is more than its recharge, particularly in the arid and semi-arid regions and has caused deepening of groundwater level by 1 to 3 metres every year. The declining water level has resulted in a widespread failure of wells and has further led to increase in the cost of well-deepening, installing new wells and pumping. This has resulted in inequality in the access to groundwater for irrigation among resource-poor marginal and small farmers as well as resource-rich, large farmers. This has led to the emergence of Ground Water Markets (GWMs) for providing access to irrigation waters (Sharma, 2002).

The ownership of private wells is confined mostly to resource-rich large farmers who have emerged as sellers of water. The surplus water after meeting their own requirements is sold to the marginal and small farmers, who become the buyers to avoid the huge initial investments needed to install a well. Even large farmers, who have fragmented holdings and are not able to install wells on each parcel of land, have resorted to buying water from the neighbouring well-owners. The phenomenon of groundwater marketing by farmers in many parts of the country has been well documented by Dhawan (1991), Kolavalli and Chicoine (1989), Patel and Patel (1970) and Shah (1988; 1993). Although the GWMs are localized in nature, these have significant implications for the equitable distribution and sustainable use of groundwater resource. Here, an attempt has been made to understand the prevailing practice of groundwater marketing in the state of Rajasthan.

The practice of selling and buying of water for irrigation, industrial, and domestic uses has become a common feature. These informal water markets are widespread in the state of Gujarat, Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Punjab and West Bengal. These markets are limited to localized water trading among neighbouring farmers. The development and functioning of groundwater markets depends upon many socio-economic and agro-climatic factors, farm characteristics and technology, and farmers' managerial ability. The specific objectives of the present paper were:

- To quantify the relative significance of important factors by using logistic regression analysis
- To study the structure and conduct of groundwater markets in the study area; and
- To review the legal issues involved in water transfers and the policies related to groundwater development.

Methodological Framework

Water has been a scarce resource in Rajasthan, particularly in its arid and semi-arid regions. The groundwater is the only source for irrigating crops and sustaining life. There has been enough inequality in the distribution of irrigation resources in Rajasthan, where the study has been carried out.

The Study Area

The arid and semi-arid regions of Rajasthan, spread respectively over the western and northeastern parts of the state, cover more than 85 per cent of the total geographical area of the state. The rainfall is lowest in the western part and moderate in the northeast area. The groundwater has been the only source of irrigation in both the regions, as more than 90 per cent of the irrigation-demand is met by it. Of the total water availability in the state, only one-fifth is available in the arid region and two-fifths in the semi-arid region. Groundwater has been comparatively less scarce in the semi-arid region, while it is most scarce in the arid region as is clear from the fact that the groundwater level was 50-60 m deep in the arid region, and 25-40 m in the semi-arid region. The depth of tube-wells is about 125-200 m in the arid region and 70-125 m in the semi-arid region. The dug-wells and dug-cum-bore wells have almost been abandoned in the arid region.

The Sampling Frame

Following the multi-stage sampling technique, 280 farmers were selected from eight villages of four districts from arid and semi-arid regions of Rajasthan. Jodhpur and Nagaur for the arid region and Alwar and Jaipur for the semi-arid region were selected purposively. These districts were categorized as over-exploited[1] or in critical stage of groundwater development. From each selected district, one block from the over-exploited category of blocks was selected randomly. A cluster of two villages was selected randomly from each selected block. In total eight villages were selected for the study. Fifteen per cent of the total farmers were drawn randomly from the list of farmers. After selecting the sample farmers, they were categorized[2] into self-users (SU), self-users + sellers (SU+S), self-users + sellers + buyers (SU+S+B), self-users + buyers (SU+B), buyers (B) and non-users (NU).

Database and Analytical Tools

The study used the primary data collected from 280 sample farmers during the agricultural year 1999-2000. The study was adequately supported by the secondary information collected from the relevant government departments.

The logistic regression analysis was carried out to quantify the relative importance of factors influencing farmers' decision to buy groundwater for irrigation. In logistic regression analysis, only buyers and sellers of water were included, as farmers of these categories were only indulged in water marketing activity. Farmers in the groundwater market categorized as Self-Users + Buyers + Sellers were not included in the analysis to maintain mutually exclusiveness of the sample.

In the groundwater markets, buying of irrigation water was a dichotomous-dependent variable. Its determinants were assessed using logit model based on logistic cumulative distribution function (McFeddan, 1974 and Maddala, 1983). This technique has been found useful in situations where we either did not have enough information to study how the actual decisions were made or were just interested in understanding the relative role of factors likely to affect such decisions in a probabilistic sense. The logit technique allowed examination of the effects of a number of variables on the underlying probability of buying or selling the irrigation water.

The behavioural model used to examine the factors affecting the purchase of groundwater was:

$$Y_i = g\,(Z_i) \qquad \ldots(1)$$

$$Z_i = \alpha + \Sigma\, \beta_k\, X_{ki} \qquad \ldots(2)$$

where,

Y_i = The observed response of the ith farmer (i.e. the binary variable Y = 1 for buyer and Y = 0 for a non-buyer)

Z_i = An underlying and unobserved index for the ith farmer (when Z exceeded some threshold Z^*, the farmer was observed to be buyer; otherwise non-buyer)

X_{ki} = The k^{th} explanatory variable of ith farmer

i = 1, 2, ………, N, where, N was the number of farmers

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

a = Constant, and

b = Vector of coefficients.

The logit model postulated that P_i, the probability that ith farmer purchased groundwater, was a function of an index variable Z_i summarizing a set of the explanatory variables. In fact, Z_i was equal to the logarithm of the odds ratio, i.e. the ratio of probability that the farmer purchased groundwater to the probability that he did not purchase and it could be estimated as a linear function of explanatory variable (X_{ki}). This could be mathematically expressed as Eq. (3):

$$Z_i = \ln\left\{\frac{P_i}{1 - P_i}\right\} = \alpha + \sum_{k=1}^{M} \beta_k X_{ki} \qquad \ldots(3)$$

Equation (3) was the logit model (Pindyck and Rubinfeld, 1981), and once this equation was estimated, P_i could be calculated as :

$$P_i = f\,(Z_i) = f\,(\alpha + \Sigma\ \beta\, X_i) = \frac{1}{1+e^{-zi}} \qquad \ldots(4)$$

$$= \frac{1}{1+e^{-(\alpha+\Sigma\,\beta_k X_{ki})}} \qquad \ldots(5)$$

where, ‘e’ represents base of the natural logarithms and approximately equals to 2.718.

The goodness of fit of the model was tested by three approaches. Firstly, predictions were compared with the observed outcomes and expressed in percentage of correctly predicted. Secondly, 2-times the log of the likelihood (-2LL) estimate was used as a measure of how well the estimated model fitted the data. A good model was one that resulted in a high likelihood of the observed results. To test the null hypothesis that the model fitted perfectly, -2LL had a chi-square distribution with N-M degrees of freedom. In this test the large observed significance level indicated that the model did not differ significantly from the perfect model. Lastly, chi-square test was used. The difference between –2LL for the model with only a constant ($-2LL_0$) and –2LL for the current model ($-2LL_{max}$) followed Chi-square (χ^2)

distribution. The degrees of freedom for the Chi-square test were the difference between the degrees of freedom for two models being used as {(N-1) – (N-M)}.

$$\text{Chi-square} = -(LL_0 - LL_{max})$$

Thus, Chi-square tested the null hypothesis that the coefficients for all the explanatory variables in the model except the constant were zero. The nature and magnitude of the estimated coefficients of the logit model would help us to identity the relative importance of different factors underlying groundwater buying-decisions of farmers.

The Model and Hypothesis

The index variable Z_i indicating whether a farmer bought groundwater or not, was expressed as a linear function of the above listed variables as:

$$Z_i = a + b_1 AREAOWN + b_2 FRAGMENT + b_3 PJOINTWL + b_4 HPPERWL + b_5 EDUCATIO + b_6 PFWORK + b_7 PNFINC + b_8 PHVCR + U_i \quad \ldots(6)$$

where, U_i was the disturbance-term.

AREAOWN: Farm-size was one of the important factors influencing the purchase of groundwater. The total operational holding was likely to affect the probability of groundwater purchasing due to the reason that farm-size and ownership of a irrigation well were directly related. Therefore, *a-priori* expectation was that the probability of purchasing of groundwater was inversely related to the size of farm.

FRAGMENT: Buying of groundwater was crucially dependent on the degree of fragmentation of farm-holding. With dispersed holding, it was presumed to be more difficult for a WEM to irrigate all the land of a farmer than if the land was in a consolidated parcel. It was, therefore, expected *a-priori* that a farmer with high degree of fragmentation was relatively more likely to purchase groundwater.

PJOINTWL: Joint ownership of WEM could reduce purchasing of groundwater by the farmers. The impact of partnership on the likelihood of purchasing could be captured by dummy variable for partnership. Therefore, it was expected that joint ownership of WEM be inversely related with the probability of groundwater purchasing.

HPPERWL: Higher capacity of the water-lifting device installed on their well/tube-well could reduce the buying probability of irrigation water. Therefore, it was expected that groundwater buying probability was negatively related with the installed capacity of water-lifting device on the wells.

PHVCR: High-value crops were mustard, cumin, groundnut, cotton and tomato that occupied higher percentages of gross cropped area in the study area. A farmer without WEM and with a large percentage of gross cropped area under high-value crops was relatively more likely to purchase groundwater to irrigate his crops. However, a farmer with own WEM and high percentage of gross cropped area under high-value crops might go for purchasing of groundwater to irrigate his plots located farther from his WEM. Therefore, nature of the relationship between percentage of gross cropped area under high-value crops and probability of purchasing of groundwater could not be established *a-priori*.

EDUCATIO: Education increased the ability of a farmer to interpret, understand and modify new information. Thus, it was treated as a proxy for farmer's managerial ability. It was, therefore, hypothesized that the probability of purchasing water by a farmer was inversely related to the farmer's education.

PFWORK: The family worker provided potential for intensive cultivation. A farmer with more family labour might go for purchasing groundwater because he had more manpower on per farm basis. The nature of relationship between the percentage of family labour to the total family and purchasing of groundwater and its probability could not be established *a-priori*.

PNFINC: The total non-farm income included income from off-farm employment plus income from off-farm investments. Steady non-farm income might help a small farm operator to achieve a level of income comparable to that of the large farmers. So, it was hypothesized that the probability of purchasing groundwater was directly related to the percentage of non-farm income of the farmer.

The relative significance of these important factors was quantified by logistic regression analysis for groundwater buying-decisions of the farmers. The factors considered to influence the groundwater markets more apparently were only included in the logit analysis. Age of the head of the family and value of farm assets were also included in the analysis but due to high degree of correlation between educational level and age of head of the family, farm size and farm assets, were subsequently dropped in the final model. The determinants of groundwater markets for water buying and selling decisions were examined separately to visualize the differences, if any.

The Groundwater Markets

The term 'water markets' describes a localized, village-level informal arrangement through which owners of a modern water extraction mechanism

(WEM) sell water to other farmers at a price. Water availability under different forms of water markets has given rise to issues related to the structure and conduct of groundwater markets (GWMs).

Households Participating in Water Markets

A perusal of Table 1 revealed that almost 70 per cent of the total farm households were participating in water trade either fully or partially. The sellers of water were 31 per cent, while buyers were about 52 per cent of the total households. The sellers of water had higher proportion of individual wells and less area owned per well, which was less fragmented (Table 1). This induced them to sell surplus water after meeting their own requirements, whereas buyers had larger size of holdings which were more fragmented. This explained the behaviour of farmers installing their own irrigation wells on a big parcel of land to irrigate their crops and to sell surplus water. However, they had to rely on buying groundwater from the neighbouring farmers for their other fragments situated away. Also, the buyers had higher proportion of joint wells and higher fragmented land. They had to rely on purchasing of water to irrigate their crops. The more fragmented lower size of holding constrained many farmers from installing their own WEMs. This resulted in buyers' form of water markets, resorting exclusively to buying groundwater.

Accessibility to Water Market

The farm-size category-wise analysis revealed that about 55 per cent of the small farmers were involved in buying of groundwater, whereas only one per cent indulged in its selling activity. About 92 per cent of the non-

Table 1. Characteristics of households participating in water markets

Particulars	SU	SU+S	SU+S+B	SU+B	B	NU
Number of households	46	46	40	38	70	40
Average size of land (ha)	7.75	6.92	7.8	4.81	1.85	1.17
No. of fragments per holding	2.15	2.13	3.28	3.05	1.99	1.8
No. of wells	63	65	53	40	0	0
Area/well (ha)	5.74	4.87	5.61	4.71	0	0
Joint wells (%)	51	26	45	77	0	0
Individual wells (%)	49	74	55	23	0	0

SU: Self-users; SU+B: Self-users + buyers; SU+S: Self-users + sellers; BL: buyers; SU+S+B: Self-users + sellers + buyers; NU: Non-users

Table 2. Farm-size category-wise farmers participation in water markets in Rajasthan

(in per cent)

Farm-holdings	SU	SU+S	SU+S+B	SU+B	B	NU	Total HHs (No.)
Small	3	1	0	3	52	41	90
Semi-medium	6	16	6	29	37	6	54
Medium	26	27	26	17	4	0	100
Large	39	25	31	5	0	0	36
Overall	17	17	14	13	25	14	280

HHs: Households; Small: < 2 ha; Semi-medium: 2-4 ha; Medium: > 4-10 ha; Large: >10ha

users were small farmers and the remaining were semi-medium farmers. About 72 per cent of the semi-medium farmers were engaged in buying of groundwater, while 22 per cent were engaged in the selling activity. The corresponding figures were 47 per cent and 53 per cent for medium farmers, and 36 per cent and 56 per cent for large farmers (Table 2). This showed that the groundwater buying activity decreased with the increase in farm-size, while the selling activity increased.

This explicitly explained that the sellers of water were the farmers with larger holdings, who had the financial capacity and break-even land to install their own WEMs and sell surplus water after meeting their own requirements, while the buyers were the farmers with smaller holdings who did not have the financial capacity and break-even land to install their own WEMs. However, Meinzen-Dick (1996), Narayanmoorthy (1994), and Shah and Raju (1988) have reported that the well-owners, who had small holdings depicted higher extent of participation in water-selling than those who owned larger holdings because of having surplus water after irrigating their own fields. Results were so in Rajasthan on account of higher cost of construction of tube-wells, due to deeper water levels in the area, and most (about 80%) of the modern WEMs were in the hands of medium and large or resource-rich farmers, who had break-even land and resources to install their own irrigation wells.

Magnitude of Groundwater Buying

The distribution of area irrigated by own irrigation wells and buying groundwater under different forms of water markets are given in Table 3. The study revealed that the self-users and self-users + sellers had cent per cent irrigation of their lands by their own irrigation wells while the lands of buyers of water were irrigated totally through purchase of groundwater

Table 3. Magnitude of groundwater buying in Rajasthan

Water markets	Percentage of owned area irrigated by		Total owned area irrigated (ha/hh)
	Own-WEMs	Buying water	
SU	100.00	0.00	7.52
SU+S	100.00	0.00	6.57
SU+S+B	80.87	19.13	6.43
SU+B	71.50	28.50	4.83
B	0.00	100.00	1.41
Total / All	83.07	16.93	5.11

Note: Non-users were not included because farmers of this category had unirrigated area with them and area with buyers was irrigated by buying groundwater.

from other farmers. Of the total owned-irrigated area of sample farmers, nearly 83 per cent was commanded by owned irrigation wells, whereas around 17 per cent of the total irrigated area was irrigated by buying groundwater. This implied that in the absence of groundwater markets, nearly one-fifth of the total area would have remained unirrigated and added to the non-users category. In other words, the prevalence of groundwater markets supported about one-fifth area of the total land irrigated by groundwater. However, Saleth (1998) has estimated that water markets were providing water for about 6 million hectares or 15 per cent of the total area irrigated by groundwater in India.

Transactions Terms for Groundwater Markets

The studies have shown that the terms of groundwater transactions might tend to be rather exploitative. Still, in the wake of failure of traditional irrigation system, the farmers might opt for purchasing of water at a higher cost rather than going without it. In the groundwater markets, two broad types of transactions were observed in the study area: ‘cash-based contracts’, and ‘in-kind contracts’. The types of contracts on the basis of which GWMs operated in the study area were:

(a) **Hourly terms:** In this arrangement, the sellers provided water to the buyers by charging at hourly rate on cash basis. This type of contract was prevalent in the semi-arid region in the Jaipur district where only electric-operated irrigation wells were in operation and the rate was Rs 30 per hour. In the Alwar district, water was being purchased from electric-operated irrigation wells by paying Rs 50 per hour, and if it was from a diesel-operated irrigation well, then the price was Rs 75 per hour; and

(b) **Crop-output sharing terms:** In this arrangement, the buyers of water had to surrender a part of their crop-output as price of water to the sellers.

This type of contract was observed in the arid region. This was the 'in-kind' contract where 40 per cent of crop-output was charged from the buyers of water at the time of harvest.

It was found that crop-output sharing contracts prevailed in water-scarce areas, arid region, while the hourly terms of payment were prevalent mainly in less water-scarce areas, semi-arid region of Rajasthan. About 47 per cent payments for water were through cash mode on hourly basis, while 53 per cent preferred to pay through crop-output sharing mode. The well-owners, in general and sellers, in particular determine these terms and conditions. The temporal change in these terms of contracts took place with changes in the energy price. The transactions of water among the buyers and sellers were made by '*osarabandi*' system, including water-turn for own farms and buyers' farms. The water was transported mostly through plastic pipes (sprinkler pipes) of the sellers of water.

Conduct of Groundwater Markets

There were 86 sellers to 207 buyers of water, i.e. each seller supported 2.41 buyers. The average area irrigated by each water seller was 11.77 ha. On an average, each seller of water supported buyers' land up to the extent of 46.50 per cent of the average area irrigated by them (Table 4). Of the total hours operated per irrigation well by sellers of water, about 53 per cent hours were used to irrigate buyers' fields. Thus, both in the terms of area and the number of irrigation hours, the extent of groundwater markets seemed to be considerable.

Costs and Returns from Water Selling

The cost of water extraction and selling price might be viewed as efficiency of water markets. If the cost of water extraction was equal to the selling price, water markets could be considered as efficient, if it was

Table 4. Extent of groundwater markets

Particulars	Number
1. Sellers	86
2. Buyers/seller	2.41
3. Average area irrigated by sellers (ha)	11.77
a. Own field (%)	53.50
b. Buyer's field (%)	46.50
4. Hours operated per WEM	1170
a. Own field (%)	46.82
b. Buyer's field (%)	53.18

Table 5. Cost of water extraction and returns from water selling

(Rs per hour)

	Particulars	Semi-arid region	Arid region
1.	Cost of water-extraction		
	(a) Fixed cost on WEM[b]	16.65 (72.11)[a]	14.92 (47.53)
	(b) Operating cost on WEM[c]	6.44 (27.89)	16.47 (52.47)
	(c) Total cost	23.09	31.39
2.	Average selling price	35.46	122.80
3.	Net Income		
	(a) Over operating cost	18.81	107.88
	(b) Over total cost	12.37	91.41

[a] Figures within the parentheses are percentages of the total cost.

[b] It included depreciation and interest on fixed investment of tube-well installation, pump sets, water conveyance structures, etc.

[c] It included operation and maintenance charges and interest on the working capital.

greater than the selling price, then water markets were regarded as inefficient ones and if the selling price of water was greater than the cost of water extraction, then the water markets could be considered as exploitative ones.

The amortized[3] total cost of water extraction was worked out to be Rs 23.09 per hour in the semi-arid region and Rs 31.39 in the arid region. It was higher in the arid region because of higher installed capacity of motors (30-40 HP). The per hour average selling price was found to be Rs 122.80 in the arid region and Rs 35.46 in the semi-arid region, which were substantially higher than the corresponding operational cost as well as the total cost of water extraction in both the regions (Table 5). This implied that groundwater markets were exploitative in nature for the buyers of water. The exploitation of buyers was more in kind-based contracts in the arid region than in the semi-arid region. In the arid region, buyers of water had to surrender their two-fifths of crop-output to the sellers of water as the water price and it was exorbitant for the buyers of water. Most of the buyers were farmers with small landholdings and they had limited livelihood options with them under the arid and semi-arid conditions of Rajasthan. Therefore, they had to participate in water trading on the existing terms and conditions for their assured employment opportunities and food security. The higher water prices in kind-based contracts were also reported by Janakrajan (1993), Palanisami and Balasubramanian (1998), Satyasai *et al.* (1997) and Shah (1993).

Sellers of water earned a net profit of Rs 18.81 per hour over the operational cost and Rs 12.37 per hour over the total cost of water extraction in the semi-arid region and Rs 107.88 per hour and Rs 91.41 per hour,

Table 6. Logistic regression coefficients of factors affecting buying of groundwater

(Buying=1, and 0 otherwise)

Factors	Coefficient	t-ratio	Odds ratio	Probability
AREAOWN	-0.68*	-4.26	0.51	0.34
FRAGMENT	3.37*	4.03	29.11	0.97
PJOINWL	0.01	1.03	1.01	0.50
HPPERWL	-0.22*	-4.02	0.80	0.45
EDUCATIO	-0.18***	-1.68	0.84	0.46
PFWORK	0.04	0.72	1.04	0.51
PNFINC	-0.03	-1.16	0.97	0.49
PHVCR	0.04	1.20	1.04	0.51
Intercept	-1.72	-0.53		
Cumulative Probability (P)		0.891		
-2 log L		57.30		
Chi-square		130.51*		
Wald statistic		29.08*		
Sample		154		

Note: * and *** indicate significance at 1% and 10% levels, respectively.

respectively in the arid region. Thus, selling of water was a remunerative business economically for the sellers of water.

Determinants of Water Buying Decision

The groundwater markets provided an opportunity to non-owners of irrigation well on a particular parcel of land to irrigate crops, raise farm productivity, generate employment for family members, and enhance income. There were several factors, which affected the groundwater buying-decision of the farmers. The relative importance of these factors were quantified by using a logit regression as water buying was a binary variable.

The important variables selected and maximum likelihood estimates of the coefficients of logistic regression analysis are presented in Table 6. The model fitted very well to the data as indicated by large observed significance of log likelihood ratio test and Chi-square test, which was significant at one per cent level. The model provided correct prediction to the extent of 94 per cent of the dependent variable.

The results of the logistic regression analysis suggested that the most significant factors affecting the farmer’s groundwater buying-decision were the size of farm holdings, extent of farm fragmentation, capacity of water lifting device installed on the well/tube-wells, and education of the decision-maker in family. With a few exceptions, the estimation yielded the expected signs for the independent variables. However, the variable with unexpected sign was not significant, as shown by the respective t-ratio.

From the results of logistic regression analysis it could be inferred that with one unit increase in the size of landholdings with farmers, the probability of buying groundwater was reduced to 34 per cent. Higher the fragmentation of the landholdings, greater was the chance of buying groundwater for irrigation. The probability of buying groundwater has increased by 97 per cent with one unit increase in land fragmentation. In other words, the farmers having larger size of operational holdings that were less fragmented had lower chance of buying groundwater. This observation was consistent with the findings of Kolavalli and Chicoine (1989); Saleth (1996), Meinzen-Dick (1996) and Singh (1998). On the other hand, the small farmers had higher chance of buying groundwater, who neither had the financial capacity nor break-even land to install their own wells/tube-wells.

The capacity of the water-lifting device installed on the well/tube-well measured in terms of horse power per well was also significantly impacting the decision of the farmers to buy groundwater. Results of the analysis showed that with the unit increase in the capacity of the water-lifting device, the chances of buying groundwater reduced by about 45 per cent. If the decision-maker was educated adequately, the probability of buying costly irrigation water reduced by around 46 per cent. A well-educated decision-maker's rational decision would, of course, be not to go for buying of water but choose alternatives like installing joint-wells.

Factors like family workers per unit area (51%) and higher proportion of gross cropped area (50%) to high-value crops and the proportion of the joint installed wells (50%) had positive effects on buying of groundwater, though these coefficients turned out to be non-significant. This implied that the farmer with more workers per unit area and higher fraction of gross cropped area under high-value cash crops had more chance of buying groundwater. The higher proportion of family income from non-farming sources reduced the buying-probability of groundwater.

Legal Status of Groundwater

The legal status of groundwater immensely differed from the popular perception of being a common property or open access resource. Based on the dominant heritage principle implied in the Transfer of Property Rights Act IV of 1882, the Easement Act of 1882 allowed private usufructuary rights in groundwater by viewing it as an easement connected to land (Singh, 1991; Saleth, 1996).

The groundwater markets are the village-level informal market institutions in which there is neither clear assignment of rights nor legal sanction to trade. Under the current legal regime, groundwater is an easement attached to land. So, from a strictly legal sense, groundwater being an easement connected to land cannot be sold apart from land, especially to make profit. This is so because under the Easement Act of 1882, an easement right is meant essentially to gain certain conveniences but not meant for making profit which is possible under *profit a pendre* kind of rights (Singh, 1991). The right approach should be to optimize the returns as well as resource-use rather than maximize. Also, the model bill framed to regulate and control the exploitation of groundwater does not touch the issue.

There should be a relevant water rights allocation system based on equitable utilization in which individual water rights are established so as to optimize the resource allocation. The optimum allocation of the resource at the societal point of view could be achieved by that price of water which is determined by the demand and supply forces. Under the current practice of groundwater markets the water prices are determined by the customs/ conventions rather than the demand and supply forces. These informal water markets, based on undefined property rights system, are incapable of determining right price. Therefore, the water sellers are charging exorbitant price from the poor, small and marginal farmers. Though the prevalence of groundwater markets in the region has helped poor farmers in the physical access to the resource and in terms of employment for their family, in strict economic terms these markets are becoming the means of increasing inequality among the resource-rich, large farmers and the resource-poor small farmers.

Conclusions and Policy Implications

Though the groundwater markets have facilitated to mitigate inequality in the physical access to the resource, i.e. irrigation water, among the resource-rich large and the resource-poor small farmers. The sellers of water are charging exorbitant prices, i.e. more than three-times of the cost of water extraction for buyers as water price. In this way GWMs have become exploitative for the buyers of water, and contribute to increasing inequality among the rich and poor farmers, whereas for the sellers it has become economically a remunerative business. Thus, selling groundwater has become a growing business for making private profit at the social cost.

The impact of groundwater markets on the small and marginal farmers and rural inequality in the long-run should become key points in formulating policies for sustainable development and utilization of groundwater resources.

The prevailing terms of water transactions, particularly in-kind terms, lead to the over-exploitation of the groundwater resources. The credit policies and the power pricing policies of the government also help the unsustainable and inequitable use of the resource. Therefore, the state has the major role to play through proper policy measures, regulating the practice of water markets (granting formal status) and their effective implementation. Recharging of abandoned wells, mainly for the sellers of water, should be made essential for the efficient and sustainable use of this scarce natural resource.

The logit regression has suggested that the farmers having lower farm-size holdings with higher fragmented-land have higher probability of buying groundwater. The consolidation of holdings may economize the irrigation investment and lead to efficient management of resources of the farmers.

Education of the farmers is significantly affecting the buying probability of groundwater, implying thereby that with the increased awareness among the farmers, this scarce natural resource could be optimally utilized. In national as well as state water policies and in the Model bill to regulate and control the groundwater resources, this is not even seen and given any consideration or emphasis.

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Notes:

1. The districts where the net annual groundwater draft was more than 100 per cent or in the range of 90-100 per cent of the net annual groundwater recharge were categorized as over-exploited or critical.

2 (a) **Self-Users + Sellers:** They are the owners of WEMs and their landholdings are consolidated. They sell surplus water to other farmers because their landholdings are small to utilize the full capacity of WEM and water markets offer an opportunity to spread its overhead expenses by increasing the WEM utilization.

(b) **Self-users + Sellers + Buyers:** Existence and operation of this form of water markets is due to high degree of farm fragmentation. On the big parcel of holding, farmers install a WEM to irrigate their field, supply surplus water to neighbouring farmers, and go for buying on the other parcel.

(c) **Self-users + Buyers:** This form of water markets exists generally because of fragmentation of holdings. When the farmers install a WEM on the big fragments to irrigate their fields only, the lack of surplus water for the other parcel of land or inaccessibility compels them to purchase water from the neighbouring WEM owners.

(d) **Buyers:** This form of water markets arises mainly because of small size of holdings. Buyers are generally resource-poor farmers and they do not get a suitable partner to pool their resources to install a WEM. Another important reason is economic viability of WEM due to small and fragmented holding. These farmers buy sufficient water from neighboring WEM as and when required.

(e) **Self-users:** Water markets do not exist in this category of farmers because they have WEMs to irrigate their fields only. Landholdings are generally consolidated. The self-users do not enter the water markets because neither they have surplus water to sell nor are interested to buy from others.

(f) **Non-users:** Water markets do not exist in this category of farmers also because of very small size and fragmented holdings that are away from the WEMs. The farmers are resource-poor and lagged in nature whose available labour force is engaged in non-farm activities. These farmers do not enter the water markets because they have very small holdings

3. Investment on tube-well was amortized over 15 years (average life of a tube-well), at 12 per cent per annum (opportunity cost of capital) to arrive at the annual cost of water extraction. The annual cost was then divided by the total duration (in hours) of running a tubewell in a year to arrive at the per hour cost of water extraction.