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Structure, Determinants and Efficiency of Groundwater Markets in Western Uttar Pradesh

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Abstract

Irrigation is a vital ingredient in the modern agriculture, groundwater development through modern water extraction mechanisms (WEMs) have therefore, been receiving greater emphasis in recent past. However, the ownership of private WEMs is confined mostly to the large farmers. The small and marginal farmers and even large farmers with fragmented holdings are buyers of irrigation water from the neighbouring WEM-owners. This has led to spontaneous emergence of groundwater markets. Although the water markets benefit both buyers and sellers in one or the other way, they have created certain implications in the utilization of this resource. The present study has examined the structure, determinants and efficiency of groundwater markets and has suggested policy options for the realization of equitable benefits from this resource in Western Uttar Pradesh. It is observed that a large proportion (82 %) of the farm holdings enter into one or the other form of water market activities. The number of buyers decreases as the farm-size increases, while the number of sellers increased with the increase in the size of farm. The buying of groundwater is favoured by the farmers with small size and fragmented holdings, low education attainment and less probability of joint-ownership of a WEM. The possibility has been shown of increasing the productivity in major crops like sugarcane and wheat by reducing the excessive water-use on self-users farms, which in turn would increase the availability of water on the buyers' farms. The study has identified various policy options which would lead to minimizing the inequitable distribution of benefits and improving the efficiency of water-use under the prevailing groundwater markets system.

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Introduction

Reliable irrigation is the vital ingredient in the modern agriculture. Initially, surface and groundwater irrigation through traditional water extraction devices brought stability in the Indian agriculture, but they could not cope fully with the demand of the modern agriculture. Therefore, policymakers and farmers have started giving more emphasis to the development of groundwater irrigation through modern water-extraction mechanisms (WEMs). The ownership of private WEMs has, however, been confined mostly to the large farmers (Dhawan,1982 and Shah, 1993). The small and marginal farmers and even large farmers with fragmented holdings are to enter into informal transaction for buying of irrigation water from the neighbouring WEM owners. This has led to spontaneous emergence of groundwater markets and their imaginative management offers major opportunities for easy access to groundwater irrigation to resource-poor small, marginal and even large farmers with fragmented holdings. The evidences suggest that water markets have developed on a very large scale in the recent years in South Asia, though in a localized manner (Lowdermilk *at. el*, 1978; Meinzen-Dick, 1995; Singh, 1998; Singh and Singh, 2002; Sharma and Sharma, 2004). The practice of selling groundwater appears to have been prevalent in many parts of India even under traditional WEMs (Patel and Patel, 1969; Moorti, 1970). Water markets benefit both buyers and sellers in one way or the other and they have created certain efficiency, equity and sustainability implications in the utilization of this resource. Earlier literature has dealt with some major issues relating to the performance of groundwater development and its impact on agricultural production, but has failed to pinpoint the causal factors for inefficiencies in its utilization. The present paper has examined the structure, determinants and efficiency of groundwater markets, and has suggested policy options for realization of maximum gains from the groundwater exploitation in Western Uttar Pradesh.

Methodology

For the present investigation, the Meerut district with a higher WEM density was chosen purposively from Western Uttar Pradesh. The primary data on different aspects of groundwater markets were collected from 180 randomly selected farmers from a cluster of four villages of two blocks. The data pertained to the agricultural year 1994-95. The selected farmers were classified as buyers, self-users+buyers, self-users+buyers+sellers, self-users+sellers and self-users, based on their accessibility to different forms of groundwater markets. Further, the selected farmers were classified into three farm-size groups, viz. marginal (up to 1 hectare), small (1-2 hectares) and others (greater than 2 hectares) in order to capture the variations among the groups.

The buying and selling of groundwater being dichotomous dependent variables, their determinants were assessed using the logit model. The model postulated that P_i, the probability that i^{th} farmer would buy 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 a farmer would buy groundwater to the probability that he would not buy groundwater and it could be estimated as a linear function of explanatory variables (X_{ki}). These could be mathematically expressed as:

$$P_i = F(Z_i) = F(X_i) = \frac{1}{1+e^{-Z_i}} \qquad \ldots(1)$$

$$Z_i = \ln\left\{\frac{p_i}{1-p_i}\right\} = \alpha + \sum_{k=1}^{M} \beta_k X_{ki} \qquad \ldots(2)$$

where,

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

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

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

a = A constant and

b = An unknown parameter

In the logistic regression, the parameters of the model were estimated using the maximum likelihood method. Since, the logistic regression model is non-linear, an iterative algorithm was used for the parameter estimation.

In the study, it was hypothesized that the probability of a farmer to buy groundwater depends on the owned operational holding in hectares (X_1), the number of farm fragments (X_2), source of energy (X_3), percentage of gross cropped area under sugarcane cultivation (X_4), education in number of years of schooling completed by the farm operator (X_5), percentage of family labour to the total family members (X_6), percentage of non-farm income to the total income (X_7), joint ownership of a WEM as a binary variable (X_8) and groundwater selling price per hour through electric-operated WEM (X_9). The total value of farm-assets, cropping intensity and age of the head of the family were also included in the analysis, but due to high degree of correlation between farm-size and farm-assets, area under sugarcane and cropping intensity, and educational level and age of the head of the family, were subsequently dropped in the final model. The index variable Z_i indicating whether a farmer installed an electric-operated WEM or not, was expressed as a linear function of the above listed variables as Eq. (3):

$$Z_i = a + b_1X_{1i} + b_2X_{2i} + b_3X_{3i} + b_4X_{4i} + b_5X_{5i} + b_6X_{6i} + b_7X_{7i} + b_8X_{8i} + b_9X_{9i} + U_i \quad \ldots(3)$$

To capture the impact of operational holding on the probability of buying and selling of the groundwater, owned cultivated area were taken into consideration. In this study, the *a-priori* expectation was that the probability of buying and selling were inversely related to the size of farm. Land fragmentation was often suggested to be an impediment to WEM ownership. With dispersed holdings, it was presumed to be more difficult to install a WEM to irrigate all the land of the farmer than a consolidated parcel. It was, therefore, expected *a-priori* that a farmer with high degree of fragmentation was relatively less likely to own an electric-operated WEM and buy water. Only electricity as a source of energy was assigned the value of one, otherwise zero because it was a cheaper source of energy in comparison to other sources. It might have a positive effect on buying of groundwater as no rational farmer would substitute cheap availability of groundwater to costly one. Sugarcane being a high water requiring and high-value crop, occupies higher percentage of gross cropped area. A farmer with high percentage of gross cropped area under sugarcane is relatively more likely to install a WEM and not buy groundwater.

Since, education increased the ability of a farmer to interpret, understand and modify new information, it was treated as a proxy variable for a farmer's managerial ability. In this study, years of formal schooling completed by the head of the farm family were used as an index for the farmers' managerial skill. It was, therefore, hypothesized that the probability of buying of groundwater was inversely related to the farmers' education. The nature of relationship between percentage of family labour to the total family and buying of groundwater and its probability could not be established *a-priori*. The non-farm income represented a rather stable component of family income, it might provide adequate resource base to install a WEM for improved agriculture. However, such a farmer might have less concentration on farming and might not like to invest heavily in agriculture. Hence, the nature of relationship between the percentage of non-farm income to the total income and the probability buying of groundwater could not be hypothesized on *a-priori* basis. Joint-ownership gave an opportunity to a farmer to install a WEM more readily by mobilizing the financial and physical resources to make the investment and utilize more of the WEM capacity to irrigate more area per WEM. The impact of partnership on the likelihood of purchasing of groundwater could be captured by dummy variable for partnership. Therefore, it was hypothesized that joint-ownership was directly related with the probability of selling of water and inversely related to the buying of groundwater.

The possible important factors contributing to the decision making on buying and selling of groundwater were identified and the farmers' perceptions were also recorded. The large fragmentation of holdings, non-availability of canal water in the canal command area, non-availability of a suitable joint-partner to install a WEM, higher WEM density around their holdings, accessibility to state-owned WEMs, part-time farming, non-availability of institutional credit, non-subsidized interest rate of institutional credit, policy of state electricity board to issue the connection, low water purchasing price, high water-table, less non-farm income, cultivation of low-value crops, high security cost of a WEM, and a symbol of social status were identified as major contributing factors to determine the buying and selling of groundwater.

The efficiency of water markets was examined with the help of resource productivity analysis and decomposition of yields of sugarcane and wheat crops and by comparing the cost of groundwater extraction and its selling price. The Cobb-Douglas form of production function was found to be the best fit in examining the resource productivity under different forms of water market. The per hectare production function was specified as per Eq.(4):

$$Y = a\, X_1^{b_1} X_2^{b_2} X_3^{b_3} \qquad \ldots(4)$$

where,

Y = Output per hectare of crop in quintals,

X_1 = Human labour used per hectare in mandays,

X_2 = Number of irrigations applied, and

X_3 = Fertilizer (plant nutrients) used per hectare in kilograms.

The total change in yield was decomposed into water management component that refers to better irrigation management under self-users' form of water markets over buyers' form of water markets and input component that refers to changes in the quantities of independent variables. Following Bisalaiah (1977), a decomposition model was developed to measure the effects of both the components on changes in yields of sugarcane and wheat crops.

Further, the efficiency of water markets was examined by comparing the cost of extraction and selling price of groundwater. If the cost of extraction was equal to the selling price, water markets could be considered as efficient.

Since, sources of energy constituted an important factor, which affected the cost of water extraction and selling price, the efficiency of water markets for electric- and diesel-operated WEMs was examined separately.

Results and Discussions

Structure of Water Markets

It was observed that, of the total farm holdings, buyers constituted the largest segment (26 %), followed by self-users+buyers+sellers (23 %), self-users+sellers (19 %), self-users (18 %) and self-users+buyers (14 %) (Table 1). In other words, a large proportion (82 %) of the farm holdings was entering into one or the other form of water market activities. The size-wise analysis showed that the number of buyers decreased as the farm-size increased, while reverse was the case in water sellers. The average size of holdings was found to be lowest (1.30 ha) for buyers only with an average number of 2.4 farm fragments per holding. As far as the accessibility to different WEMs was concerned, on an average 66 per cent of the farmers and 78 per cent of the area had accessibility to the electric-operated WEMs (Table 2). It was also noted that only two per cent farmers had accessibility to diesel-operated WEMs with an average of 14 per cent accessibility to their irrigated land. This was mainly due to the fact that a substantial parcel of land had total dependency on this mode of WEMs. On the other hand, 32

Table 1. Structure of water markets

Particulars	Buyers	Self-users +buyers	Self-users+ buyers+ sellers	Self-users + sellers	Self-users	Total
Farm holdings (Numbers)						
Marginal	19(53)	4(11)	3(8)	5(14)	5(14)	36(100)
Small	20(27)	13(18)	16(22)	13(18)	11(15)	73(100)
Others	7(10)	9(13)	22(31)	17(24)	16(22)	71(100)
Total	46 (26)	26(14)	41(23)	35(19)	32(18)	180(100)
Irrigated area (ha)						
Marginal	13.8(52)	2.6(10)	1.92(7)	4.4(16)	4.0(15)	26.7(100)
Small	26.9(26)	18.3(18)	23.8(23)	19.3(18)	16.0(15)	104.4(100)
Others	18.4(7)	34.1(14)	83.4(33)	58.4(23)	59.7(23)	254.1(100)
Total	59.2(16)	55.1(14)	109.1(28)	82.1(21)	79.7(21)	385.2(100)

Note: Figures within the parentheses indicate percentages to total.

Table 2. Farmers' accessibility to WEMs across the water markets

Water markets	Percentage of the total farmers access to		
	Electric WEMs	Diesel WEMs	Electric+Diesel WEMs
Buyers	65(76)	0(12)	35(12)
Self-users +buyers	62(80)	0(14)	38(6)
Self-users+ buyers+sellers	51(71)	0(18)	49(11)
Self-users +sellers	72(77)	11(19)	17(4)
Self-users	84(86)	0(6)	16(8)
Total	66(78)	2(14)	32(8)

Note: Figures within the parentheses are percentages of cultivated area having access to respective WEMs.

per cent farmers had access to the electric+diesel-operated WEMs but irrigating only 8 per cent of their total land. The buyers' category had proportionately higher accessibility to diversified WEMs than that of self-users category, mainly due to their fragmented nature of holdings.

Determinants of Groundwater Markets

Determinants of Buying of Groundwater

The important variables selected and maximum likelihood estimates of the coefficients of logistic regression analysis are reported in Table 3. The model fitted very well to the data as indicated by the larger observed significance of log likelihood ratio test, and chi-square test, which was significant at one per cent level. The model provided 79 per cent correct prediction of the dependent variable. The results clearly indicated that the total operational area, number of fragments per farm, years of schooling of head of the family and joint-ownership of a WEM were significant factors which affected the water buying decision of farmers. Sign and magnitude of the coefficients were according to prior expectations. The size of operational holdings, years of schooling and joint-ownership of a WEM had negative sign, indicating that the buying of groundwater would be favoured by the small-sized farmers with low education and low probability of joint-ownership to install a WEM. Number of fragments per farm had a positive significant effect on water buying. It is obvious that with more dispersed holdings, farmers would not be able to install many WEMs to irrigate their fragmented land but would prefer to purchase water. High percentage of gross cropped area under sugarcane, family worker to the total family

Table 3. Logistic regression coefficients of factors affecting groundwater buying

Factors	Coefficient	t-value	Mean
Intercept	1.7904	1.1226	1.00
Total operational area (hectares)	-0.5046*	-3.3861	2.15
Number of fragments per farm	1.0995*	4.8437	2.41
Cheap source of energy (electricity)	0.5018	0.8453	0.66
Percentage of gross cropped area under sugarcane	-0.0227	-1.2688	50.88
Number of years of schooling	-0.0910**	-2.2304	5.63
Percentage of family worker to family size	-0.0058	-0.2851	33.29
Percentage of non-farm income to total income	-0.0112	-1.0969	21.95
Joint-ownership of WEM	-1.4625*	-3.6869	0.47
Groundwater price per hour (electric WEM)	-0.0132	-0.0917	6.89
Minus 2 log likelihood	180.97		
Chi-square	56.67*		
Correct prediction (%)	78.89		
Number of observations	180		

Note: * and ** indicate significance at 1 and 5 per cent levels, respectively.

members and non-farm income to the total income, and higher water price though showed negative effect on buying of groundwater in the study area, they were non-significant.

The results of farmers' perception about the buying of groundwater are presented in Table 4. Nearly half of the respondents were buying water due to larger fragmentation of their holdings. Nearly 40 per cent of the small and marginal and two-thirds of others category of farmers reported to buy the groundwater due to larger farm fragmentations. Non-availability of canal water in its tail-end area was identified as another important factor reported as their first choice by 15 per cent of the respondents. Lack of suitable joint partnership to install a WEM appeared to be another important factor which was considered by 12 per cent of the respondents as their first choice to buy water. Higher WEM density around their holdings was preferred by 8 per cent respondents which varied from 3 per cent for others to 12 per cent for the marginal farmers. The smaller size of operational holdings was considered by the marginal (15 %) and small (8 %) farmers as their first choice to buy groundwater. Only a few farmers chose accessibility to state owned WEM, part-time farming, non-availability of institutional credit, non-subsidized interest rate of institutional credit, policy of state electricity board of not issuing electricity connections to the farmers having power requirement

Table 4. Buyers' perception about the buying of groundwater

Factors	Percentage of respondents as their first choice			
	Marginal	Small	Others	All
Respondent (number)	26	49	38	113
Larger farm-fragmentation	42	39	68	49
Non-availability of canal water	12	20	11	15
Non-availability of a suitable partner	15	11	13	12
Higher WEM density	12	10	3	8
Small size of holding	15	8	0	7
Access to state WEM	0	4	3	3
Part-time farmer	4	2	0	2
Non-availability of institutional credit	0	2	0	1
Non-subsidized interest rate	0	2	0	1
Low water price	0	2	0	1

less than 7.5 HP and low water charges for water buying. The other factors such as level of water-table, non-farm income, cultivation of low-value crops and high security cost of WEM were found to be non-influencing variables as not a single farmer responded to these factors.

Determinants of Selling of Groundwater

The logit model predicted the groundwater selling decision of the farmers with 71 per cent accuracy (Table 5). Large observed significance level of log likelihood ratio test and one per cent significance level of chi-square indicated that model fitted very well to the data. The size of owned operational holdings, number of farm fragments, installed electric horse power (HP) per unit of land and joint-ownership of WEM were the significant factors which affected selling decision of the farmers. The farmers with larger size of operational holding were in a position to install a WEM with an intention to hire out excess water for the additional earnings. This was possible as most of the small and marginal farmers did not have financial capabilities to install their own WEM to irrigate their crops. The probability of selling water showed a direct relationship with farm fragmentation. It could be explained that as the fragmentation of holdings decreased, the capacity utilization of a WEM and selling increased. Higher horse power (HP) per unit of cultivated land had increased the probability of selling water as expected. Joint-ownership gave an opportunity to install a WEM, therefore it also increased the probability of selling of water.

Table 5. Logistic regression coefficients of factors affecting groundwater selling

Factors	Coefficient	t-value	Mean
Intercept	-3.7824**	-2.1939	1.00
Owned operational area (ha)	0.3026**	2.0671	2.12
Number of fragments per farm	0.4150**	2.2663	2.41
Cheap source of energy (electricity)	-0.1553	-0.2648	0.66
Percentage of gross cropped area under sugarcane	0.0321	1.5872	50.88
Number of years of schooling	-0.0205	-0.5365	5.63
Percentage of family worker to family size	0.0045	0.2201	33.29
Percentage of non-farm income to total income	-0.0043	-0.3820	21.95
Joint-ownership of WEM	1.2373*	3.1835	0.47
Groundwater price per hour (electric WEM)	-0.2320	-1.5601	6.89
Installed horse power per hectare (electricity)	0.6276*	4.4577	1.79
Minus 2 log likelihood	184.61		
Chi-square	60.55*		
Correct Prediction (%)	71.11		
Number of observations	180		

Note: * and ** indicate significance at 1 and 5 per cent levels, respectively.

Table 6. Farm returns and yield of major crops across the water markets

Particulars	Buyers	Self- + users buyers	Self- users+ buyers+ sellers	Self- users+ sellers	Self- users
Cost of cultivation (Rs/ha)	34658	38551	36281	39768	39723
Gross income (Rs/ha)	37253	42598	40643	44516	43865
Net income (Rs/ha)	2295	4047	4362	4748	4142
Wheat yield (t/ha)	3.83	3.96	4.10	4.19	4.15
Sugarcane yield (t/ha)	48.70	55.20	54.60	58.60	57.60

Efficiency of Groundwater Markets

Productivity and Farm Income

The perusal of Table 6 revealed that the realization of crop productivity and farm income varied widely across the water markets. The yields of sugarcane and wheat crops were found to be highest on the owners' category farms and lowest on the buyers' farms. The differences in costs and returns

Table 7. Production elasticities of factors influencing sugarcane productivity

Variables	Buyers	Self- + users buyers	Self- users+ buyers+ sellers	Self- users+ sellers	Self- users
Constant	2.3194 (1.5230)	3.2334* (1.1088)	2.4322** (0.9566)	2.3953* (0.8107)	1.7645 (1.4306)
Human labour	0.7081** (0.2923)	0.5920* (0.1959)	0.8207* (0.2025)	0.7436* (0.1349)	1.3996* (0.2844)
Irrigation	0.4946* (0.1709)	0.2639 (0.2103)	-0.0576 (0.0803)	-0.0770 (0.1152)	-0.8565* (0.1958)
Fertilizers (NPK)	-0.1338 (0.1442)	-0.09748 (0.1370)	-0.0450 (0.0758)	0.0593 (0.0800)	-0.1428 (0.1881)
R^2	0.34	0.38	0.32	0.55	0.58
No. of observations	45	26	41	35	31

Note: Figures within the parentheses are standard errors.
* and ** indicate significance at 1 and 5 per cent levels, respectively.

were more pronounced in sugarcane than wheat. Although, the self-users categories of farmers incurred relatively higher costs on cultivation of all crops, they realized higher returns than that of buyers' category. This was partially due to proportionately more land devoted for high-value crops by the WEM owners and partially due to better accessibility and reliability of groundwater irrigation.

Resource-use Efficiency

Among different forms of production function, the Cobb-Douglas production function, which gave the best fit, was selected. The coefficient of irrigation was found to be positive and significant for buyers only, suggesting that an increased use of irrigation would further increase the productivity of sugarcane on this type of farms. The irrigation coefficient, however, was negative and significant for self-users' farms, indicating overutilization of this resource (Table 7). In the case of wheat, irrigation was found to be positively significant on buyers' farms and non-significant on other categories of farms (Table 8). This suggested the possibility of increasing the productivity of sugarcane and wheat by reducing the excessive water-use on self-users' farms, which in turn would increase the availability of water on buyers' farms.

Table 8. Production elasticities of factors influencing wheat productivity

Variables	Buyers	Self- + users buyers	Self- users+ buyers+ sellers	Self- users+ sellers	Self- users
Constant	1.4478** (0.7716)	2.0053** (0.9117)	2.3219* (0.7607)	1.0248* (0.7891)	2.6787* (0.7995)
Human labour	0.1892 (0.1670)	0.3681 (0.2322)	0.1065 (0.1165)	0.0589 (0.0975)	0.0289 (0.1401)
Irrigation	0.4848* (0.1670)	0.0948 (0.2481)	0.0581 (0.1590)	0.1044 (0.1546)	0.0774 (0.2245)
Fertilizers (NPK)	0.1562** (0.0803)	0.0278 (0.1288)	0.2020** (0.1174)	-0.0974 (0.1305)	0.1893** (0.1026)
R^2	0.27	0.18	0.18	0.15	0.18
No. of observations	46	26	41	35	32

Note: Figures within the parentheses are standard errors.
*and ** indicate significance at 1 and 5 per cent levels, respectively.

Table 9. Determinants of change in productivity among different forms of water market

Particulars	Sugarcane		Wheat	
	Self-users *vs* buyers	Self-users + sellers *vs* buyers	Self-users *vs* buyers	Self-users + sellers *vs* buyers
Total change in productivity (actual)	15.93	18.01	6.85	7.10
Total change in productivity (estimated)	13.11	18.33	6.47	6.99
Sources of changes				
Change due to irrigation management	22.62	15.0	4.29	6.15
Total change due to inputs	-9.51	3.32	2.18	0.84
I. Human labour	7.69	4.48	0.11	0.47
II. Irrigation	-15.43	-1.55	0.93	1.15
III. Fertilizers	-1.78	0.39	1.14	-0.78

Decomposition of Productivity

Irrigation facilities under different forms of water markets had influenced the use of inputs in crop production and timeliness of farm operations. It caused structural change in production process and created a new production function. As a result of these factors, farmers were getting substantially higher yields under owners' category of WEMs than the buyers of irrigation water. The decomposition analysis provided the mechanism for decomposing the total difference in yields among different forms of water markets in their constituent. It was evident that water management accounted for higher yields of 15 to 23 per cent of sugarcane and 4 to 6 per cent of wheat on the farms under self-users and self-users+sellers categories as compared to that of purely buyers of irrigation water (Table 9). This implied that the same level of input-use would produce 15-23 per cent more output per unit of land for sugarcane and 4-6 per cent for wheat on self-users category of farms through better management of irrigation. Intensive use of irrigation water per unit of land under the self-users' category resulted in a declining productivity of sugarcane by 15 per cent over purely buyers. The situation in the case of wheat crop was a bit different. The increase in productivity due to intensive use of human labour, irrigation water and fertilizer use per unit of land under self-users' category had been 2 per cent over that of purely buyers. The analysis, thus, clearly indicated that there was a close association between the change in actual productivity and ownership of WEMs in both the crops. The role of irrigation management was more prominent in sugarcane crop than wheat crop, as sugarcane happened to be an annual crop and its water requirement was much higher, particularly during the summer season than that of wheat crop grown in winter.

Table 10. Cost of water extraction and selling price

(Rs /hour)

Particulars	Electric-operated WEM	Diesel-operated WEM
Fixed cost		
(i) Depreciation	1.47(11.70)	5.29(11.84)
(ii) Interest	4.42(35.16)	15.86(35.50)
(iii)Total fixed cost	5.89(46.86)	21.15(47.34)
Operating cost		
(i) Electricity/Diesel charges	3.63(28.88)	16.75(37.49)
(ii) Maintenance cost	2.67(21.24)	5.45(12.20)
(iii) Interest	0.38(3.02)	1.33(2.97)
(iv)Total operating cost	6.68(53.14)	23.53(52.66)
Total cost of water extraction	12.57(100)	44.68(100)
Average selling price	6.89	29.53

Note: Figures within the parentheses indicate percentage to the total cost.

Cost of Water Extraction and Selling Price

The total cost of water extraction of electric- and diesel-operated WEMs were worked out to be Rs 12.57 and Rs 44.68 per hour, respectively (Table 10). Of the total, the share of fixed and operating costs accounted for about 47 and 53 per cent for these WEMs, respectively. The interest on fixed capital constituted the highest share (35 %) in the total cost of water extraction, followed by the share of electricity tariff (29 %) in electric-operated WEMs. On the other hand, fuel cost constituted the highest share (37 %) in the total cost of water extraction in diesel-operated WEMs. The average selling prices of groundwater extracted through electric- and diesel-operated WEMs were Rs 6.89 and Rs 29.53 per hour, respectively. Since, selling prices were lower than cost of water extraction, it implied that water markets were not efficient in the pure market theory sense, and water buyers were in a better position in comparison to the WEM owners. Although the water selling was not economically a viable proposition, it provided rationality to the WEMs owner to recover a part of the expenditure incurred on electricity/ diesel charges, maintaining wear and tear through the sale of surplus water. Thus, both owners of the WEMs and buyers of the groundwater were benefited in one way or the other by the water markets.

Conclusions and Policy Options

The area under study has been found dominated by small and fragmented farm holdings. More than four-fifths of the total sample farmers have entered into one or the other form of water market activities. The number of buyers have inverse relationship with the farm-size, while reverse has been the case in water sellers. The electric-operated WEMs dominate the groundwater irrigation. The buyers have accessibility to both the electric as well as the diesel-operated WEMs. The buying of groundwater is favoured by the farmers of small-sized holdings with low educational attainment and less probability of joint-ownership of a WEM. Higher the number of fragments, more has been the level of water buying. On the other hand, source of energy, sugarcane acreage, size of family, family workers and water prices have been found to be non-significant factors in influencing the water-buying decisions of the farmers. The significant factors determining the groundwater-selling decisions of farmers have been the size of owned operational holdings, number of farm fragments, possibility of joint-ownership of WEMs and horse power per unit of land.

The costs and returns structure has been found more in favour of owners' category than buyers' category. The resource productivity analysis has illustrated the possibility of increasing the productivity of sugarcane and wheat by reducing the excessive use of water on the owners' category of farms, which in turn would increase the availability of water on buyers' farms. The decomposition analysis has revealed a close association between increased productivity and better irrigation management due to ownership of the WEMs. None of the water-extraction mechanisms has been found to be efficient in the existing water market system as the selling price is markedly lower than the average cost of water extraction. However, the selling price is more than the operating cost of water extraction in both types of WEMs. Thus, both owners of the WEMs and buyers of the groundwater are benefited in one way or the other by the working of water markets. In order to achieve better distributive social justice and encourage efficient water markets, suitable water price policy needs to be evolved. Similarly, the erratic electricity supply compels the farmers to install more than optimum number of WEMs, thereby making them to bear high fixed cost per unit of water extraction. This has called for rationalization of the electric distribution system. The study has also identified policy options such as consolidation of landholdings and joint-ownership of WEMs for the realization of equitable benefits from groundwater irrigation.

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