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An Impact Study on the Pattern of Groundwater Use by Farmers and Commercial Sectors in Tirupur District, Textile City, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Groundwater is the major source of water for agriculture, domestic and industrial uses. Falling water table and depletion of economically accessible groundwater resources could have major social and economic consequences. Many are hailing groundwater transfer as the quickest, least cheapest, and most ecologically friendly answer to large cities' water supply and reliability problems. The water transfers generally focus on the purchase of water from willing sellers in agriculture to meet urban domestic and industrial water demand. The present study was undertaken mainly to study the pattern of groundwater use by the farmers and commercial sectors in Tirupur district. Out of the 180 farms selected for the study, 67.78 per cent of farms were water sellers and 32.22 per cent of farms were non-sellers. Among the three types of wells viz., open wells, open cum bore wells and bore wells; open wells formed the majority in all categories of farms. Whereas in all the farm categories

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of both the seller and non-seller groups, bore wells dominated the total number of wells owned by each of the farm categories. Bore wells dominated for more than 50 per cent of the total number of wells in large farms, whereas in case of small farms, bore and open-cum-bore wells have been shared equally. According to the farmers, bore wells were having more success rate than the open cum bore wells. The number of abandoned bore wells was also significantly higher in all categories of farms, since open wells were acted as a storage tank for storing the water extracted from bore wells. The percentage of failed bore wells to the total number of wells per farm had ranged from 41.89 per cent in large farms to 57.26 per cent in small farm group in seller category. The number of wells per farm among sellers was significantly higher whereas irrigated land per well was significantly lower. The present study was undertaken mainly to study the where groundwater transfer has been an increasing phenomenon over years resulting in pollution hazards and reduction in irrigated area.

Keywords: Ground water pattern; farmers; commercial sector; regression; tobit equation.

1. INTRODUCTION

Water is a natural gift it is available everywhere and plays a vital role in both the environment and human life. One of the major issues in the groundwater transfer is the third party impact on the economic base of rural farming communities. Water transfers can generate three different types of impacts namely, direct, indirect and induced impacts. Direct impacts are those employment and income impacts that are immediately and explicitly related to agriculture. The direct impacts include the loss of irrigated acreage, change in farming practices, change in employment and rural income. Indirect impacts are determined by forward and backward inter-industry linkages, i.e., the extent to which agricultural products are used in the production of other locally produced products (e.g., ginned cotton, edible oils, fruit juices, etc.,), or those agricultural products which utilize raw materials or intermediate products or services that are also provided locally. Induced impacts occur through changes in local income and population. Impacts of agriculture to urban/industrial water transfers that result in loss of irrigated agriculture may have no significant economic impacts. When viewed from a micro level, such impacts are substantial but not devastating. Farmers and other local interests' fear that water transfers will lead to idling of farmland, loss of jobs and local income, reduced government revenue, and increased costs of social programmes. Increase in groundwater transfer from agriculture to urban/industrial uses have resulted in changes in productivity, reduction in area irrigated and employment opportunities in agriculture and an increased negative externality through groundwater table depletion, increased investment on wells and probability of well failures.

Colby, studied water laws evolved to protect those who divert water for off-stream uses such as mining and agriculture, granting property rights in water for these early uses. Historically, the primary concern in evaluating proposed water transfers has been protection of water right holders. Broader access to property rights in water and to the transfer approval process can allow a wider array of externalities to be considered and will make water transfers more expensive than previously. State water transfer criteria are not arbitrary hindrances imposed upon the marketplace. These policies protect existing investments by water right holders and, as they can reflect public good values affected by water use and transfer [1].

Charney and Woodard examined from a state viewpoint, research on the effects of rural-to-urban transfers that result in the loss of irrigated agriculture did not resulted in significant economic impacts when viewed from a state perspective.

When viewed from country level, such impacts were substantial but not devastating. Similarly, fiscal impacts were real but not catastrophic. However, the impacts tend to be highly concentrated because the factors that make particular parcels suitable water farms could result in geographic clustering of purchases. Therefore, if water transfers result in the levels of economic gains claimed for buyers, strong arguments could be made for mitigation and compensation. However, some of the more important potential losses associated with transfer including loss of autonomy and reduced option for future development, could be neither estimated nor compensated [2].

Zhang et.al. explained the Central Valley Production and Transfer Model (CVPTM) developed for the analysis of CVPIA (Central Valley Project Improvement Act) alternatives. The study focused on CVPTM's structures and its linkages to other economic and hydrologic models. Results from a model confirmed that the CVPIA water transfer provision - allowing CVP water service contract and exchange water to be transferred - would significantly affect water transfer market in California. The transfer demands by both municipal and industrial and agricultural buyers were expected to increase due to the greater availability of less expensive CVP water closer to buying region. Central and south coast municipal and industrial users were expected to be the largest buyers under all the alternatives, followed by the municipal and industrial users in San Francisco Bay Area [3].

Zachariah and Rollins studied and indicated that rural-urban conflict was common in communities where tea quantity or quality of water was compromised by over extraction or contamination. This study presented an investigation into quantification of the cost of portable water using the case of the aquifer beneath Wilmot Township (Ontario, Canada). An overview of economic justification of policy decision regarding water quality management was studied [4].

Hearne and Easter studied the economic and financial aspects of water markets; crop budgets were used to estimate the value of water in agricultural production. The value of water-use rights to urban water-supply companies was estimated using the avoided cost of an alternative investment in a water-storage reservoir. The analysis demonstrated that the water transfer of water-use rights did produce substantial economic gains-from-trade in both the Elqui and Limari Valley in Chile. Economic gains produced rents for both buyers and sellers. Sellers, especially farmers growing profitable crops who buy water-use rights and individuals buying water-use rights for potable water supply, received higher rents then sellers [5].

One of the earth's most precious and widely distributed resources is groundwater. When surface and groundwater aquifers are misused, this most precious resource may not always be sufficient. Groundwater is impacted by the research area's extensive urbanization and diverse textile industry processes. Sixty-two bore well water samples have been collected and examined for various physic-chemical parameters in order to examine the groundwater methodology stated by K.Arumugam et al., [6].

Worldwide, it's anticipated that water transfers from agricultural to urban and environmental applications will become more frequent. Groundwater aquifers beneath many agricultural areas are crucial to their operations. Over time, out-of-basin surface water transfers will change how the groundwater aquifer system and agricultural production evolve by increasing aquifer withdrawals and decreasing recharge stated by Keith C et al. [7].

Devineni, N et al. stated the exploitation and protection of groundwater resources depend on the identification of groundwater vulnerability. The current study evaluated the susceptibility of the Tiruppur taluk in the southern Indian state of Tamil Nadu, where groundwater pollution from industries (textile) and overpopulation is on the rise [8].

Sivakumar V et al. used Optimization model to demonstrate, by changing the geographic areas where crops are grown and procured from, the government's procurement targets could be met on average even without irrigation, while also increasing net farm income and halting groundwater depletion. We do this by utilizing over a century's worth of daily climate data as well as recent spatially detailed economic, crop yield, and related parameters. Permitting irrigation results in a 30% increase in average net agricultural income [9].

Hence, an attempt has been made in the present study to identify and evaluate third party impacts of a groundwater transfer from economically weaker region to strong ones using field level evidences.

2. METHODOLOGY

This chapter provides a detailed outline of the methodology followed for the study. Selection of study area, sampling procedure followed for the selection of farms, sources of data, nature of data collected and quantitative/statistical tools employed for analysis of data are discussed in detail.

2.1 Selection of Study Area

2.1.1 Farm level survey on water transfer

Tirupur district in Tamil Nadu State has been purposively selected for the study in the context of its well-known history of the industrial development and particularly in the field of textiles and related industries, predominance of well irrigation and groundwater overexploitation [10]. This district is in the forefront of agricultural and industrial development in the entire state. In the field of hosiery industries, Tiruppur district hosts a knitwear industry that has been noted in literature for its dynamic growth since the early 1980s [11]. Its nature of sub-contracting system and the active role played by industrial associations have been well reputable in the case of employment and income generation. Because of its historic dynamism, demand for water to bleaching and dyeing units in Tiruppur is very high and after using the water transferred from agricultural sector in industrial production process, these industrial units let out the effluent water into river Noyyal, which leads to serious pollution problem in the downstream farms [12,13]. In general, abandoning of agriculture by farmers is very common in the areas especially, farms situated near to the towns/cities and industrial locations due to large quantum of water transfer for industrial and domestic purposes which are increasing at an increasing rate. Another reason for the purposive selection of the district is that, there has been no study on the impact of groundwater transfer from agriculture to urban use and the pollution problem induced by such transfers. Following the selection of the district, the further sampling was done in three stages.

In Farming village in Tiruppur district, Palladam and Pongalur blocks were selected randomly. Ten villages are selected randomly in blocks in different directions and distances from Tiruppur municipality. Then 180 farmers were selected randomly from the selected villages and the selected farmers were post-stratified into three groups based on the distance of their fields from the town viz., inner (3-5 km radius), middle (6-10 km radius) and outer most rings (above 10 km radius). The sample was also post-stratified into three farm size categories viz., small (< 2 hectares), medium (2-4 hectares) and large (> 4 hectares) farms to study the farm characteristics (Table 1).

2.1.2 Farm level survey on groundwater pollution

Since 1986, industrial effluent released into Noyyal River and local waterways has increased from 1,000,000 liters to over 13,000,000 liters per day. The polluted effluent from the bleaching and dyeing units finally flow into an agricultural reservoir (Orathupalayam dam) located 20 km away from Tiruppur city. Groundwater resources along the river Noyyal in a 0.1-5 km radius has been contaminated to a depth of 60-150 meters. To quantify the effect of groundwater pollution due to industrial effluent, adjoining Kangayam and Chennimalai blocks were purposively selected.

Based on the water sample analysis, the villages were classified into unaffected villages (with TDS less than 1500 mg l^{-1}) moderately affected villages (TDS ranging from 1500 to 3000 mg l^{-1}) and severely affected villages (TDS more than 3000 mg l^{-1}) and 50 sample farms were selected from all of these three categories of villages and one village under each category was randomly selected both under right banks of Noyyal river and left banks of Noyyal river (Table 2). The sample was limited to 50 due to quality data to be collected.

Table 1. Groundwater transfer – selection of sample farms

Location	Direction	Name of village	Distance (km)	Number of farms selected	Total
Outer ring (> 10 km)	KGM road	Vannanduraipudur	17	25	80
	Dharapuram road	North Avinashipalayam	22	25	
	Palladam road	Ganapathipalayam	19	30	
Middle ring (6-10 km)	KGM road	Maniyampalayam	9	20	80
	Dharapuram road	Peruntholuve	10	20	
	Palladam road	Karaipudur	9	20	
	Mangalam road	Kolathupudur	7	20	
Inner ring (3-5 km)	Dharapuram road	Sevanthampalayam	5	10	20
	Palladam road	Veerapandi	4	5	
	Mangalam road	Andipalayam	4	5	
Total				180	180

Table 2. Groundwater pollution – selection of sample farms

Direction	Name of village	Distance from Noyyal river (km)	No. of farms selected
Right bank of river			
Severely affected	Ramagarampalayam (Thambattipalayam)	0.1-1	10
Moderately affected	Sembankulipalayam (Maravapalayam)	1.01-4.99	10
Unaffected	Reddivalasu (Keeranur)	Above 5	5
Left bank of river			
Severely affected	Ramalingapuram (Kodumannal)	0.1-1	10
Moderately affected	Saanarpalayam (Ekkattampalayam)	1.01-4.99	10
Unaffected	Chavadipalayam	Above 5	5

However, for the analysis of the pollution effect due to storage of effluent in the dam alone, the area covered under two villages viz., Orathupalayam and Sembankulipalayam hamlet of Maravapalayam which are situated downstream of the dam covering an area of 202.50 hectares (40.50 and 162 hectares respectively) was analysed.

The Tobit equation was fitted to find out the factors affecting the groundwater transfer from agriculture to urban uses.

TGWSALES = f (FSIZE, DIST, ONFINC, OFFFEMP, LABOR, GWAVAIL, OWNERSHIP, SQLTY, EXP)

Where;

TGWSALES = Total Groundwater sales (million liters)
FSIZE = Farm size (ha.)
DIST = Distance from farm to city/town (kms)
ONFINC = On-farm income (Rs./ha.)
OFFFEMP = Dummy for off-farm employment
LABOR = Represented by ratio between agricultural wage and industrial wage
GWAVAIL = Groundwater availability measured as a ratio between days of well water availability and crop duration in days
OWNERSHIP = Dummy for well ownership (if, own well = 1; jointed well = 0)
SQLTY = Dummy for soil quality (if, good = 1; bad = 0)
EXP = Farming experiences (years)

This model measures not only the change in the probability of selling water but also the change in intensity of water selling and also to understand the motivation behind farmer perceptions towards water sales.

Distance from the city/town has important implications for water quality and availability of groundwater and farms on the periphery of the city/town are having groundwater with low in quantity and quality aspects. Hence the distance in kilometers to the city will indicate the level/intensity of quality deterioration of groundwater. Water availability is also another principal determinant of farm profitability. The general relationship is explained in Fig. 1.

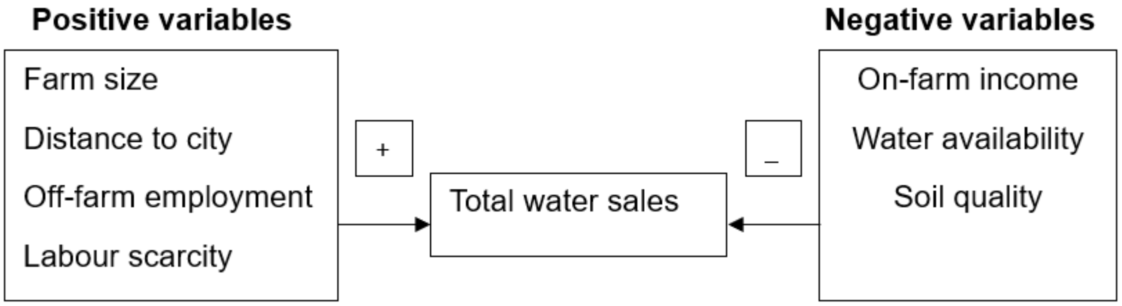

Fig. 1. General relationship between variables

3. RESULTS AND DISCUSSION

The farm-level analysis of groundwater seller and non-seller has covered characteristics such as land holding particulars, well ownership, type, number, cost & depth of wells, extent of water sales, water use pattern viz., distance to the city and nearest well, family details, quantity of water sales, investments made on water sale structures and horse power. These characteristics are discussed in detail in the following sections.

3.1 General Characteristics of Sample Farms

The general characteristics of sample farms are presented in Tables 3 and 4.

Out of the 180 farms selected for the study, 67.78 per cent of farms were water sellers and 32.22 per cent of farms were non-sellers. The small and large farm categories accounted for 65.55 cent and 34.45 per cent respectively. The average size of farms was found to be marginally higher in seller group than that of non-seller group and it was statistically significant. It could also be observed from the table that the proposition of dry land to the total farm size was found to be lower in non-sellers than in sellers in the two farm-size categories. This could be one of the reasons for water sales by the well owners. Similarly, the mean non-farm income and the mean number of persons engaged in non-farm activities were significantly higher in seller group than in non-sellers.

The current value of all farm assets has ranged from Rs. 5.10 lakhs to Rs. 11.06 lakhs in different farm categories in sellers, while it varied from Rs. 3.15 lakhs to Rs. 9.22 lakhs in non-sellers. The value of irrigation structures ranged from Rs. 84,196 to Rs. 1,31,828 in sellers, since the sellers invested more money on bore wells, electricity connection, motors (submergible motor) and water storage structures, whereas in the case of non-sellers, the investment was significantly lower on irrigation structures, which has ranged from Rs. 23,577 to Rs. 45,496.

3.2 Pattern of Well Ownership

The farm size category-wise distribution of wells, number of wells per ha. of land and number of failed wells are given in Table 5.

Table 3. Farm size, family size and non-farm income (area in ha.)

Category	No. of farms	Farm size			Family size	On-farm income (Rs.)	Non-farm employment	
		Garden land	Dry land	Total			Income Rs./year	No. of persons engaged
Sellers								
Small	77	1.60***	0.91***	2.51***	4.11***	3725***	59854***	1.91***
Large	45	2.88***	3.81	6.69**	4.45***	8644***	114155***	1.61***
Non-sellers								
Small	41	1.12	0.43	1.55	3.51	23089	18783	0.64
Large	17	2.30	3.36	5.66	3.46	42348	58076.5	0.31

*Note: ***, ** and * indicate that the values were significantly different from corresponding figures for the other category at 1%, 5% and 10 % levels respectively*

Table 4. Value of farm assets (Rs. per farm)

Farm category	Current value of			Total
	Land (Rs./ha.)	Buildings	irrigation structures	
Sellers				
Small	421157***	4304	84196***	509657
Large	1067243***	6773	131828***	1105844
Non-sellers				
Small	257192	34640	23577	315409
Large	873225	36215	45496	922342

*Note: ***, ** and * indicate that the values were significantly different from corresponding figures for the other category at 1%, 5% and 10 % levels respectively*

Table 5. Farm size and ownership of wells

Category	Number of wells per farm			Total number of wells per farm	Number of abandon-ed bore wells	Number of functioning bore wells per farm	Irrigated land in hectare per function-ing wells
	Open well	Bore well	Open-cum-bore well				
Sellers							
Small	1.06*	2.96***	0.51$^{\mathrm{NS}}$	4.53***	1.24**	1.72***	0.28***
	(23.40)	(65.34)	(11.26)	(100)	(41.89)	(58.11)	
Large	2.04**	5.03***	1.06$^{\mathrm{NS}}$	8.13***	2.88**	2.15*	0.67***
	(25.09)	(61.87)	(13.04)	(100)	(57.26)	(42.74)	
Non-sellers							
Small	0.80	2.02	0.44	3.26	0.88	1.14	1.18
	(24.54)	(61.96)	(13.5)	(100)	(43.56)	(56.44)	
Large	1.62	3.08	0.92	5.62	1.73	1.35	2.21
	(28.83)	(54.80)	(16.37)	(100)	(56.17)	(43.83)	

*Note: ***, ** and * indicate that the values were significantly different from corresponding figures for the other category at 1%, 5% and 10 % levels respectively*

Among the three type of wells viz., openwells, open cum bore wells and bore wells, open wells formed the majority in all categories of farms, whereas in the seller and non-seller groups, bore wells dominated the total number of wells owned by each of the farm categories. This might be due to the declining groundwater table and continuous deepening of existing wells. To meet the industrial and domestic water requirements and to maintain the existing irrigated area due to increasing water scarcity, farmers were forced to invest more on wells and related investments. Deepening of the existing open wells and making new ground level bores (bore wells) to cope up with decreasing groundwater table over the years were common. Bore wells dominate for more than 50 per cent of the total number of wells in large farms, whereas in the case of small farms, bore and open-cum-bore wells have been shared equally. The general opinion indicated was that making new bore wells is cheaper, when compared to open-cum-bore wells due to operational difficulties. According to the farmers, bore wells were having more success rate than the open cum bore wells. This is because, many farmers found it difficult to add bore holes in the existing open wells as these wells have already dried up.

Another reason for the distribution of more number of bore wells is that the groundwater exploitation and well density had resulted in low rate of success in the case of open-cum-bore wells. The yield obtained through open-cum-bore wells had affected the functioning of open wells in several cases indirectly, and also storage of extracted water from open-cum-bore wells is an another problem. Because, the rocks have a high permeability and result in drainage of entire water stored in the open well.

Other most important observation noted from the table is that both the total numbers of wells per farm as well as the irrigated area per functioning well were significantly higher in non-sellers than in sellers. Further, the higher irrigated land per well in non-seller categories than those in seller farms might be an indicator of intensity of water transfer out of agriculture and hence less area irrigated per well. This also implied that increasing tendency to sell water irrespective of the farm size. The number of abandoned bore wells was also significantly higher in all categories of farms, since open wells have acted as a storage tank for storing the water extracted from bore wells. The percentage of failed bore wells to the total number of wells per farm has ranged from 41.89 per cent in large farms to 57.26 per cent in small farm group in seller category. For non-seller category, it had varied from 56.17 per cent in large farms to 43.56 per cent in small farms.

The details of depth, age of wells, pumping capacity and distance to nearest well are presented in Table 6 which revealed that the depth of open wells has ranged from 31.06 to 33 metres in the seller category and in the case of non-sellers, it was 22.84 to 25.47 metres. The depth of bore wells was in the range of 138.86 to 152.65 metres in the sellers' farms and 104.48 to 115.26 metres in non-sellers farms. There was a high difference in the depth of open wells and bore wells among the seller and non-seller category, which was due to difference in water use pattern as sellers were receiving comparatively attractive price through selling the water to industries rather than doing agriculture. Hence sellers were investing more money on extracting large quantum of water, through deepening of existing open wells and making six inch bore wells rather than 4 ½ inch diameter bores. In the case of non-sellers, income was comparatively less due to less remunerative price for their agricultural produce. Further, deficit water supply coupled with high labour wage affected their income levels.

The age of the wells in both categories was almost similar. Even though the depth of wells in the seller category was significantly different from those in non-seller category, the occurrence of water transfer could be explained by the following facts. The number of wells per farm in sellers was significantly higher even though irrigated land per well was significantly lower. This showed that there was high rate of extraction of groundwater that was not used in agriculture.

The mean distance to nearest well was significantly lower in seller category than in non-seller category, indicating higher density of wells and hence there was higher rate of competitive digging of wells among sellers to pump more quantum of water for sales.

The mean pump capacity was higher in sellers category rather than non-sellers category, since most of the sellers had commercial electricity connection through which they could install more powerful extraction mechanism to extract groundwater even up to a depth of 300 metres. The pump capacity in seller category has ranged from 5.12 to 9.03 HP while it has varied from 4.63 to 7.50 HP in non-sellers. The higher pump capacity in the sellers might be due to the higher depth of wells; use of submersible pumps and to operate large number of bore wells to extract more quantum of water in a given time. Some sellers were installing the generators with capacity up to 30 HP and a cost of Rs. 1.5 lakhs to extract water during power cut periods.

3.3 Productivity of Water in Agriculture - Production Function Approach

Tomato, maize and cotton were the three major crops cultivated in the farms by sellers and non-water sellers. Using the production function approach marginal productivity of water in the production of major crops was derived. The estimates of Cobb-Douglas production function are presented in the Tables. 7 to 9.

Table 6. Depth, age of wells and the distance to nearest well (Distance and depth in metres)

Farm size	Depth of well		Mean age of the wells	Mean distance to nearest well	Mean pump capacity (HP)
	Open wells	Bore wells			
			Sellers		
Small	31.06**	138.86**	40	123.68	5.12**
Large	32.67**	152.65*	58	202.48**	9.03
			Non-sellers		
Small	22.84	104.48	36	128.29	4.63
Large	25.47	115.26	60	268.85	7.50

*Note: ** and * indicate that the values were significantly different from corresponding figures for the other category at 1% and 5% levels respectively. The open-cum-bore wells were included in the bore well category*

Table 7. Regression estimates of factors of production on tomato yield

Variables	Regression Coefficients		Standard errors	t-ratio
	Non-sellers	Sellers		
CONSTANT	2.0907	2.0907	0.3948	5.295**
LNWATER	0.3068	0.3068	0.0690	4.447**
LNCOST OF CULTI.	0.0935	0.0935	0.0119	0.787
LNLABOR	0.2339	0.2339	0.0600	3.900**
DUMMY	0.0472	--	0.0105	4.493**
R^2	0.7868			
N	87			

*Note: ** - significant at 1% level and * at 5% level.*

The R^2 is 0.79 indicating that 79 per cent of the variation in the tomato yield is explained by the variables such as water applied, cost of cultivation, labour used and dummy variable for capturing the effect of non-selling of water. The regression coefficient for water applied per hectare area has indicated that there is a strong positive relationship between the water applied and tomato yield. A one % increase in water application, would increase tomato yield per hectare by 0.31 per cent. Likewise, labour used in tomato cultivation had strong positive relationship, as tomato being a labour intensive crop. Among the four factors of production the influence of water was higher on tomato yield, as evidenced through the regression estimates. Inclusion of dummy variable indicated that there existed that positive relationship between non-selling of water and productivity of tomato. This fact might be due to continuous and efficient water supply to the crop during its critical stages of growth in non-selling farms.

Production function for non-seller and seller can be written as:

LNYLD = 2.0907 + 0.3068 LNWATER + 0.0935 LNCOST OF CULTI. + 0.2339 LNLABOR + 0.0472 DUMMY

Non-seller function, where dummy variable for non-seller is one

LNYLD = 2.1379 + 0.3066 LNWATER + 0.1003 LNCOST OF CULTI. + 0.2349 LNLABOR

Seller function, where dummy variable for seller is zero

LNYLD = 2.0907 + 0.3068 LNWATER + 0.0935 LNCOST OF CULTI. + 0.2339 LNLABOR

The R^2 of maize production function is 0.82, which has indicated that 82 per cent of the variation in maize yield was explained by the variables viz., water applied per hectare, cost of cultivation, labour used in man-days and dummy variable to represent non- water selling. The regression coefficient for water used has indicated that there is a strong positive relationship between the water used and maize grain yield. A one per cent increase in the water applied, ceteris paribus, would increase the maize yield by 0.46 per cent. Another factor, cost of cultivation has a significant influence on maize production. Addition of dummy variable had shown that strong positive relationship between non-selling of water and productivity of maize. This shows that continuous irrigation could increase the grain maturity and fodder growth in non-selling farms.

Production function for non-seller and seller can be written as:

LNYLD = 4.8048 + 0.4584 LNWATER + 0.2044 LNCOST OF CULTI. + 0.0924 LNLABOR + 0.0743 DUMMY

Non-seller function, where dummy variable for non-seller is one

LNYLD = 4.8791 + 0.4584 LNWATER + 0.2044 LNCOST OF CULTI. + 0.0924 LNLABOR

Seller function, where dummy variable for seller is zero

LNYLD = 4.8048 + 0.4584 LNWATER + 0.2044 LNCOST OF CULTI. + 0.0924 LNLABOR

The R^2 of the production function for cotton crop is 0.98 which had indicated that 98 per cent of the variation in cotton yield was explained by the variables viz., water applied, cost of cultivation, labour used in man-days and non-water selling behaviour of the farmer expressed through dummy variable. The regression coefficients for water use has indicated that there is a strong positive relationship between the water applied and cotton yield. A one per cent increase in the quantity of water applied, ceteris paribus, would result in the cotton yield increase by 0.90 per cent. Cost of cultivation has a strong positive relationship with the cotton yield, where one per cent increase in the cost of cultivation would result in 0.16 per cent increase in cotton yield. This is due to high cotton cultivation expenditure incurred to control the boll warms and leaf-eating caterpillars by frequent spraying of pesticides. Strong positive relationship between cotton yield and dummy variable might be due to special attention given by the non-selling farmers towards cotton production since this crop is a commercial and long duration crop.

Table 8. Regression estimates of factors of production on maize yield

Variables	Regression Coefficients		Standard errors	t-ratio
	Non-sellers	Sellers		
CONSTANT	4.8048	4.8048	0.7711	6.231**
LNWATER	0.4584	0.4584	0.1406	3.261**
LNCOST OF CULTI.	0.2044	0.2044	0.0453	4.510**
LNLABOR	0.0924	0.0924	0.0741	1.246
DUMMY	0.0743	--	0.0189	3.921**
R^2	0.8178			
N	82			

*Note: ** - significant at 1% level and * at 5% level.*

Table 9. Regression estimates of factors of production on cotton yield

Variables	Regression Coefficients		Standard errors	t-ratio
	Non-sellers	Sellers		
CONSTANT	1.0802	1.0802	0.8953	1.207
LNWATER	0.8963	0.8960	0.1679	5.337**
LNCOST OF CULTI.	0.1584	0.1583	0.0255	6.197**
LNLABOR	0.0944	0.9533	0.0402	2.351*
DUMMY	0.0222	--	0.0093	2.390*
R^2	0.9812			
N	52			

*Note: ** - significant at 1% level and * at 5% level.*

Table 10. Geometric mean value of inputs and outputs

Crops	Yield (qtls./ ha.)	Water used (ha. cm)	Cost of cultivation (Rs. in ‘000s/ha.)	Labour used (man-days per hectare)
Tomato	256.26	55.23	7.37	403.88
Maize	52.73	51.41	16.46	170.36
Cotton	22.13	53.14	18.48	245.15

Production function for non-seller and seller can be written as:

LNYLD = 1.0802 + 0.8963 LNWATER + 0.1584 LNCOST OF CULTI. + 0.0944 LNLABOR + 0.0222 DUMMY

Non-seller function, where dummy variable for non-seller is one

LNYLD = 1.1024 + 0.8963 LNWATER + 0.1584 LNCOST OF CULTI. + 0.0944 LNLABOR

Seller function, where dummy variable for seller is zero

LNYLD = 1.0802 + 0.8963 LNWATER + 0.1584 LNCOST OF CULTI. + 0.0944 LNLABOR

3.4 Value of Marginal Product of Water in Agriculture and Opportunity Cost in Sales

From the above production function estimates, the elasticity of output with respect to water for tomato, maize and cotton crops were derived from the output elasticity the Marginal Physical Product (MPP) of water has been calculated. Multiplying the MPP of water with output price resulted in the Value of Marginal Product (VMP) of water.

When the VMP of water in crop production is greater than price of water, it could be inferred that further use of water in the agriculture sector until VMP of water equal to marginal cost is recommended. If the VMP of water in crop production is less than price of water, then it is economical to transfer water from agriculture to industrial use by reducing the water use in agriculture. The calculated geometric mean values of inputs are presented in Table 10.

In the regression analysis leading to estimation of VMP in the above table the unit of water is measured in terms of hectare centimetres (ha. cm), which is equivalent to one lakh litres. So the VMP of crops was compared to amount realised from sales of water to industrial use from this comparison and it could be seen that water transfer to industrial use either using oil engine or electricity is greater than VMP of water use in agriculture for all the crops compared. Thus, transferring of water from agriculture to industrial use is more profitable. In addition, the risk and uncertainties involved in crop production and other factors such as labour scarcity, high inputs cost and lack of markets for agricultural produce, farmers preferred selling water rather than using it for growing crops such as tomato, maize and cotton. This might be the reason for selling the water by the farmers to non-agriculture uses. However, indepth analysis will throw much light on this issue.

4. CONCLUSION

Groundwater is the major source of water for agriculture, domestic and industrial uses. In fact, in many places groundwater is the only source of water. Falling water table and depletion of economically accessible groundwater resources could have major social and economic consequences. Both National and State water policies also give first priority for domestic water supply.

The sample farms in each of the two categories viz., groundwater seller and non-sellers were grouped into small and large farms. Out of the 180 farms selected for the study, 67.78 per cent of farms were water sellers and 32.22 per cent of farms were non-sellers. The value of irrigation structures ranged from about Rs.84196 to 131828 for sellers, since sellers invested more money on bore wells, electricity connection, motors (submergible motor) and water storage structures, whereas in case of non-sellers, the investment was significantly less on irrigation structures.

Among the three types of wells viz., openwells, open cum bore wells and bore wells; open wells formed the majority in all categories of farms. Whereas in all the farm categories of both the seller and non-seller groups, bore wells dominated the total number of wells owned by each of the farm categories. Bore wells dominated for more than 50 per cent of the total number of wells in large farms, whereas in the case of small farms, bore and open-cum-bore wells have been shared equally. According to the farmers, bore wells were having more success rate than the open cum bore wells. The yield obtained through open-cum-bore wells might affect the functioning of open wells indirectly, and also storage of extracted water from open-cum-bore wells is an another problem. Further, the higher irrigated land per well in non-seller categories than those in seller farms might be an indicator of intensity of water transfer out of agriculture and hence less area under irrigated agriculture per well and also of increasing tendency to sell water irrespective of the farm size. The number of abandoned bore wells was also significantly higher in all categories of farms, since open wells were acted as a storage tank for storing the water extracted from bore wells. The percentage of failed bore wells to the total number of wells per farm had ranged from 41.89 per cent in large farms to 57.26 per cent in small farm group in seller category. There was a significant difference in the depth of open wells and bore wells among the seller and non-seller category.

The number of wells per farm among sellers was significantly higher whereas irrigated land per well was significantly lower. The mean distance to nearest well was significantly lower in seller category than in non-seller category, indicating higher density of wells and hence there was higher rate of competitive digging of wells among sellers to trap more quantum of water for sales.

Tomato, maize and cotton were the three major crops cultivated in the farms of non-water sellers and sellers. The regression coefficient for water applied per hectare area indicated that there is a strong positive relationship between the water applied and tomato yield. A one per cent increase in water application would increase tomato yield per hectare by 0.31 per cent. A one per cent increase in the water applied would increase the maize yield by 0.46 per cent. Likewise, the regression coefficients for water use had indicated that there is a strong positive relationship between the water applied and cotton yield. A one per cent increase in the quantity of water applied would result in the cotton yield increase by 0.90 per cent.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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