Gains or losses? A quantitative estimation of environmental and economic effects of groundwater transfer from agriculture to urban areas in Tiruppur district

Suggested title: Exploitation of agricultural groundwater for urban areas

Abstract

Ground water is the most accessed source of water for domestic, industrial, and agricultural purposes. Significant social and economic repercussions could result from a declining water table and the depletion of groundwater resources that are economically accessible. Domestic water supply is given top emphasis in both National and State water policy formulation. Recently, there has been a rise in water transfers to satisfy the needs of the industrial and residential sectors. With the success of the state water supply, many are heralding groundwater transfer as the quickest, least expensive and most environmentally benign solution to large cities water supply and reliability problem. In order to satisfy urban domestic and industrial water demand, the majority of water transfers concentrate on buying water from farmers who are prepared to sell it to them. The present study was undertaken mainly to study the impacts of economic and environmental gains and losses related to the groundwater transfer in Tiruppur district. Without doubts groundwater transfer from agriculture to industrial uses would benefit individual sellers, buyers and the Nation as whole. The adverse direct economic impact in groundwater selling or water transferring areas to total revenue in agriculture was Rs. 54.32 lakhs per every crop season. Scarcity of water resulted in shifting of irrigated agriculture to rainfed agriculture and labour intensive to labour less intensive crops. The total employment lost per hectare of land was 198.33 man-days. Secondly, another adverse indirect economic and environmental impact of water transfer is discharge of large quantum of industrial effluent water. Moreover, there is indirect economic and environmental impact on effluent receiving areas due to highly polluted industrial effluent discharge into open lands and river/streams could cause a Rs. 22,296 net personal income loss for every hectare of land. At larger perspective impacts of groundwater transfer could be considered insignificant.

Keyword: Ground water transfer, Economic gain, Cobb-Douglas regression

1. Introduction

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[1]. 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.

Also, groundwater pollution and quality need to be recognized as point of environmental significance. On one level, pollution and water quality affect the usability of groundwater resources for domestic, industrial, or agricultural applications. If groundwater becomes degraded, human demands will focus on other resources such as surface streams, with potentially huge secondary impacts. On another level, groundwater quality and pollution have direct implications for the environment. These ranges from salinization of overlying land to toxic contamination[2].

The impacts of groundwater transfer and pollution are potentially far reaching, not only for the agriculture sector. Farming can inflict off-farm costs on land degradation through the processes of depletion and salinisation and changes in hydrological pattern and water quality. Ultimately, the continuous exploitation of groundwater resources can reduce future economic growth considerably. Policy makers require answers to questions related to the cost and benefit structure of groundwater transfer and its related pollution from agriculture to industrial use, and to prioritize problems and design incentive structure that make groundwater conservation and management measures more attractive. An important task is to appraise the actual extent and impact of groundwater transfer from agriculture to urban/industrial uses and its related groundwater pollution in effluent receiving land areas and to evaluate their economic and environmental significance. This is possible only if an appropriate assessment framework and tools are available that allow for the identification, quantification and valuation of the impacts of groundwater transfer from agriculture to urban/industrial use and its related groundwater pollution in effluent receiving land areas. In this context, it is imperative to take up a study on the economic and environmental impacts of groundwater transfers.

2. Review of Literature

Many economic theories were confounded that the appropriate principle establishes well defined property rights to water in the form of permits (values), and transferability of these permits creates a market price for water. The reasoning for holds for price is an information-rich signal about the relative scarcity of water and that gesture motivates individuals to do the right things in response to scarcity level. In this context, some of the past studies on valuation of water were reviewed below.

Thobani stated that in most countries the state owns the water resources and the hydraulic infrastructure, and public officials decide who gets the water, how it is to be used, and how much would be charged for it. Costly inefficiencies in the supply and use of water support a shift from government provision to a market-based approach that was more effective and less wasteful. Markets could allow rapid changes in allocation in response to changing demands for water and could stimulate investment and employment as investors were assured of access to secure supplies of water. By designing appropriated water laws and regulations and by strengthening private and public institutions to administered them formal water markets could efficiently addressed to meet the rising demands for groundwater and for water found in rivers, lakes, and canals. Lessons were presented briefly from Chiles experience to demonstrate that formal water markets could improve the economic efficiency of water use and stimulate investment[3].

Reddy stated that based on household level information from six villages in a water scarce region of India (Rajasthan), examined inter and intra-village variations in water use and the costs. Direct and indirect, involvement in obtaining water and also estimated households willingness and ability to pay for water, using the Contingent Valuation Method (CVM). Using qualitative as well as quantitative methods, it was argued that failure of government policy and of institutions, which has been led to severe water shortages in harsh environments rather than supply or financial bottlenecks *per se*. While the estimates of price elasticity water use indicated the feasibility of water pricing in the rural areas, the willingness to pay estimates, question the general assumption that rural households were willing to pay 5% of households income/expenditure for water. Various economic and extra economic factors such as household income and low opportunity costs of women and children, and attitudes towards female labour and public goods were vital in influencing the households' willingness to pay for water[4].

In the present study, the price is the embodiment of available information on the scarcity of water and is an effective tool for motivating appropriate levels of individual action in response to this scarcity or misuse of the resource.

Moench defined over-development in technical sense as the point where extraction exceeded recharge. Under the economic efficiency objectives, over-development would occur when the social cost of development exceeds the social benefits[5].

According to Dhawan, overexploitation took from the form of annual withdrawals from groundwater stock exceeded total annual replenishment or recharge of this stock from rainfall infiltration; seepage from tanks lakes, canals and ponds[6]. Globally there is decline in ground water due to pollution and ground water level is also decreases in the global scale[7][8].

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 groundwaterMethodology stated by K.Arumugam et al.,[9].

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.,[10].

Devineni, Net 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 [11].

SivakumarV 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[12].

Hence, an attempt has been made in the present study to identify and evaluate impacts of a groundwater transfer from agriculture to urban areas in Tiruppur district.

3.Methodology

3.1 Assessment of the Changes in Productivity

The basic methodology for the assessment of changes in productivity is due to straightforward and easy to comprehend.

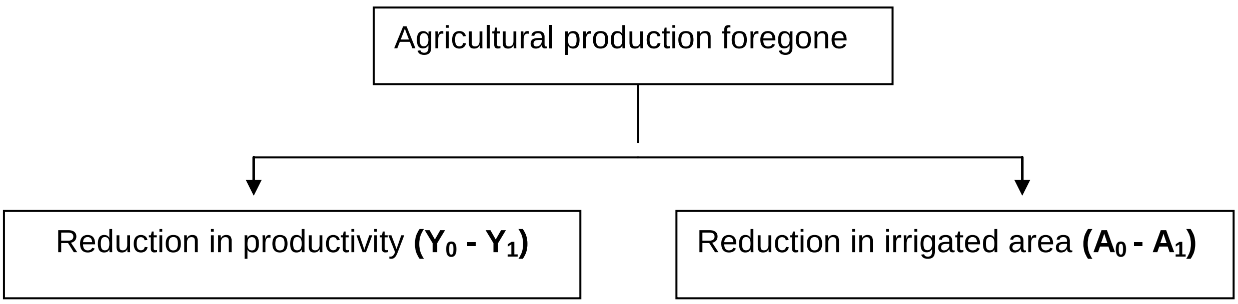
- Identification of all components relevant for analysis, i.e. setting the scope.
- Quantification of physical variables, i.e. environmental impact and resources; and
- Valuation i.e. translating physical variables into monetary terms.

The variables to be included in the impact quantification are:

- impact of groundwater depletion.
- impact of groundwater pollution.
- relative changes in yield due to groundwater transfer and induced groundwater depletion.
- relative changes in yield due to groundwater pollution caused by industrial effluent.
- factor wise impacts/costs such as capital, materials, labour and land.
- impacts of hydrological pattern (i.e. land use changes and not on groundwater depletion); and
- population and lowland economy.

The methodology to assess productivity changes needs the relationship between groundwater transfer and pollution, and yield measured over time. Comparison between farms of seller and non-seller will help to estimate yield changes due to water transfer. Similarly, comparison between farms facing polluted and non-polluted groundwater will help to estimate yield changes due to pollution.

This study tested the significance of various possible agricultural productivity losses as well as reduction in irrigated acreage. The quantification was done as follows:



Reduction in productivity X Existing area **$(Y_0 – Y_1)$ x A_0**	Normal Productivity X Reduction in area **Y_0 x $(A_0 – A_1)$**

Where

Y_0 = Normal productivity in kgs per hectare realised in irrigated agriculture by i^{th} farmer in j^{th} crop (j =1 to 3,1 = Tomato, 2 = Maize and 3 = Cotton

Y_1 = Rainfed/reduced productivity in kgs per hectare realised by i^{th} farmer in j^{th} Crop (j =1 to 3, 1 = Tomato, 2 = Maize and 3 = Cotton

A_0 = Normal area under irrigated agriculture in hectares

A_1= Rainfed/reduced area under irrigated agriculture in hectares

$$Total\ on - farm\ impact\ due\ to\ water\ sales = \sum_{i-1}^{3} AGRL.PROD_{foregone}\ XPRICE\ _{output}$$

Where,

AGRL. PROD.$_{foregone}$ = Agricultural production foregone in of i^{th} crop[1]

PRICE$_{output}$ = Current market price of output of i^{th} crop (Rs./kg)

Using the loss in irrigated acreage as the proxy variable, the effect of groundwater transfer from agriculture to urban uses on the rural households through loss of employment was quantified.

Loss in employment = [{Reduction in irrigated hectare-age per well} **X** {Forgone employment per hectare}] **X** Total number of wells used for water transfer

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3.2 Production impacts

Effect of groundwater pollution at village level was quantified through the following formula.

Potential production foregone = Decline in productivity X Area affected

Effects of groundwater pollution on agricultural production at farm level were quantified through production function approach. This is otherwise called "yield damage function" approach. The following functional relationship was specified for the present study.

$$YLD_I = f(TDS, CC_{i,} Labour_i and\ pH$$

Where,

YLD_i = Yield in kgs per hectare of i^{th} crop
(i = 1 to 3), 1 = sorghum, 2 = maize and 3 = cotton

TDS = Total dissolved salts[2].It can be calculated through (TDS = Electrical Conductivity (EC) X 640) in mg l^{-1})

CC_I = Capital spent on different inputs in crop cultivation excluding labour (Rs./hectare) of i^{th} crop (I = 1 to 3)

$Labour_i$ = Labour in man days per hectare of i^{th} crop (i = 1 to 3)

pH = pH meter reading (ranges from 5 to 10)

Generally, 65 per cent of the total rural population's employment opportunity depends on agriculture and its allied activities. In this context, groundwater transfer from agriculture to urban uses and it related groundwater pollution in lowlands would cost the local agricultural labourers dearly. Under the groundwater transfer and pollution conditions, employment opportunity was drastically reduced due to decline in area under irrigated agriculture.

3.3 Employment impact

The total effect of groundwater pollution on rural employment was calculated through the following equation.

$$E_i = a_i + b_i \Delta ACI_i + c_i \Delta WQ_I$$

Where,

E_i = employment per farm due to irrigation in i^{th} farm

b_i = slope from the irrigated acreage response curve for employment loss in i^{th} farm

c_i = slope from the groundwater quality response curve for employment loss in i^{th} farm

ΔACI_i = change in area cultivated under irrigation in i^{th} farm

ΔWQ_i = change in groundwater quality due to industrial effluent in i^{th} well expressed through Total Dissolved Salts (TDS) in mg l^{-1}

4. Result and Discussion

Decreasing saturated concentration of the aquifer, increasing water selling to industrial requirement and well pumping extracted large quantum of water over the past 25 years from the aquifer in this hard rock region of Tiruppur. There is an average decrease in the groundwater table of the aquifers over the time in the region was 10 percent in every decade, while tremendous increase in the number of wells at the rate of 2.43 per cent per annum during the last 25 years in the region was observed. In Tiruppur town, Palladam and Pongalur blocks had experienced the greatest change with regard to decreasing groundwater table with increased wells and pumping, resulting in increased area under rainfed agriculture. As irrigation water availability decreased, the only option available to farmers was to cultivate crops that require less irrigation water or switching over to rainfed agriculture or to increase the fallow land. Especially, the Tiruppur town and Palladam block witnessed large increases in the proportion of land under current fallow by about 27.05 per cent over the past two decades. Dry land farming increased significantly in composite of Tiruppur town and Palladam block. It could be inferred from these two measurements of water availability that greater the change in well pumping rate, groundwater table and water use pattern, the faster the shift towards rainfed agriculture.

4.1 Impacts of groundwater transfer at farm level

The details on depth to water table and other information in the sample farms are presented in Table 1. The data revealed that the mean depth to water in dry yearsin seller farms has ranged from 22 to 26 metres below surface level, while it was lower in the case of non-seller farms ranging from 20 to 25 metres. In normal years, the water table level in the region was higher in both the farm categories and it was in the range of 6 to 9 metres below surface level.

Table 1. Impacts of groundwater transfer at farm level

Variables	Seller		Non-seller	
	Small	Large	Small	Large
Average depth to water table (metres)				
a). Normal years	8.90	6.50	7.81	5.94
b). Dry years	21.87	25.99	20.01	24.74
Average reduction in area irrigated due to intensive water selling of the nearest farm (ha.)	--	--	0.54***	0.26***
Investment on open well (Rs./well)	98921*	127084***	108275	86924
Investment on bore well (Rs./well)	23455	60746***	32797	39417
Investment in water selling structures (Rs.)	45780	90540***	---	---
Cropping intensity(%)	43.80	26.32	146.70	113.85

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

2. The information on dry years and normal years were obtained by recalling the latest dry and normal years by the respondents and compared with the observation well readings maintained by PWD.

It could be inferred that even though non-seller has been using groundwater in a conjunctive way, the water table would be in the declining trend, because of the external effect caused by the seller through continuous pumping for sales. The average reduction in area irrigated by the non-seller sample well, after the continuous pumping of water for sales by the nearest seller was significantly higher ranging from 0.54 and 0.26 hectares in small and large farms respectively. The effect of water sales on large farms was very low when compared to small farms, because large farms could manage to dig a new bore well, since their land area was large, they could easily find a new source to cope up with the water scarcity. The reduction in area irrigated by wells would indicate not only a reduction in farm income and employment, but also resulted in higher variability in income to non-sellers over time and space.

The investment in wells was higher among sellers rather than among the non-sellers. The investment per open well at current price has ranged from Rs. 98921 to Rs. 127084 among the sellers and from Rs. 108275 to Rs. 86924 among the non-sellers by small and large farms respectively. There was significant difference in the investment pattern on open wells among two categories. Generally, small farms were more dependable on open wells and open-cum-bore wells rather than bore wells, since cost of bore wells is cheaper but costs on other accessories required for pumping water such as casing pipe, delivery pipe, etc., were higher. The investment made on bore wells had ranged from Rs. 23455 to Rs. 60746 for seller category of small and large farms respectively, while it varied between Rs. 22797 and Rs. 39417 in non- seller category of small and large farms. There was significant difference in investment pattern on bore wells between seller and non-seller categories. Reason for the difference in investment pattern was due to continuous pumping of water for sales by sellers and through which sellers were receiving good revenue. In some cases within short period bore wells dried off due to continuous pumping. In such cases, sellers invested on new borewells, but in the case of non-sellers, they would not invest much on bore wells, since they notice that the resultant returns was marginal. Generally, non-sellers would prefer to invest more on open well deepening wherein, the open wells would help the non-sellers after canal water period and monsoon seasons as well as it would act as storage tank for storing the water pumped from borewells. The investment made on water selling structures such as storage tank, generator, advanced motors and pumps were significantly higher in large seller farms compared to the other group.

The cropping intensity in the non-seller farms was higher both in the two farm types than in the seller farms. Especially, in the case of large farms, cropping intensity was very low, since they were engaged in off-farm activities and they were in a position to sell the available well water to the industries[13].

4.2 Changes in Productivity Approach to Quantify On and Off Farm Economic Impacts of Groundwater Transfer from Agriculture to Industrial Use

Direct impacts represented the decrease in production, in terms of value of crops produced. Indirect impacts represented the loss of employment and other agricultural related activities at the farm level in response to water transfer from agriculture to other purposes.

The amount of land fallow in the sample farms due to water sales was 431.6 hectares. Estimated amount of water transfer was about 12.54 million liters per day from water sellers across all sample farms. Thus, transferred water has to be adjusted by fallowing land and switching over to less water intensive or rainfed or using water saving techniques such as drip irrigation for perennial crops. From the production function analysis, it could be inferred that water plays a major role in the production of the irrigated crops especially tomato, maize and cotton crops.

The estimated production values for cotton, tomato and maize are given in Table 2. The non-seller is fixed as baseline for the representing the optimal crop production scenario in which no water transfer has taken place. This scenario is used to facilitate comparisons with seller to quantify the economic impact of groundwater transfer on farm economy.

Table 2. On and off farm economic impacts of the water transfer on farm economy

Particulars	**Tomato**	**Maize**	**Cotton**
Direct losses from water sales			
Land fallow as a result of transfer (in ha.)	273.60	275.88	323.61
Crop revenue foregone (Rs. in lakhs/crop season)	58.78	61.25	134.73
Personal income foregone (Rs. in lakhs/crop season)	39.38	45.44	78.15
On-farm employment foregone (man-days/hectare)	295	72	228
Gains from water sales			
Amount of water sold (in ha. m)	15048	13794	19437
Receipts from transfers (Rs. in lakhs/crop season)	125.4	114.95	167.2
Total personal income (Rs. in lakhs/crop season)	100.32	91.96	133.76
On-farm employment gain (man-days/hectare)	Nil	**Nil**	Nil
Net gain/loss			
Personal income (Rs. in lakhs)	60.94	46.52	55.61
Employment (man-days/hectare)	-295	-72	-228

Based on the quantity of water sold by the sample farms, foregone area under irrigation and foregone yield due to switching / change in quantity of water application, economic impacts on regional agriculture was calculated and presented in the above table. The total water sold from the sample farms would be sufficient to irrigate 273.60, 275.88 and 323.61 hectares of tomato, maize and cotton respectively.

Total personal income realised from groundwater sales was Rs. 100.32, Rs.91.96 and Rs.133.76 lakhs compared to the value of personal income realised from tomato, maize and cotton crops (Rs. 39.38, Rs. 45.44 and Rs. 78.15 respectively) that otherwise would be produced using the water.

As water availability declines, farmers faced lower prices for agriculture produce, high agricultural wage with decreased productivity of labour and re-evaluated their traditional cropping patterns from irrigated agriculture to rainfed agriculture. Some of the farmers, who have faced the above problems, have been doing agriculture with crops that utilised less water and have high values in the market such as vegetables and coconut. For the perennial crops, farmers have adopted the most efficient irrigation technology like drip irrigation. In comparing the net returns of all possible combinations of crops and technology, irrigated cotton, maize and tomato crops surpassed all other crops. Although irrigated maize has recorded higher gross returns with less irrigation water and the low cost of inputs, had become reduction in area within the region. The low profitability of irrigated and rainfed sorghum and red gram caused this crop area to decrease, although production of rainfed sorghum had increased in the recent years.

The loss of irrigated maize and sorghum production had resulted in the declining of dry fodder production in these blocks. This might negatively affect the cattle population and milk industry in these blocks considerably. Once these Tiruppur, Palladam and Pongalur tracks were very famous for cotton and regarded as the crop of prime choice for farmers. But in recent years area under irrigated cotton has been continuously declining and shifted towards rainfed cotton with low yield.

This analysis represented a lower bound estimate in terms of the negative economic impacts resulting from the increased groundwater transfer out of agriculture and its related groundwater depletion of the aquifer in the region which would indicate that all farmers are in transition to rainfed agriculture.

4. 3 Loss of employment in water transferring areas

Based on the secondary data analysis, it could be inferred that area irrigated was worked out to 1.094 hectare per combined open and bore wells in Tiruppur the district. In the present study, about 194 open and 200 bore wells were used for water selling. Water selling from these wells would result in 431.60 hectares of land area under fallow or rainfed agriculture.

The man-days of employment for agricultural labour generated due to additional irrigation created through percolation ponds induced groundwater recharge was calculated[14]. The values of man-days per season for major crops are given in the Table 3.

Table 3.Labour required in man-days per hectare of irrigated land for different crops

S.No.	Crops	Man-days per hectare
1.	Sorghum	105
2.	Maize	152
3.	Groundnut	190
4.	Pulses	89
5.	Tomato	384
6.	Sugarcane	172
7.	Cotton	255
8.	Banana	300

Based on the above references, it could be inferred that amount of water transferred from the sample farms to industrial use would result in 295, 72 and 228 man-days per hectare of loss in on-farm employment in tomato, maize and cotton cultivation respectively.

4.4 Indirect Impact of Groundwater Transfer from Agriculture to Industrial Use on Farms

About 99 per cent of the textile processing units had treatment facilities viz., through individual or common effluent treatment plants. Even then all effluents have been discharged into Noyyal River and its tributaries (Figures. 1 and 2). Finally, all the effluents were flown into reservoir, which is an agricultural reservoir, located 20 kilometres downstream from Tiruppur town. This resulted in the contamination of groundwater in a 2-4 km radius around reservoir upto a depth of 60-90 meters. Groundwater had become brackish and considerably harder. Other harmful substances included the number of dyes and many were based on Benzedrine structures or heavy metals both known to be toxic. Before construction of the dam, agricultural production was high and cultivated major crops such as tobacco, coconut, turmeric, maize, cotton and vegetables in this area. At present, majority of farmers were cultivating only dry crops in these villages and wet crop cultivation limited to a few farmers whose wells are not yet severely polluted.

4.5 Production impact analysis through yield damage function

The contribution of different factors on the crop production and the interrelationships among these factors were studied using the production function approach. After careful analysis of various factors; factors that damaged the crop yield such as operating cost, labour used in man-days, total dissolved salts (TDS) and pH of irrigation water were identified. The Cobb-Douglas production function was selected to quantify the nature and extent of damage of different factors influencing the crop yield. The per hectare production function was used to capture the effect of various inputs on the productivity of crops. The results are presented in Table 4.

The R^2 of the production function for cotton crop is 0.97 indicating that 97 per cent of the variation in cotton yield is explained by the explanatory variables included in the model. The regression coefficient for TDS had indicated that there is a strong negative relationship between the TDS and cotton yield. An one per cent increase in the TDS, ceterisparibus, reduced the cotton yield by 0.44 per cent. However, labour use has a strong positive relationship with the cotton yield where, one per cent increase in the labour use would result in 0.27 per cent increase in cotton yield. That means in polluted groundwater farms, initial seed germination could be increased by pot irrigation for cotton crop with the good quality water, through which cotton plant population could be maintained and finally yield would increase.

Table 4. Effect of crop yield using Cobb-Douglas regression coefficients

Variables	**Regression coefficient**		
Crops	**Cotton**	**Maize**	**Sorghum**
Constant	10.09	4.7915	11.151
	(3.399***)	(0.4902)	(1.8098*)
TDS (Total Dissolved Salts)	-0.448	-0.4832	-0.9352
	(-5.951***)	(-3.8676***)	(-2.821***)
PH	-0.0736	-0.037Effect	-0.0627
	(-0.346)	(0.0462)	(-0.1927)
Operating cost	-0.142	0.0807	0.4932
	(-0.545)	(0.0459)	(0.860)
Labour	0.2734	1.3411	-0.3093
	(2.935***)	(0.9699)	(-0.7045)
	$R^2 = 0.97$	$R^2 = 0.93$	$R^2 = 0.94$
	N = 45	N = 42	N = 35

Note: 1. Figures in parentheses are t - ratios

Note: 2. ***, ** and * indicate that the coefficients were significant at 1%, 5% and 10% level

The strong negative relationship between TDS and cotton yield indicated that the highly polluted groundwater would decrease the cotton yield significantly. It was estimated that to offset or overcome the negative effect of one per cent increase in TDS on cotton yield per hectare, an additional 1.7 per cent labour is required at a cost of Rs. 110.

The R^2 estimates of maize production function is 0.93 indicating that 93 per cent of the variation in maize yield are explained by the variables viz., TDS (Total Dissolved Salts in mgl^{-1}), pH, operating cost and labour used in man-days. The regression coefficient for TDS indicated that there is a strong negative relationship between the TDS and maize grain and fodder yield. A one per cent increase in the TDS would reduce the maize yield by 0.48 per cent. The regression estimates of other factors were non-significant and it did not mean that other factors were not contributing to maize grain and fodder yield. Compared to sorghum, maize requires more quantum of irrigation water and water quality could also play an important role in determining the productivity of maize crop. Generally, farmers of the study area were using same level of other inputs in maize production and hence the estimated function could not capture their effect on yield.

Next to maize, the most important crop grown by the sample farmers was sorghum. The marginal productivity of various factors of production on sorghum yield could be derived through production function. The R^2 of 0.94 indicated that 94 per cent of the variation in sorghum grain and fodder yield could be explained through TDS, pH, operating cost and labour used. The regression coefficient for TDS has indicated that there is a strong negative relationship between the TDS and sorghum yield. A one per cent increase in the TDS would reduce the sorghum grain and fodder yield by 0.93 per cent. That means polluted groundwater would affect the sorghum seed germination and even after germination polluted groundwater farms were not irrigating the sorghum fields. The reason for not irrigating was that polluted water could severely reduce the plant growth and drying of plant.

This implies that the increase in TDS of groundwater would aggravate the problem of crop yield reduction and overall negative externality of reduction in area under irrigation as well as productivity of crops.

5. Conclusion

Water transfers can generate three different types of impacts namely, direct, indirect and induced impacts. An important task is to appraise the actual extent and impact of groundwater transfer from agriculture to urban/industrial uses and its related groundwater pollution in effluent receiving agricultural areas. The present study was undertaken mainly to study the economic and environmental impacts of groundwater transfer from agriculture to urban sector. The study was done covering Tiruppur town and the surrounding blocks.

Off-farm employment opportunity significantly influenced farmer participation in water selling. The elasticity of intensity of the off-farm employment had shown that one percentage increase in the off-farm employment would result in 0.98 per cent increase in water sales. The probability of participation in water sales could increase by 0.46 percent as off-farm employment increases, while the intensity of water would increase by 0.52 percent. The probability of participation will decrease by 12.09 percent, while the elasticity of intensity of water transfer would decrease by 13.59 percent, The water availability will increase the farming activities such as vegetables cultivation since farms close to city centres would get more remunerative price than selling water.

Ownership of well has the largest influence on participation and intensity of water sales. The elasticity of probability of participation in water sales falls by 0.1568, whereas the elasticity of intensity of water sales decreases by 0.1763 as soil quality is good. Many farmers cited non-profitability due to low price for agricultural produces and low yields due to inadequate water as factors influencing water sales. A number of recent happenings have contributed to reduced water availability and uncertainty over future water supplies. Since quantum of water transfer is very high, the impact of water selling on neighbouring farms is very serious and damage on irrigated agriculture is irreversible.

Major constraints in irrigated agriculture are less remunerative price for agricultural produce, high agricultural wage with low labour productivity, inadequate water availability for agriculture and increased input costs. Pollution even damages the quality of the crop which effects the photosynthetic systems, leaf longevity, and patterns of carbon allocation within plants.As a result, several farmers repeatedly did water selling after all of water requirements of standing perennial crops and livestock were met. Water available in the wells were not sufficient to raise the crop and in that conditions farmers cultivated crops that required less amount of water and sold the remaining water.

There is a high demand for good quality water (TDS less than 1000 mg l^{-1}) in the industrial sector and they offered good price for water and farmers were induced to sell the water out of agriculture. Rapid urbanisation and the ever increasing urban water needs for industrial and domestic purposes; and pollution by industries, resulted in scarcity for good quality water.

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