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# Comparative Analysis of Cost and Efficiency in Water Use of Groundwater Market Participating and Non-Participating Farms in Cuddalore District of Tamil Nadu

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**ABSTRACT**

Crop production and human survival primarily depends on available freshwater resources, where upto 70% of the resource is used for irrigation purpose either as surface water or groundwater. Lack of surface water resources increases the dependence on groundwater. Ground water is the backbone of available fresh water resources. Country's economic growth is always dependant on high market opportunity and in-order to boom agricultural economy of our country, groundwater market plays a vital role. This is a highly sensitive market as it has multiple dependant factors like growing population, effective water usage, availability, water restoration which changes demand and decides the role of water market. Although water market is an informal structure, the demand and availability leads the exchange of water for monetary value charged on the basis of area, volume and time. Due to increase in demand and decrease in availability which is caused by various environmental factors, water market plays a vital role in overall contribution towards agrarian economy. This study tries to compare the cost and water use efficiency between water participating and non-participating farms in cuddalore district of Tamil Nadu.

***Key words :*** *Irrigation, Groundwater, Groundwater market, Water use efficiency*

## Introduction

Ground water is one of the nation's most important natural resources. Ground water is not a non-renewable resource, such as a mineral or petroleum deposit, nor it is completely renewable in the same manner and timeframe as solar energy. Ground water is expensive and relatively scarce in recent years.Due to short supply of surface water the farmers are to depend on groundwater to irrigate their land for crop cultivation.

Irrigation water uses up around 70-80% of the world's renewable fresh water supplies. Among the different sources of irrigation water, groundwater has a mammoth share of 43% and it registered an exponential growth in recent decades owing to its reliable and ready at command features. This over dependence on this source and pressurising demand from the other sectors of the economy leads to over exploitation and unsustainable use of this resource. In such a, scenario the water markets have emerged as an economic instrument to ensure the allocative and technical efficiency in water use and sustain this resource base for inter and intergenerational equity. As water demand increases, the dependence on groundwater increases, this leads to the formation of groundwater markets. Buying and selling of groundwater is common in

arid and semi-arid parts of the world. Informal water markets are reported in many countries like India Pakistan, China and Nepal. In India the water market span over 15 per cent of the total irrigated area (Mukherji, 2008) and it is expanding due to water scarcity and rising irrigation costs. About 55 per cent of farmers are involved in water markets in India (Molle *et al.,* 2003).

With this background, the present study is attempted to study the probable impact that water market creates on the cost and use efficiency of groundwater in two different groundwater scarcity regimes. The objectives of the study are: analysing the existing water market conditions, analysing the irrigation cost differences and its resultant impact on net income, comparing the water use efficiency visa-vis water market participation status and suggesting suitable recommendations to improve the efficiency of water markets and water use efficiency for future operations.

## Materials and Methods

### Study Area

The study was conducted in Annagramam and Cuddalore blocks of Cuddalore district in TamilNadu which represents two different groundwater scarcity regimes viz., semi critical and over exploited status. This region is situated in the tail end of cauvery delta region and characterized by an average annual rainfall of 1315.8 mm. The purposive selection was made for the reason that the number of tubewells and area irrigated under the groundwater were the highest in this district in Tamilnadu.

### Sampling Design

In terms of groundwater extraction Annagramam block falls under semi-critical (70-90 per cent of draft) category and Cuddalore falls under over – exploited (more than 100 per cent draft) category as per the stage of groundwater development status. A sample size of 200 groundwater-dependent farmers were equally allocated between the two selected blocks as 100 each. In each block two villages wherein agricultural activities where hectic were purposively selected and the sample size of 100 was distributed as probability proportion to number of tubewells. The sample was later post stratified as: self-users , water sellers and water buyers for all further analysis.

### Data Analysis

Simple percentage analyses were done to understand the existing groundwater market condition and making comparison on irrigation cost of different water market participating stakeholders. Cost A, Cost B and Cost C concepts were used for working out the cost of cultivation and irrigation cost share of major principal crops so as to make comparison between the water market participating and non- participating farms of the study area.

Cost $A_1$- All actual expenses in cash and kind incurred in crop production by the farmers
Cost $A_2$- Cost $A_1$ + rent paid for leased in land.
Cost B 1- Cost $A_1$ + Interest on value of owned capital assets
Cost B2 - B1+ Rental value of owned land (net of land revenue) and rent paid for leased in land
Cost C 1- Cost B1 + imputed value of family labour
Cost C2 - B2+ Imputed value of family labour
Cost C3 - Includes managerial cost (C2+ 10 per cent of Cost C2)

### Water Use Efficiency

It was found that among the sample farmers, some farmers are participating in water markets i.e. involvedinbuying and selling of water. Some farmers sell surplus quantity of water to their neighbours and some farmers did not participate in water markets even though they have surplus quantity of water.Buyersalso differed in their quality, quantity and timing of water purchased. The difference among various group of farmers in how much quantity of water is effectively utilized for crop production and the influence of other inputs in production are related using the Cobb-Douglas production function. The following model of Cobb-Douglas production function was fitted by incorporating the variables relevant at field level so asto examine the resource productivity of water.

$$Y = aX_1^{b1}X_2^{b2}X_3^{b3}X_4^{b4}X_5^{b5}\mu_i$$

Where,

Y = output per acre (in Rs),
$X_1$ = seed cost per acre (in Rs),
$X_2$ = labour cost per acre (in Rs),
$X_3$ = fertilizer cost per acre (in Rs),
$X_4$ = cost of per irrigations (in Rs),
$X_5$ = cost of plant protection (in Rs).
$\mu_i$ = error term and

$b_1$, b2, b3, b4, b5 = parameters to be estimated.

## Results and Discussion

### Existing water market conditions of the sample farms

Table 1 shows the tube well operational details of the sample farms such as depth of operation, horsepower distribution, operational size of holding etc. It is observed that inAnnagramam and Cuddalore block the average depth of tube well operation was found to be higher among the water sellers group (230 and 350 feet) compared to self users group (229 and 348 feet). Between the blocks the tube well depth was higher in Cuddalore block in both self user (348 feet) and seller group (350 feet).

The distribution of depth of operation showed that the proportion of farmers operating in higher depth (200-250 feet) was found to be greater in self user category which accounted for 66 percent of the total size of sample in Annagramam block. But in Cuddalore block the percentage of farmers operating in higher depth (>450 feet) was noticed higher in sellers category. The horsepower distribution of motors varied in accordance with the depth of operation. The farmers operating with higher HP power motors *viz.*, 20 and 25 HP motors put together was found to be more in water seller group (53 and 75 per cent) compared to self-user group (20 and 10 per cent)in these two blocks.

The operational size category was found in line with the depth and HP. The average operational farm size in each category of marginal, small, medium farmer and overall size of holding was higher in water selling group in Annagramam block, where as in Cuddalore block no much difference was observed between the self user and seller groups in their average farm size. In case of buyers, most of the farmers belonged to marginal and small farmers category and in sellers category, most of the farmers were falling in large farm size category.

### Cost of Irrigation

It was found that the investment rate was higher for water sellers compared to self-users. However between self-user and water seller the difference ininvestment was more in Cuddalore block (15237.93) compared to Annagramam block (13947.81).

The annual cost of tube well irrigation is presented in the Table 2. The annual cost (apportioned fixed cost was the major component and variable cost was negligible due to free electricity) and apportioned fixed cost were higher for cuddalore block compared to Annagramam block. This was due to the difference in investment on tube wells, which was attributed to higher depth and HP's. However the repair and maintenance cost was higher in Annagramam block. Between the two groups the annual cost was naturally higher for water sellers compared to self-users in both the blocks.

**Table 1.** Tubewell Operational Details of the Sample Farms in the Selected Blocks

| S. No. | Particulars | Cuddalore (OE) | | | | Annagramam (SC) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Self user | Buyer | Seller | Total | Self user | Buyer | Seller | Total |
| 1 | Average depth in feet | 348.60 | | 350.35 | 348.50 | 229.69 | - | 230.80 | 230.24 |
| | 150-200 ft | 25(65.78) | - | 1(3.12) | 26(37.14) | 10(33.33) | - | 1(3.03) | 11(17.46) |
| | 200-250 ft | 9(23.68) | - | 11(34.37) | 20(28.57) | 20(66.66) | - | 17(51.51) | 37(58.73) |
| | >250 ft | 4(10.52) | - | 20(62.5) | 24(34.28) | - | - | 15(45.45) | 15(23.80) |
| | Total | 38(100) | - | 32(100) | 70(100) | 30(100) | - | 33(100) | 63(100) |
| 2 | Horse power | | | | | | | | |
| | 5 and 7.5 hp | 8(21.05) | - | - | 8(11.42) | 6(20) | - | | 6(9.52) |
| | 7.5 and 10 hp | 26(68.42) | - | 8(25) | 34(48.57) | 18(60) | - | 5(15.15) | 23(36.50) |
| | 15 and 20 hp | 4(10.52) | - | 24(75) | 28(40.00) | 6(20) | - | 28(84.89) | 34(53.96) |
| | Total | 38(100) | - | 32(100) | 70(100) | 30(100) | - | 33(100) | 63(100) |
| 3 | Operational area size in acres | | | | | | | | |
| | Marginal farmer< 2.5 ac | 16(42.10) | 17(56.66) | - | 33(33.00) | 3(10.00) | 30(81.08) | - | 33(33.00) |
| | Small farmer 2.5-5 ac | 8(21.05) | 13(43.33) | 2(6.25) | 23(23.00) | 19(63.33) | 7(18.91) | 12(36.36) | 38(38.00) |
| | Large farmer >5ac | 14(36.84) | - | 30(93.75) | 44(44.00) | 8(26.66) | - | 21(63.63) | 29(29.00) |
| | Average area | | | | | | | | |
| | Total | 38(100) | 30(100) | 32(100) | 100(100) | 30(100) | 37(100) | 33(100) | 100(100) |

In any economic operations, the variable cost will only reflect the operational efficiency. However, in this case,since electricity is provided on free of cost and unmetered its estimation and inclusion in the cost assessment has become an infesible task. Hence, comparing the water use efficiency of water market participating and non- participating farms in terms of irrigation cost with the non -inclusion of its variable cost is incomplete and will not reflect the real efficiency of the water market operations. With this handicap this study tries to capture the economic advantage of water market operations in the prevailing conditions by taking into account only the rectangular hyperbolic nature of the average fixed cost.

**Cost of Cultivation**

It was observed from the secondary data that banana and sugarcane were the predominant crops of Cuddalore and Annagramam blocks respectively

**Table 2.** Annual cost of Tube well Irrigation

| I S. No | Particulars | Fixed cost | | | |
|---|---|---|---|---|---|
| | | Cuddalore (OE) | | Annagramam (SC) | |
| | | Self user | Water seller | Self user | Water seller |
| | Total investment | 156323.60 (100.00) | 171561.53 (100.00) | 132059.60 (100.00) | 146007.41 (100.00) |
| A | Total depreciation on fixed capital @ 12.5per cent | 19540.45 | 21445.19 | 16507.45 | 18250.92 |
| B | Interest on fixed capital@ 7per cent | 10942.65 | 12009.30 | 9244.17 | 10220.51 |
| | Annual fixed cost(A+B) | 30483.10 | 33454.49 | 25751.62 | 28471.43 |
| II | Variable cost | | | | |
| C | Repair & Maintenance cost | 5984.37 | 6081.96 | 6982.35 | 7095.23 |
| D | Variable cost* | 0.00 | 0.00 | 0.00 | 0.00 |
| **E** | **Annual total cost (I+II)** | **36467.47** | **39536.45** | **32733.97** | **35566.66** |

**Table 3.** Cost of Cultivation of Banana in Cuddalore Block

| S. No. | Particulars | Category | | |
|---|---|---|---|---|
| | | Self-user | Sellers | Buyer |
| **I** | **Cost of Cultivation** | | | |
| 1. | Planting Material | 7578.94 | 7496.87 | 7470.00 |
| 2. | Human Labour | 14138.68 | 14342.81(27.62) | 14182.50(26.29) |
| 3. | Machine Labour | 8500.00(16.70) | 8420.00(16.22) | 8520.50(15.79) |
| 4. | Manures and fertilizers | 6273.68(12.32) | 6250.00(12.03) | 6206.66(11.50) |
| 5. | Irrigation** | 3120.00(6.13) | 3750.00(7.22) | 5670.00(10.51) |
| 6. | Plant Protection Chemicals and Growth Regulators | 869.21(1.70) | 885.31(1.70) | 903.70(1.67) |
| 7. | Land Revenue | 700(1.37) | 700(1.34) | 700(1.29) |
| 8. | Interest on Working Capital | 2763.58(5.43) | 2740.14(5.27) | 2763.83(5.12) |
| 9. | Cost A1 | 43944.09(86.34) | 44585.13(85.88) | 46417.19(86.04) |
| 10. | Interest on Fixed Capital | 1925.34(3.53) | 1875.00 (3.56) | 1490.75 (3.56) |
| 11. | Cost B1 | 45869.43 | 46460.13 | 47907.94 |
| 12. | Rental value of Own Land | 3900(7.66) | 4275.62(8.23) | 4152.24(7.64) |
| 13. | Cost B2 | 49769.43 | 50735.75 | 52060.18 |
| 14. | Imputed value of Family Labour | 1250(2.45) | 1200(2.31) | 1450(2.68) |
| 15. | Cost C1 | 47119.43 | 47660.13 | 49357.94 |
| 16. | Imputed value of Family Labour | 1250(2.45) | 1200(2.31) | 1450(2.68) |
| 17. | Cost C2 | 51019.43 | 51935.75 | 53510.18 |
| 18. | Cost C3 | 56121.37 | 57129.32 | 58861.19 |
| **II** | **Income** | | | |
| A | Income from crops | 74912.68 | 75029.79 | 73095.30 |
| B | Income from water selling | - | 3700 | - |
| 19. | Total Income(A+B) | 74912.68 | 78729.79 | 73095.30 |
| 20. | Net income | 18791.31 | 21600.47 | 14234.11 |

which had a share of 20 and 27 percentage of the gross area cultivated. Water rent in the study area are charged on hourly basis irrespective of the crop and type of irrigation.

It could be observed from the cost of cultivation of banana in table 3 that the human labour accounted for a major share among all other input components followed by machine labour and cost of planting material for all the three groups. The total cost of cultivation was the highest in buyers followed by seller and self-user group. The irrigation cost was found to be higher for buyers because of the purchase of water for irrigation. The sellers group get revenue from selling of groundwater for irrigation purpose to the small and marginal farmer's category. Thus the seller's category got benefitted by water market participation.

It could be observed from the cost of cultivation table 4 of sugarcane in that the machine labour cost accounted for a major share among all other inputs components followed by human labours cost and then cost of manure and fertilizers for all the three groups. The total cost of cultivation was higher for buyers followed by self-users and seller group. The irrigation cost was the highest for buyer group as they purchase water for irrigation. The sellers category got extra revenue from selling of groundwater and it appreciably reduced the seller's cost burden in groundwater extraction. The seller's category got more cost benefit by water market participation.

Between the two blocks the irrigation cost share was higher for banana compared to sugarcane. The income rceived by the water sellers from groundwater tradind was higher in Cuddalore block (over exploited) compared to Annagrammam block (semi critical)

**Water Use Efficiency**

Cobb- Douglas form of production function was fitted to compare the water use efficiency between the water market participating and non-participating farms. Seed cost, fertilizer cost, irrigation cost,

**Table 4.** Cost of Cultivation of Sugarcane in Annagramam Block

| S. No. | Particulars | Sugarcane | | |
|---|---|---|---|---|
| | | Self-user | Seller | Buyer |
| 1. | Planting Material (Setts) | 10500.00(16.63) | 10287.80(16.63) | 10500.00(16.14) |
| 2. | Human Labour | 11000.00(17.42) | 11830.00(19.12) | 11200.00(17.22) |
| 3. | Machine Labour | 16000.00(25.35) | 15500.00(25.06) | 16000.00(24.60) |
| 4. | Manures and Fertilizers | 10994.50(17.42) | 8757.73(14.15) | 9482.57(14.58) |
| 5. | Irrigation | 2750.00(4.35) | 3000.00(4.85) | 5400.00(8.30) |
| 6. | Plant Protection Chemicals and Growth Regulators | 1074.67(1.70) | 1063.93(1.72) | 1062.16(1.63) |
| 7. | Land Revenue | 500(0.79) | 500(0.80) | 500(0.76) |
| 8. | Interest on Working Capital | 3592.34(5.69) | 3425.76(5.53) | 3300.13(5.07) |
| 9. | Cost A1 | 56411.51(89.38) | 54365.22(87.89) | 57444.86(88.32) |
| 10. | Interest on Fixed Capital | 3000(3.16) | 2750(4.04) | 2000(3.93) |
| 11. | Cost B1 | 59411.51 | 57115.22 | 59444.86 |
| 12. | Rental value of Own Land | 3200(5.07) | 3565(5.76) | 3460(5.32) |
| 13. | Cost B2 | 62611.51 | 60680.22 | 62904.86 |
| 14. | Imputed value of Family Labour | 1500.00(2.37) | 1420.00(2.29) | 1570.00(2.41) |
| 15. | Cost C1 | 60911.51 (100.00) | 58535.22 (100.00) | 61014.86 (100.00) |
| 16. | Imputed value of Family Labour | 1500.00(2.37) | 1420.00(2.29) | 1570.00(2.41) |
| 17. | Cost C2 | 64111.51 | 62100.22 | 64474.86 |
| 18. | Cost C3 | 70522.66 | 68310.24 | 70922.34 |
| II | Income | | | |
| A | Gross income | 104014.60 | 107625.00 | 104046.90 |
| B | Income from water selling | - | 4500 | - |
| 19. | Total income (A+B) | 104014.60 | 112125.00 | 104046.90 |
| 20. | Net income | 33491.94 | 43814.78 | 33124.56 |

Note: Irrigation cost was apportioned from the annual cost of tubewell irrigation derived from tubewell investment and for the buyers it was the water market price charged on per hour basis.

**Table 7.** Water Use Efficiency of Banana in Water Market Participating and Non -Participating Farms ofCuddalore Block (OE)

| S. No. | Particulars | Self user | | | Seller | | | Buyer | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Co-efficient | P Value | Mean | Co-efficient | P Value | Mean | Co-efficient | P value |
| 1 | Sucker cost | 7578.94 | 0.6158 | 0.14* | 7486.66 | -0.3667 | 0.001*** | 7003.12 | 0.7996 | 0.13 |
| 2 | Fertilizer cost | 6273.68 | 0.6603 | 0.11* | 6233.33 | 0.3645 | 0.001*** | 5818.75 | 0.7013 | 0.19 |
| 3 | Cost/Irrigation | 863.00 | 0.0086 | 0.78 | 619 | -0.01211 | 0.67 | 330.31 | 0.3334 | 0.05** |
| 4 | Labour cost | 6138.68 | 0.0920 | 0.79 | 6145.66 | 0.31199 | 0.67 | 5702.34 | -0.3673 | 0.04** |
| 5 | Plant protection | 869.21 | -0.1379 | 0.45 | 882.66 | -0.32764 | 0.20 | 851.25 | -0.0675 | 0.72 |
| 6 | $R^2$ | 0.61 | 0.75 | 0.67 | | | | | | |

*** = 1% level of significance, ** = 5% level of significance, * = 10% level of significance

**Table 8.** Water Use Efficiency of Sugarcane in Water Market Participating and Non-Participating Farms of Annagramam block (SC)

| S. No. | Particulars | Self user | | | Seller | | | Buyer | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Co-efficient | P Value | Mean | Co-efficient | P Value | Mean | Co-efficient | P Value |
| 1 | Sett cost | 8996.66 | 1.3368 | 0.001*** | 10287.8 | 1.4373 | 0.004** | 7983.68 | 0.4042 | 0.611 |
| 2 | Fertilizer cost | 10994.5 | 0.9388 | 0.005** | 8757.73 | -0.5577 | 0.100* | 6482.57 | 1.0903 | 0.10* |
| 3 | Cost/ Irrigation | 710.33 | 0.0341 | 0.253 | 672.72 | -0.0142 | 0.487 | 256.48 | 0.1246 | 0.004** |
| 4 | Labour cost | 8431.17 | -1.0382 | 0.003** | 8830.91 | 0.3176 | 0.367 | 6613.78 | -0.1807 | 0.443 |
| 5 | Plant protection | 1074.67 | -0.0110 | 0.931 | 1063.93 | 0.0838 | 0.518 | 1062.16 | 0.0218 | 0.977 |
| 7 | $R^2$ | 0.57 | 0.71 | 0.73 | | | | | | |

*** = 1% level of significance, ** = 5% level of significance, * = 10% level of significance

labour cost and cost of plant protection chemicals were the variables used to find the water use efficiency.

In Cuddalore block, sucker cost and fertilizer costs were found to be the significant factors in self-users and sellers category. In the case of buyers, labour cost and irrigation cost were found to be significant factors.

In Annagramam block, sett cost and fertilizer cost were found to be the significant factors in self-users and sellers category. In case of buyers fertilizer and irrigation cost were found to be significant factors.

The cost per irrigation was found to be positively significant in buyer category of both the blocks which indicated that an increase in per irrigation cost due to increase in the quality of irrigation (increased hours or higher water output rate) increased the gross income per hectare because of improvement in water productivity effect. The underlining reason for this phenomena was the explicit nature of the irrigation cost borne by this buyer category farmers, which had a similar type of influence as that of the variable cost in the water buyer farmers decision on water use. In the case of self-user and seller categories the per irrigation cost did not exert any influence on gross income due to its implicit nature (apportioned to fixed cost) and the farmers decision on water use did not depend on this cost factor.

## Conclusion

Groundwater is the predominant source of irrigation in the study area. Since, agriculture heavily dependent on groundwater, water market plays a crucial role in sustaining the groundwater use. Groundwater market gave an opportunity for small and marginal farmers (Most them belonged to buyer's category) to irrigate their own piece of land by participating in the water market transactions which increased their production and helped to sustain their income. Water buyers followed frugal and efficient utilisation of groundwater as compared to self-users and water sellers as they paid for water from their pockets. The water seller group of farmers benefitted much through water sharing even after meeting their own irrigation requirements.

Unlike surface water, groundwater is expensive and relatively scarce in recent years. But its stabilisation function in assuring the production, productivity and thereby farmer's income is immense. Hence to ensure equity by cutting across the farmer's size categories, enabling their physical and economic access to this precious groundwater is essential and which may be possible through strengthening and streamlining the informal groundwater markets. To promote it as a policy option the lacunae in the key areas of water economics such as water pricing,joint ownership, collective farming etc., may be alleiviated so as to improve the water use efficiency among the farming community.

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