ANALYSIS OF IRRIGATION EFFICIENCY AND PRICING OF GROUNDWATER IN THE EAST COAST OF SOUTHERN INDIA

ANANDAN POUCHEPPARADJOU

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE
&
RESEARCH INSTITUTE, KARAIKAL, INDIA ,
E-mail:pouchepparadjou@gmail.com

INTRODUCTION

- The steep increase in the ownership of private WEMs over years has led to continuous decline in water table, which has in turn led to the drying up of tube wells and increasing well failures causing higher costs of installing new tube wells, deepening of existing tube wells, and pumping and other maintenance activities (Moench, 1992; Shah, 1985).

- Competitive deepening of wells or installing deep tube wells makes the distribution of access to groundwater increasingly skewed in favor of large and resource rich farmers leaving the marginal and resource poor farmers out of race (Bhatia, 1992; Janakarajan, 1993; Shah, 1993 and Saleth, 1996).

- It is in this scenario that groundwater markets have emerged as an alternative water management strategy for equitable and efficient use of scarce resource.

- Although buying and selling of water are nothing new in India, the recent water markets are significant in that they occur in an entirely different economic, institutional and technological environment.

- The evidences suggest that water markets have developed on a very large scale in the recent years in South Asia specially in India though in a localized manner .

- Water markets benefit both buyers and sellers in one way or the other and they have created certain efficiency, equity and sustainability implications in the utilization of this resource.

- The present study conducted in Puducherry region located in the east coast of southern India.

- The study has examined the structure, determinants, Pricing and efficiency of groundwater markets .

- The irrigated area in Puducherry region constitutes about 88.86 percent of the total cropped area..

METHODOLOGY

- A two stage random sampling procedure was followed to select four villages from the list of villages of the selected commune in the first stage, followed by selection of 30 farmers from each village totally to a sample of 120 farmers.
- The selected farmers were classified as buyers, self-users+buyers, self-users+buyers+sellers, selfusers+ sellers and self-users, based on their accessibility to different forms of groundwater markets.

- Further, the selected farmers were classified into three farm-size groups, viz., marginal (up to 1 hectare), small (1-2 hectares) and large (greater than 2 hectares) in order to capture the variations among the groups.

TOOLS OF ANALYSIS

- **Logit Model of Groundwater Buying and Selling Decision**

Z_i = Intercept + β1 (AREA OWN) + β2 (FRAGMENT) + β3 (PGCASC) + β4 (EDUCATION) + β5 (PFWORK) +β6 (ARAIN) + β7 (QFERT) + β8 (PJOINTWL) +β9 (HPPERWL) + U_i

(a) Production function Analysis:

The Cobb-Douglas

$$Y = a\,X_1^{b_1}\,X_2^{b_2}\,X_3^{b_3}\,\mu_i$$

Y	= Output per acre of crop in kilograms,
X1	= Human labour used per acre in mandays,
X2	= Number of irrigations per acre,
X3	= Fertilizer used per acre in kilograms.
b1, b2, b3	= Coefficients of respective variables.
μi	= Error term.

(b) Decomposition of Productivity

Self-users

$$\ln Y1 = \ln A1 + a1 \ln L1 + b1 \ln F1 + c1 \ln I1 + u1$$

Buyers

$$\ln Y2 = \ln A2 + a2 \ln L2 + b2 \ln F2 + c2 \ln I2 + u2$$

where,

Y = yield (Rs/ha).

L = labour (Rs/ha).

F = fertilizer (Rs/ha).

I = Irrigations (Rs/ha)

A = scale parameter.

a, b & c = regression parameters (factor elasticities)

u = random disturbance term.

Decompose the total change in crop output:

$\ln Y_2 - \ln Y_1 = (\ln A_2 - \ln A_1) + (a_2 \ln L_2 - a_1 \ln L_1 + a_2 \ln L_1 -$

$a_2 \ln L_1) + (b_2 \ln F_2 - b_1 \ln F_1 + b_2 \ln F_1 - b_2 \ln F_1) + (4)$

$(c_2 \ln I_2 - c_1 \ln I_1 + c_2 \ln I_1 - c_2 \ln I_1) + (u_2 - u_1)$

Further rearrangement yields

$$\ln (Y2/Y1) = \ln (A2 / A1) + [\ (a2 - a1) \ln L1 + (b2 - b1) \ln F1 + (c2 - c1\ ) \ln I1\ )] + [\ (\ a2 \ln (L2/L1) + b2 \ln (F2/\ F1) + c2 \ln (I2/\ I1)] + (\ u2 - u1)$$

Nash Equilibrium Model of Groundwater Pricing

$$Y = f(X1, X2, X3)$$

where,

Y= Water price per acre-inch

X1 = Gross irrigated area of seller.

X2 = Total water extracted by seller.

X3 = Gross irrigated area of buyer.

$$Y = a + b1X1 + b2X2 + b3X3 + c1X1^2 + c2X2^2 + c3X3^2 \;..$$

RESULTS AND DISCUSSION

- The analysis of structure of groundwater market revealed that a large proportion (82 percent) of the farm holdings enter into one or the other form of water market activities.

- The magnitude of groundwater market clearly indicates that 23 per cent of the total area in the study villages benefited through groundwater markets by buying irrigation water.

- The absence of groundwater markets about one-fifth of the total land in the study area would have remain unirrigated. The analysis of conduct of groundwater markets revealed that the seller- buyer concentration ratio was 1:2.39 in the selected sample.
- Rice, a high water intensive crop, dominates the cropping pattern in all forms of water market followed by sugarcane and groundnut.

- **The share of sugarcane in cropping pattern was marginally less on purely buyers farm. The cropping intensity was found to be highest (154 percent) for buyers and irrigation intensity was found to be highest(150 per cent) for self-users category as expected.**

- **Cash-based hourly terms of contract (Rs. 25 per hour) and crop output sharing contract (33 per cent of crops produce for rice and 25 per cent of crops produce for other crops) were prevailing in the study commune for groundwater trade.**

Table 1 Coefficients of Logistic regression for factors influencing groundwater selling

Variable	Coefficient	Exp(b)	Standard error	Level of significance
AREA OWN	0.826	2.284164	0.501	0.009
FRAGMENT	-1.624	0.197109	0.619	0.009
PGCASC	-0.075	0.927743	0.055	0.171
EDUCATION	-0.757	0.469072	0.356	0.633
PFWORK	0.023	1.023267	0.026	0.364
ARAIN	0.434	1.543467	0.681	0.524
QFERT	0.015	1.015113	0.009	0.125
PJOINTWL	11.597	108771	3.343	0.001
HPPERWL	0.565	1.759448	0.148	0.000
Intercept	-1.458	0.232701		

Value of Chi-square (Significant at 1 percent)= 97.21

Value of -2 log likelihood (Significant at 1 percent) =65.79, Nagelkerke R square =0.75

Prediction of success = 86.70 Number of observations=120

Table 2 Coefficients of Logistic regression for factors influencing groundwater Buying

Variable	Coefficient	Exp(b)	Standard error	Level of significance
AREA OWN	-1.123	0.325302	0.404	0.005
FRAGMENT	0.225	1.252323	0.301	0.046
PGCASC	0.212	1.236148	0.062	0.061
EDUCATION	0.029	1.029425	0.257	0.911
PFWORK	0.031	1.031486	0.020	0.134
ARAIN	-0.853	0.426135	0.538	0.113
QFERT	0.022	1.022244	0.008	0.086
PJOINTWL	-1.815	0.162838	0.976	0.063
HPPERWL	-0.187	0.829444	0.104	0.041
Intercept	-3.508	0.029957		

Value of Chi-square (Significant at 1 percent)= 64.52

Value of -2 log likelihood (Significant at 1 percent) =94.26

Nagelkerke R square =0.57 Prediction of success = 85.80 Number of observations=120

Table 3. Production elasticity of factors influencing Rice productivity

Variables	B	SU +B	SU+B+S	SU+S	SU
Intercept	2.643	2.133	2.373	1.448	3.747
Human labour	0.111 (0.088)	0.104 (1.802)	0.050 (1.262)	0.368 (0.232)	0.041 (0.060)
Irrigation	0.636*** (0.129)	0.023 (0.079)	0.039 (0.081)	0.014 (0.079)	-0.079** (0.032)
Fertilizers	0.087*** (0.026)	-0.064*** (0.021)	0.557*** (0.086)	-0.113*** (0.033)	0.082** (0.034)
R^2	0.70	0.54	0.58	0.52	0.73
Returns to scale	0.834	0.063	0.646	0.269	0.044
Number of observations	29	17	28	24	21

Table 4 Production elasticity of factors influencing sugarcane productivity

Variables	B	SU +B	SU+B+S	SU+S	SU
Intercept	2.493	3.020	1.086	2.164	2.144
Human labour	0.769*** (0.169)	0.596** (0.240)	0.299** (0.139)	0.592*** (0.198)	0.821*** (0.203)
Irrigation	0.596** (0.240)	0.031 (0.142)	0.097 (0.137)	-0.077 (0.115)	-0.141** (0.055)
Fertilizers	-0.360 (0.185)	-0.080 (0.128)	-0.360 (0.185)	0.417 (0.173)	0.067 (0.301)
R^2	0.79	0.55	0.58	0.63	0.85
Returns to scale	1.005	0.547	0.036	0.932	0.747
Number of observations	20	15	28	24	21

Table 5. Production functions of self-users and buyers form of water market

Variables	Rice			
	Self-users		Buyers	
	Coefficients	Geo-mean	Coefficients	Geo-mean
Intercept	3.0745	82500	3.7828	35000
Labour(Rs/ha)	0.1531*** (0.0507)	6125	0.3425*** (0.0824)	2750
Fertilizers(Rs/ha)	0.2431** (0.1152)	4625	0.1020 (0.1442)	2975
Irrigation (Rs/ha)	-0.0113*** (0.0040)	5550	0.0224*** (0.0050)	3603
Dummy variable	-		-	
R^2	0.63		0.54	
Number of observations	20		20	

Table 6 Estimates of decomposition of output difference between Self users and buyers of water

S.No	Particulars	Percentage
1	Total observed change in productivity	21.65
2	Total estimated difference in productivity	18.13
3	Changes due to irrigation management	17.89
4	Total change due to all inputs	0.12
a)	Labour	0.97
b)	Fertilizer	0.77
c)	Irrigation	-1.62

Table 7. Nash bargaining model of groundwater niche market

Explanatory variables	Coefficients	t-value
Intercept	-1.726	
X_1	2.005** (0.912)	2.198
X_2	0.139*** (0.014)	9.929
X_3	3.786** (1.533)	2.469
X_1^2	-0.210** (0.082)	2.561
X_2^2	-0.077 (0.115)	0.669
X_3^2	-0.264 (0.210)	1.257
R^2	0.77	
Number of observations	29	

- The elasticity of price of ground water with respect to each explanatory variable was calculated and
- it was found that for one percent increase in gross irrigated area of the seller the price of groundwater per acre inch increased by 0.063 per cent.
- For one per cent increase in gross irrigated area of buyer the price increased by 0.130 percent.
- Gross irrigated area of buyer and seller were the key explanatory variables in price determination

Table 8 Cost of irrigation water on different categories of farm sizes

Categories of farm size	Average number of working hours in one year	Average fixed expences in one year (Rs)	Cost of irrigation water per hour in terms of fixed expences (Rs/hr)	Average variable expences in one year (Rs)	Cost of irrigation water per hour in terms of variable expences (Rs/hr)	Cost of irrigation water per hour (Rs/hr)
Marginal (< 1 ha)	354	2500	7.06	5500	15.54	22.60
Small (1-2 ha)	666	5000	7.50	10000	15.01	22.51
Large (>2 ha)	950	7500	7.89	14750	15.53	23.42
Average	657	5000	7.48	10083	15.36	22.84

Table 9 Cost of water extraction and selling price

S.No	Particulars	Electric operated modern WEM
1	Cost of water extraction	
a)	Fixed cost[a]	7.48(32.75)
b)	Operating cost[b]	15.36(67.25)
c)	Total cost	22.84(100)
2	Selling price	25.00
3	Net income	
a)	Over fixed cost	17.52
b)	Over operating cost	9.64
c)	Over total cost	2.16

POLICY IMPLICATIONS

- The present policy framework related to groundwater market in Puducherry is inadequate and unsustainable.

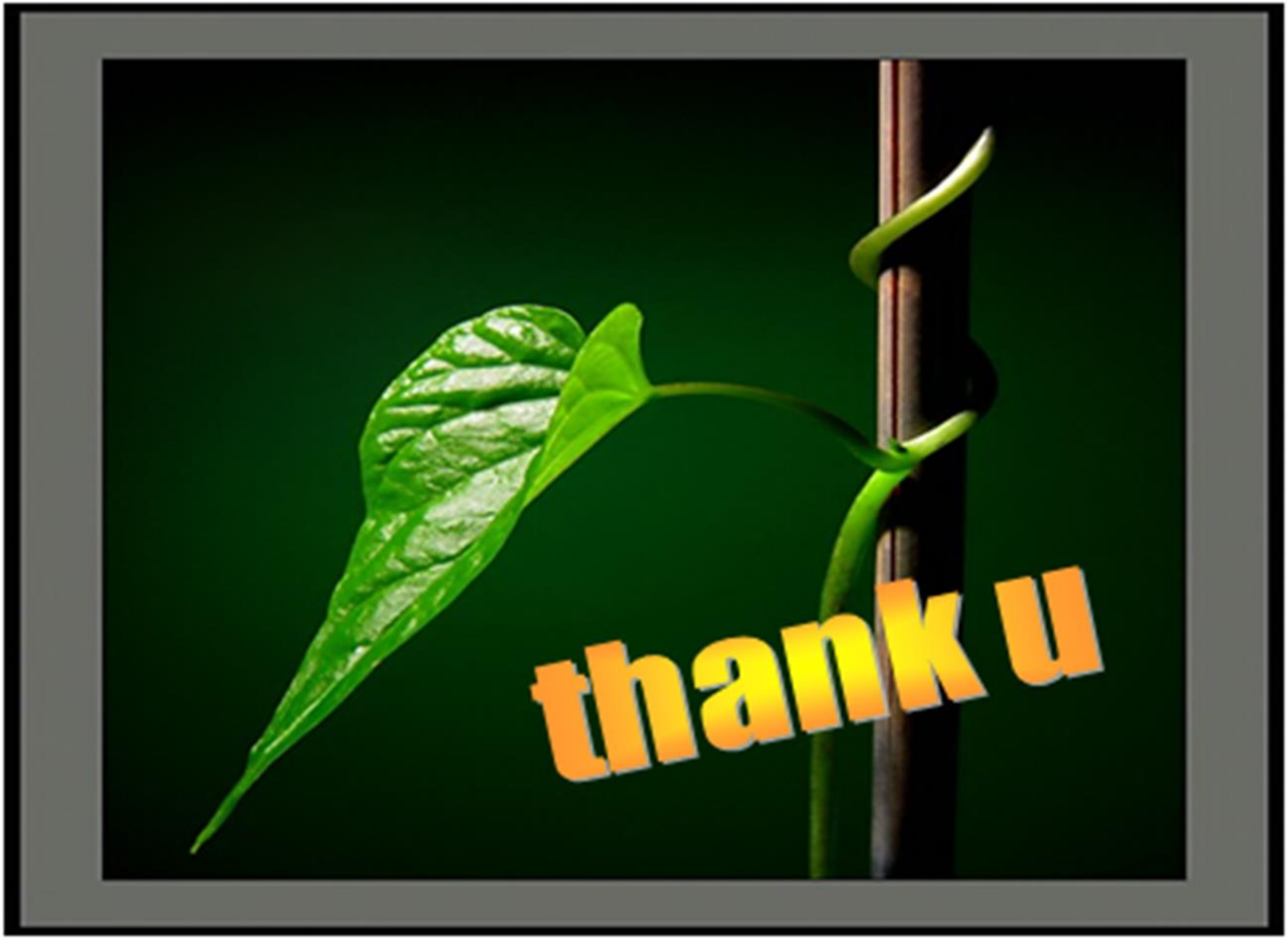
- The logit of regression has suggested that the farmers having lower farm-size holdings with higher fragmented land have higher probability of buying groundwater. The consolidation of holdings may economize the irrigation investment and lead to efficient management of resources of the farmers.

- Also the logit regression showed that the increase in capacity of water lifting devise increases the chances of selling groundwater.
- As electricity is used for pumping groundwater from aquifers and the linkage between groundwater and electricity is rather straight forward.
- Hence, the regulation of the electricity supply and changes in electricity pricing and subsidies can provide an effective tool for governing groundwater use.

- The Nash equilibrium model revealed that the gross irrigated area of the buyer and seller were important one in price determination giving a policy clue to reduce the undesirable extraction of groundwater, efforts to change the cropping pattern from water intensive crops. Water users may be restricted to grow water intensive crops accordingly.

❖The study also revealed that the excessive irrigation resulted in declining productivity of both Rice and Sugarcane . This has a policy implication that measures which promote efficient irrigation technologies are feasible avenue for reducing the demand for groundwater and electricity.

❖Uniform policy isolation may be evolved, regarding groundwater exploitation So as to prevent indiscriminate and differential use of groundwater and to prevent ingress of saline water into groundwater aquifer in a ecologically fragile region like East coast of Southern India.


thank u