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The Economic and Environmental Impact of Shrimp Farming in Nagapattinam District, Tamilnadu

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Introduction

The trade policies of tariff reduction and export promotion coupled with the surging global demand and rising unit values of marine products boosted marine product trade particularly shrimp exports from India since the initiation of economic reforms in 1991. The frozen shrimps alone account for 42 percent of marine product exports by value, and in 2009-10 the sector earned foreign exchange of Rs 4,182 crore (US $ 0.88 billion). Shrimp is cultivated in an area of 200,000 hectares largely in the states of Andhra Pradesh, West Bengal, Kerala, Orissa, Maharashtra and Tamil Nadu and exported in diversified forms to Japan, USA, Europe and elsewhere. Shrimp production grew steadily during the period 2000-2001 to 2008-2010 with scientifically managed shrimp farming expanding in acreage by 8.7 percent per year and in production by 8.4 percent per year (Kumar et al, 2011).

The short-term financial returns from shrimp farming are high but intensive method of shrimp farming has an environmental impact that extends beyond the immediate farming zone. The use of sea water along with fresh water for shrimp culture can cause salinisation of land and groundwater and affect the productivity of agricultural crops and quality of groundwater. Legislations to reduce the adverse impact of shrimp farming exist in India but only rarely has it been enforced. Of current concern to many environmentalists is the Aquaculture Authority Bill which is designed to regulate coastal aquaculture activities. If approved, the bill will give legal status to the industry and promote large-scale growth of shrimp farming in India.

The environmental externalities of shrimp farming on rice growing lands have been reported in India (Primavera, 1997), Thailand (Flaherty et al., 1999), Vietnam (Thanh et al., 1999) and Bangladesh (Bhattacharya et al., 1999). But estimates of shrimp salinity that integrate economic and soil aspects are not available for India. The study estimates the external cost of shrimp farm-induced salinisation of land on paddy productivity by comparing paddy yields in two similar villages in southern India, one affected by shrimp farms and the other located further away from the shrimp farms.

Study Area

Shrimp is a major enterprise in the coastal tracts of Nagapattinam in Tamilnadu. Paddy is the major crop grown during samba season (October-February). Shrimp is cultivated in summer (February-June) and during monsoon (October-January). Currently, modified extensive and semi-intensive methods of shrimp farming are practiced in this area. Chandrapadi in Nagapattinam district was the study village. There are 14 shrimp farms in the in this village along the Nandalaru tertiary and have a combined pond area of 65 ha. The shrimp farms in Chandrapadi are located on the Tamilnadu-Puducherry boundary. The adjacent paddy village is Poovam and next is Thiruvettakudy. These two villages were chosen as the treatment and control villages for the study. These are homogenous villages with an average annual rainfall of 1350 mm, 70 percent of which is received during north-east monsoon which coincides with the second season. Paddy is the major crop cultivated during samba and rotated with gingelly or black gram. Canal water is the major source of irrigation, although supply from the canal is very erratic as both the villages are located at the tail end of the deltaic zone. Soil texture varies from sandy to sandy clay and sub-surface texture is sandy throughout.

All farm households that had cultivated paddy during 2011 rabi were surveyed. In Poovam, paddy was cultivated in 49.36 ha. The land holding per household is 1.27 ha and fallow land area accounts for 29 percent of the total land area of 70 ha. The survey of 110 farm households in Thiruvettakudy revealed that land holding per household is 2.08 ha and the total land area is 228.84 ha. Paddy accounts for 88 percent of gross cropped area, which is 218 ha. Farmers of this village are all members of Farmer's Irrigation Society (FIS) which maintains canals and temple ponds operate sluice gates to regulate canal water supply and settle disputes between farmers. In 2009-2010 about 88 ha of land was bought by a private firm to set up shrimp farms. But as FIS opposed, shrimp farming could not proceed and this parcel of land has since remained fallow.

Data

Secondary data on agro-climatic features, land use and cropping details for the study villages during 2000-2001 to 2010-2011 were collected from Directorate of Economics and Statistics at Karaikal to confirm the homogeneity of paddy villages prior to the establishment of shrimp farms. Secondary data on soil salinity for the villages were collected from the Soil Testing Laboratory at Karaikal to record the salinity during pre-shrimp period (2004-2005) in the paddy villages. Primary data from paddy farmers was collected using interview schedule for 2010 rabi season for farm fragments. The final sample size includes 165 paddy households covering 257 fragments. Of the total sample, 55 farms and 48 fragments are from Poovam and 110 farms and 209 fragments are from Thiruvettakudy. In addition, surface soil samples upto 30 cm depth were taken from the villages during September and October 2011. A total of 314 and 577 soil samples were collected from Poovam and Thiruvettakudy respectively. The salinity indicator, electrical conductivity was measured after processing the soil samples.

Homogeneity of Paddy Villages

Poovam is adjacent to shrimp farms whereas Thiruvettakudy is physically separate from them. In the pre-shrimp period, Poovam had 48 percent of its GCA under paddy while it was 59 percent for Thiruvettakudy. Their cropping and irrigation intensity were similar and so was the ratio of net sown area to total land area. In the post-shrimp period, area under paddy as a percentage of GCA remained stagnant in Poovam, while it increased to 83 per cent in Thiruvettakudy as Poovam encountered greater levels of soil salinity due to shrimp farms. There was a decline in GCA in both the villages, mainly due to the problem of water scarcity.

Soil characteristics

An EC value less than 1 indicates that soils are highly suitable for cultivation, EC value of 1-3 is injurious to crop growth, EC values between 3 and 4 will definitely cause yield reduction and soils with EC value more than 4 are designated as saline soils and need reclamation to restore them for cultivation. In the pre-shrimp period (Table 1), salinity levels were below one in both the villages. Further, the point estimates of means are the same, which provides evidence that the selected paddy villages were similar with regard to soil salinity at this time. In Thiruvettakudy, EC values ranged from 0.01 to 0.96 (Table 3), implying normal soils. To know the current salinity level, soil samples were taken from cultivated lands and fallow lands in Poovam in 2011 and they showed EC values ranging from 0.02 to 6.60. In areas adjacent to shrimp farm, EC levels were very high ranging from 4.95-15.89. In the cultivated lands, the EC ranged from 0.02-2.13 (Table 2).

Graph-1: Externality Effect of Decline in Soil Quality

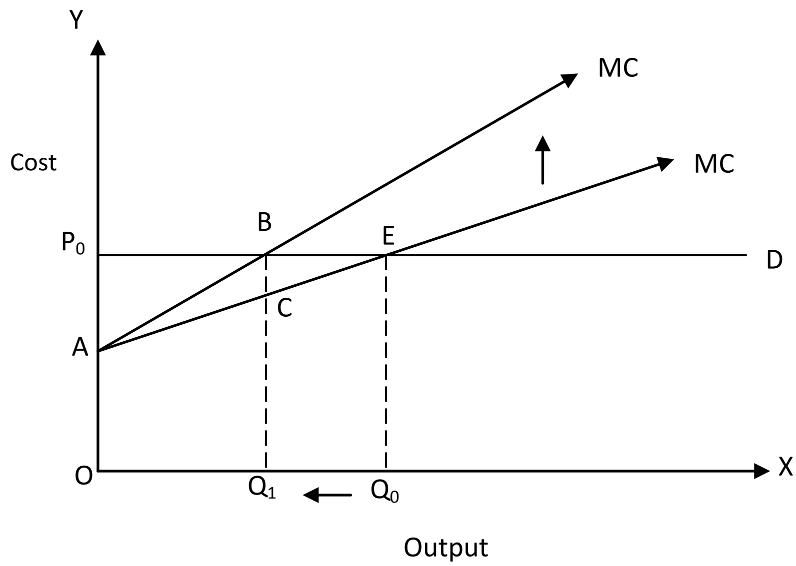

Table-1: Soil Salinity during Pre-shrimp Period (2009-2010)

Soil Status	Soil EC (dS m^{-1})			
	Min	**Max**	**SD**	**Means^{+}**
Poovam	0.1	0.4	0.125	0.23

Thiruvettakudy	0.1	0.7	0.136	0.23

Source: Soil Testing Laboratory, Karaikal. * t test: p value= 0.461.

Table-2: Range of EC Values for Poovam Soil Samples

S.No.	Category of Land	Soil Samples (no)	EC range (dSm^{-1})
1.	Cultivated lands	215	0.02-2.13
2.	Current fallows	36	0.20-3.90
3.	Permanent fallows	17	1.70-6.60
4.	Near shrimp farms	18	5.64-15.89
a)	Distance of 100 ft	28	4.95-11.09
b)	Distance of 200 ft	314	0.02-15.89

Table- 3: Range of EC values for Thiruvettakudy Soil Samples

Soil salinity indicator	Range
EC in $dS\ m^{-1}$	0.01-0.96
Total soil samples	577

Economics of Paddy Cultivation

The chief difference between the paddy economics of the two villages is seen in the net returns figures; per hectare net returns is Rs 5348 for Thiruvettakudy farmers versus a loss of Rs 5058 per ha for Poovam farmers. Although the variable cost per hectare is higher in Thiruvettakudy (Rs 16930 as against Rs 14796 in Poovam) it is the large gap in productivity between the two villages that makes the significant difference. In Thiruvettakudy the yield is 3519 kg ha-1, which is 86 % more than Poovam's 1888 kg ha-1 (Table 4).

Theoretical Framework for the Study

Shrimp farming in agricultural lands causes two kinds of externalities (i) An intra-generational externality borne by the current generation due to decline in crop yields caused by increasing salinization of land and water resources and the associated adverse socio-economic effects in the region. By adopting reclamation measures and better water management, salinity could be reversed or minimized; (ii) An inter-generational externality that will be borne by future generations because of environmental damage to land and groundwater resources. In this study, we value the intra-generational externality cost of salinization of land.

The externality effect of decline in soil quality is depicted in Graph 1.Given the market price P_0 and MC, the marginal cost of production (i.e. the supply curve), TR is the total revenue obtained from sale of the main produce of paddy. TVC is total variable cost, which includes costs of seeds, manures, fertilizers, plant protection chemicals, human labour and machinery. Output is Q_0. OP_0EQ_0 is TR; $OAEQ_0$ is TVC; AP_0E is producers' surplus, which equals the sum of fixed costs and profit. With externality, MC shifts to MC', output falls and Q_1BEQ_0 is the loss in TR; ABE is both loss in profit and loss in producer surplus, because fixed costs are fixed. The externality cost ABE caused by salinity is valued using change in productivity method by a comparison of salinity affected and unaffected paddy villages.

Estimation of Externality Cost

In order to assess the salinity externality on paddy yields, a production function was estimated with soil salinity as one of the independent variables affecting paddy cultivation.

*ueXXXXY*43214321ββββα= (1)

where,

Y = Paddy yield (kg ha-1)

X1 = Human labour cost (Rs ha-1)

X2 = Machinery cost (Rs ha-1)

X3 = Quantity of Urea + DAP (kg ha-1)

X4 = Mean EC (dS m-1)

D: Village dummy variable (1=affected village)

X5 = Quantity of Urea + DAP (kg ha-1) x Mean EC (dS m-1) eu = error term

β's are the regression coefficients of respective variables.

In order to estimate the production function, pooled regressions of paddy yield in both control and treatment villages on input variables were used. Yield is measured as kg of paddy per hectare. The model is a Cobb-Douglas production function and includes all the variable inputs identified in equation 1 in log form. Also included is a village dummy, and takes a value of 1 if the farm is a Poovam (shrimp-affected) farm and 0, if the farm is from the shrimp-unaffected village. The model showed that salinity had significant influence on paddy yield. The estimates from various specifications showed that there is non-linear relationship between salinity and land productivity explained by either logarithmic or exponential functions (Table 5).

Welfare Gains from salinity Reduction

The next step is to estimate welfare gains from decreases in salinity or equivalently the welfare losses accruing to villagers as a result of increased salinity using different methods of estimation (Table 6). Estimates of welfare gains are obtained by comparing predicted yields per hectare corresponding to the salinity levels of 1 and 3, given the sample mean values of all other variables in the production function. The productivity gain with the Cobb-Douglas specification of production function (method 1) is 172 kgs of paddy per hectare. With the production function considering the synergistic effects of fertilizers and salinity, the production gain falls to 141 kg per hectare. In the case of production function that considers the exponential relationship between paddy yield and salinity, a change in salinity from the maximum level of 3 to the safe level of 1 result in a gain of 836 kg per hectare. Method IV estimates the gains that would accrue if salinity decreases by comparing the productivity in the controlled farms with the salinity affected farms as is often done in the cost-benefit. The predicted per hectare yield of unaffected and affected farms are 3252 kg and 1606 kg respectively. These estimates are obtained by substituting mean values of input variables for unaffected and affected villages into the estimated Cobb-Douglas production function. Using this method, the average per hectare gain from reducing salinity is estimated to be 1647 kgs.

There are indeed welfare gains that range from Rs. 1000 to potentially Rs. 5000 per hectare depending on the specification of the production function. It should be noted that these are the maximum average gains that can be obtained from reducing salinity.

Interestingly, an examination of the controlled means in the affected and un-affected villages suggests that the losses could be as high as Rs 10,000 per hectare.

Conclusions

The study examines the externality effect of shrimp-induced salinity on productivity of paddy. The data collected shows that soil salinity status was normal in both the currently affected and unaffected villages in the pre-shrimp period (2004-2005). Also, analysis of soil samples taken during 2010 shows that soil salinity is in the normal range in the unaffected village. However, in the salinity-affected village, a spatial pattern in soil salinity is observed. In the lands adjoining shrimp farms, the mean EC level is very high ranging from 4.95 to 15.89 dS m-1, while cultivated lands have an EC range of 0.02 to 3.0 dS m-1. The farm budget analysis shows that the net returns in Poovam (the affected village) are negative at Rs -5058 per ha. In the un-affected village, net returns are positive and it is Rs 5348 per ha. This situation has forced few farmers in Poovam to sell their lands. By estimating paddy production functions with different specifications, we find that salinity has a negative and statistically significant influence on paddy yield. In the case of the Cobb-Douglas specification, a one percent increase in EC is associated with a 0.063 percent decrease in paddy yields. It is also clear that the relationship between paddy production and land salinity is non-linear. The estimates of gains in paddy yield from reduced salinity increase with the more non-linear specifications of production function.

What are the likely gains to Poovam from a reduction in soil salinity? Observed data from the cropped areas in Poovam show a maximum salinity level of 3 in cropped areas. For those farms that are bordering on this salinity level, the average gain would be Rs 1000 to Rs 5000 per hectare depending on the specification of the production function. This amounts to an increase in yield of 172 to 836 kgs per hectare. There are many farms that have not reached this level of salinity – however, with continued exposure to shrimp neighborhood effects, they may well do so. Also, we note that the non-cropped areas in Poovam are much more saline, with the maximum salinity in the permanent fallows being 6.60. Some of this land may have previously been agricultural land and farmers have had to make them into fallows because they were no longer productive.

Thiruvettakudy, the un-affected village, has been transformed into a prosperous agricultural tract partly because of the role played by the Farmer's Irrigation Society in water management. Such an institutional mechanism with farmer's participation in salinity management may be the answer for managing agriculture elsewhere in the coastal tracts. Salinity can be decreased in Poovam as well. This will require maintenance and regulation of shutters, adoption of the recommended salinity control activities such as rainwater harvesting, leaching and drainage and soil test based application of amendments like gypsum. Proper monitoring of soil and water salinity is necessary for effective implementation of the reclamation measures to prevent a further build-up of salinity in the long run. The study suggests the need to internalize the costs of externality the shrimp farmers generate by salinizing land and water resources. A regulatory framework for taxing externalities can be developed for sustainable agricultural development in the region.

Table -4 Descriptive Statistics for Paddy

S. No.	Items	Poovam (n=48)		Thiruvettakudy (n=209)		t test p-value
		Mean	CV%	Mean	CV%	
1	Seeds (kg ha^{-1})	139.32	39.48	127.27	15.02	0.140
2	Organic manure (kg ha^{-1})	9111.28	95.43	5594.61	62.36	0.008
3	Urea fertilizer (kg ha^{-1})	241.82	117.95	300.65	99.65	0.205
4	DAP fertilizer (kg ha^{-1})	68.43	126.01	119.02	89.28	0.000
5	MOP fertilizer (kg ha^{-1})	83.79	167.95	42.59	269.80	0.063
6	Plant protection cost (Rs ha^{-1})	284.64	147.96	84.01	365.56	0.002
7	Human labour (Rs ha^{-1})	7517.46	42.69	8770.39	33.94	0.016
8	Machinery charges (Rs ha^{-1})	1884.20	62.35	2375.29	54.68	0.012
9	Variable cost (Rs ha^{-1})	14796.35	40.14	16930.53	37.21	0.029
10	Productivity of paddy (Kg ha^{-1})	1888.28	49.59	3519.79	44.65	0.000
11	Price (Rs ha^{-1})	5.42	8.15	6.29	11.28	0.000
12	Gross returns (Rs ha^{-1})	9737.78	54.55	22278.63	49.66	0.000
13	Net returns (Rs ha^{-1})	-5058.57	147.03	5348.09	202.03	0.000

Table -5 Estimates of Production Function

Dependent Variable LnY	Model I		Model		Model III	
Independent Variable	Coefficient	T Statistics	Coefficient	T Statistics	Coefficient	T Statistics
Ln X_1	0.1372*	1.827	0.1340*	1.788	0.1343*	1.790
Ln X_2	0.0949	1.424	0.1086*	1.613	0.1094*	1.629
Ln X_3	0.1422***	3.986	0.1838***	3.894	0.1305***	3.517
Ln X_4	-0.0628**	-2.031	-0.1952*	-1.889	---	--
D	-0.4860***	-6.297	-0.4765***	-6.158	-0.4953***	-6.600
X_4	--	--	--	--	-0.1981**	-2.084
X_5-Ln X_3* Ln X_4	--	--	0.0244	1.343	--	--
Constant	5.1194	7.414	4.829	6.683	5.294	7.670
R^2	0.3963		0.4007		0.3968	
Adjusted R^2	0.3843		0.3863		0.3848	
F	32.957		27.853		33.029	
N	257		257		257	

Notes: ***, ** and * denote significance at 1% level, 5% and 10% levels.

Table 6: Estimates of Losses for Hectare from Increased Salinity Obtained Using Different Methods

Estimate	Per Hectare Land Productivity (Mean EC=1 in dS m^{-1})	Per Hectare Land Productivity (Mean EC=3 in dS m^{-1})	Loss per hectare (kgs)	Loss per hectare (Rs)
I	2582	2410	172	1008
II	2681	2540	141	826
III	2557	1721	836	4899
IV	-	-	1647	9651

Note: Estimates, I, II and III use different production function specifications and the estimate IV is obtained by comparing farm productivity of affected and unaffected villages. Losses in Rs are calculated by assuming an average paddy price of 5.86 per kg.

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