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Should Shrimp Farmers Pay Paddy Farmers? The Challenges of Examining Salinisation Externalities in South India

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Abstract

There has been growing concern over conversion of coastal rice paddies to shrimp farms. This study estimates the external cost of shrimp-induced salinity on crop production by comparing two villages in southern India: Poovam, which is affected by salinity, with Thiruvettakudy, which is not. Our data show that the soil salinity status was normal in both villages in period prior to shrimp farming, in 1994-95. However, soil samples taken in 2006 show high soil salinity in Poovam, while salinity is in the normal range in Thiruvettakudy. Paddy yields are significantly lower in Poovam compared with those of Thiruvettakudy, with average net returns to paddy cultivation being negative. We estimate paddy production functions with different specifications and find that salinity has a negative and statistically significant influence on paddy yield. In the case of the Cobb-Douglas specification, a one per cent increase in salinity is associated with a 0.06 per cent decrease in paddy yields. We find that farms with highly saline soils can gain if soil salinity is reduced to safe levels, and that the gain can range from Rs 1,000 to Rs 5,000 per hectare.

Should Shrimp Farmers Pay Paddy Farmers? The Challenges of Examining Salinisation Externalities in South India

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1. Introduction

Shrimp farming is an important socio-economic enterprise in a number of coastal regions of India. It accounts for about two-thirds of marine product exports by value, and in 2004-05 the sector earned foreign exchange worth Rs 8,348 crore (US$ 1.61 billion[1]) according to the Marine Products Export Development Authority (MPEDA), India's nodal agency for the promotion of seafood exports. Shrimp is cultivated in an area of almost 200,000 hectares largely in the states of Andhra Pradesh, West Bengal, Kerala, Orissa, Maharashtra and Tamil Nadu (MPEDA 2005) and exported in diversified forms to Japan, USA, Europe and elsewhere. Shrimp production grew steadily between 1990-91 to 2001-02 (Kumar et al., 2004) with scientifically managed shrimp farming expanding in acreage by 8.7 per cent per year and in production by 8.4 per cent per year.

The short-term financial returns from shrimp farming are high but the intensive approach of shrimp farming does have an environmental impact which extends beyond the immediate farming zone. The use of sea water along with freshwater for shrimp culture can cause salinisation of land and groundwater and affect the productivity of agricultural crops and quality of groundwater. For coastal communities, which depend on a mix of agricultural activities, intensive and semi-intensive shrimp farms carry with them a high risk of crop failure. Legislation whose objective it is to reduce the adverse impact of shrimp farming exists 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 salinisation of rice-growing lands and groundwater in India by shrimp farms have been documented (Primavera 1997), but estimates of the costs of shrimp salinity that integrate economic and soil aspects are not available. Studies from elsewhere, such as Flaherty et al. (1999), have found that the salt load introduced per hectare for cultivation of one crop of shrimp is as high as 3,048 kg in rural Thailand. Thanh et al., (1999) estimate that the salinisation costs of shrimp farming in Vietnam in the form of lost paddy production, dike construction cost and delayed cost of planting is US$ 0.15 per hectare in the Mekong delta.

In another study, Battacharya et al. (1999), report a production loss of 146,160 metric tonnes of rice due to salinisation of agricultural lands caused by semi-intensive methods of shrimp culture in Bangladesh. Our study examines similar issues and asks whether there are major environmental externalities associated with shrimp farms. In particular, the study asks: What is the external cost of shrimp farm-induced salinisation of land on paddy productivity? This question is answered by carefully comparing paddy yields in two similar villages in southern India, one affected by shrimp farms and the other located further away from shrimp farms.

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[1] 1 USD = 51.735 INR

2. Study Area

Shrimp farming in area that has otherwise been used as cropland has become a vexed issue in districts of the Kaveri river delta in South India, and particularly in Nagapattinam district (in the state of Tamil Nadu) and its adjoining areas (Naganathan et al 1995). Paddy is the major crop cultivated in the region during the 'samba'[2] season (October-February). The district of Nagapattinam accounts for 38 per cent of total shrimp production of Tamil Nadu and the union territory of Puducherry. This district was also reported (Ahmed, 2005) to contain 146 illegal shrimp farms. For these reasons, we chose this district and the adjoining district of Karaikal (in Puducherry) as the study area.

Shrimp is cultivated during the summer (February to June) and during monsoon (October to January). Summer is the major growing season, with production high because of higher salinity levels. The second crop coincides with the northeast monsoon and production is relatively lower as rains dilute the salinity in shrimp ponds. This is the time when both sea water and fresh water are pumped into shrimp farms to reach the desired level of salinity. This leads to the intrusion of soluble salts into aquifers and salinity gradually builds up in the soil.[3] Currently, the modified extensive and semi-intensive methods[4] of shrimp farming are practiced in this area. Over the last two decades the region has seen several changes in shrimp farming methods in response to multiple disease outbreaks.

To identify our study villages we took the help of a local NGO and traversed the coastal stretches of Nagapattinam and Karaikal, which together form a major shrimp farming belt on the Coromandel coast. We chose the village of Chandrapadi in Nagapattinam as our study village (see Map 1). There are 14 shrimp farms clustered in the north-eastern part of this village along the Nandalaru tributary and these have a combined pond area of 65 ha. We chose this area because: (i) paddy fields are located nearby; (ii) the shrimp cluster has been in use for a long period; (iii) there are no other shrimp farming clusters in the neighbourhood which removes the possibility of overlapping salinity effect on the paddy fields; and (iv) time-series data on soil characteristics and cropping details to confirm the homogeneity of affected and unaffected paddy villages are available.

The shrimp farms in Chandrapadi are located on the Tamil Nadu-Puducherry boundary. As seen in Map 1, the adjacent paddy village is Poovam followed by Thiruvettakudy. These two villages were chosen as the treatment and control villages for our study. These are homogenous villages with an average annual rainfall of 1,350 mm, 70 per cent of which is delivered by the north-east monsoon which coincides with the second season ('samba'). Paddy is the major crop cultivated during 'samba' and is rotated with gingelly or black gram. Paddy farmers from both villages depend on canal water as the major source of irrigation, although the supply from the canal is very erratic as both villages are located at the tail end of the deltaic zone. In this region, soil texture varies from sandy to sandy clay and the sub-surface texture is sandy throughout.

In order to understand the effects of salinisation on crop yields, we undertook farmer surveys in Poovam and Thiruvettakudy. We surveyed all farm households that had cultivated paddy during

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2 Samba denotes second crop season.

3 The salinity level required for culture is 25-30 ppt whereas seawater has a salinity level of 30-35 ppt.

4 Modified extensive method has a stock of 10 animals/sq ft and semi-intensive method has a stocking density of 20-50 animals/sq ft.

2005 rabi. Thus, 55 farm households in Poovam and 110 farm households in Thiruvettakudy were surveyed (see Maps 2 and 3).

Poovam village has a population of 1,264 and the literacy rate is 67 per cent. Out of 200 households, 85 are farm households and others are wood traders and agricultural labourers with a number of households depending on work at brick kilns. The survey of 55 farm households revealed that during 'samba' 2005, paddy was cultivated in 49.36 ha. The land holding per household is 1.27 ha and fallow land area accounts for 29 per cent of the total land area of 70 ha. The village has three sluice gates one of which is defunct and the other two are used to drain excess water out of the fields during heavy rains. Our 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. The population is 2,918 and the village's literacy rate is 60 per cent. Paddy accounts for 88 per cent of the gross cropped area in the village, which is 218 hectares. Thiruvettakudy's farmers are all members of the Farmers Irrigation Society (FIS) whose responsibility it is to maintain canals and temple ponds, to operate sluice gates that regulate canal water supply and to adjudicate disputes between farmers. There has been tension over land use between paddy farmers and the private sector shrimp farming industry: when in 1994-95 about 88 ha of land was bought by a private firm to set up shrimp farms, the FIS opposed their project. Shrimp farming could not proceed, but this parcel of land has since remained fallow.

3. Data

Our study uses secondary data and survey data. Secondary data on agro-climatic features, land use and cropping characteristics of the study villages during the period 1990-91 to 2003-04 were collected from the Directorate of Economics and Statistics (its village annual crop abstracts) at Karaikal to confirm the homogeneity of paddy villages prior to the establishment of shrimp farms. Secondary data on soil salinity in Poovam and Thiruvettakudy were collected from the Soil Testing Laboratory at Karaikal to record the salinity during the pre-shrimp period (1994-95) in the paddy villages. Soil salinity data for the post shrimp period of 2002-03 for Thiruvettakudy were collected from the National Agricultural Technology Project (an Indian Council of Agricultural Research programme).

Primary data from paddy farmers was collected using a pre-tested interview schedule with questions on socio-economic profile, input use, cost and returns from paddy cultivation, and attitude towards shrimp farming. Data pertaining to paddy cultivation are for the year 2005 rabi season (October 2005 to February 2006). There exist variations in the variety sown, technology adopted (transplanted/direct sown paddy) and consequently input use in different fragments operated by the same farmer. Fragments are parcels of land that are owned/leased in by a farmer at various locations in the same village. A fragment may include one or more contiguous plots. A plot – treated as a sampling unit in soil science terminology – is an area of land enclosed by bunds on all four sides. This meant that data on paddy cultivation aspects had to be collected for individual 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.

We also collected soils data from the two villages. Surface soil samples (up to a depth of 30 cm) were taken from cultivated lands, current fallows and permanent fallows and also from agricultural land 30 and 60 metres away from shrimp farms to ascertain the intensity and spread of soil salinity in Poovam. In the control village of Thiruvettakudy, soil samples were taken only from paddy lands. Soil samples were taken from land fragments at the start of the paddy season during the months of September and October 2006. For easy management farmers divide their fragments into plots. From each plot, soil samples were taken from three different locations, and mixed to get a representative soil sample for that plot. A total of 314 and 577 soil samples were collected from Poovam and Thiruvettakudy, respectively. The samples were air dried to remove moisture content and then processed: inert material was removed, the soil was pulverised and a soil solution was prepared for analysis. Thereafter the salinity indicator, electric conductivity, was measured.

4. Homogeneity of Paddy Villages

Poovam is immediately adjacent to shrimp farms whereas Thiruvettakudy is physically separate from them. The secondary data on land use, irrigation and crop cultivation and soil data for the pre-shrimp period were collected and analysed to establish that the two villages were identical with respect to agro-climatic and cropping characteristics and soil salinity status before the introduction of shrimp farms.

Table 1 contains details about agriculture in Poovam and Thiruvettakudy for both periods, before and after the operation of shrimp farms. In the period before shrimp farming was brought to the region, Poovam and Thiruvettakudy had 70% and 80% respectively of village lands under crops. Poovam had approximately 48% of its gross cropped area (GCA) under paddy while the proportion for Thiruvettakudy was nearly 59% under paddy. Their cropping and irrigation intensity were similar and so was the ratio of net sown area to total land. Thus, although Thiruvettakudy is nearly twice the size of Poovam, in terms of cropping pattern the two villages were homogenous. In the post-shrimp farming period, area under paddy as a percentage of GCA remained stagnant in Poovam, while it increased to 83 per cent in Thiruvettakudy. Given the agricultural histories of both villages and their crop growing patterns, we infer that this difference has been caused by rice farmers in Poovam encountering greater levels of soil salinity than their counterparts in Thiruvettakudy. There was, however, a decline in GCA in both the villages, mainly due to problem of water scarcity.[5]

5. Soil Characteristics

The soil testing laboratory maintains a register in which electrical conductivity (EC: a measure of salinity), pH (its acidic or alkaline value) and nutrient status of soil samples brought in by farmers are tested and recorded. The test results are used to prescribe use of fertiliser to farmers. We summarise the EC data of the soils in Table 2. An EC value of less than 1 (EC < 1) indicates that soils are highly suitable for cultivation, whereas an EC in the range of 1-3 is injurious to crop growth. EC values between 3 and 4 will definitely cause yield reduction and soils with an EC

[5] A sharp increase in fallow lands (other fallows and cultivable waste) by 29.16 per cent and 27.05 per cent was observed in both Poovam and Thiruvettakudy, respectively during 1990-2003. This is reflected in a decline of Net Sown Area (NSA) in these villages. A large area is left fallow (203.18 ha) in Thiruvettakudy mainly for use as house plots and for construction of institutions. Further, the problem of seawater intrusion in the tract of land adjoining Poovam and Thiruvettakudy during heavy rains in the north-east monsoon season is another cause for the presence of fallow lands. But, our discussions with farmers indicated that historically seawater intrusion has not been a major problem in Poovam village itself

value more than 4 ($EC \geq 4$) are designated as saline soils and need reclamation to restore them for cultivation. In the pre-shrimp farming period, salinity levels were below one in both villages. Furthermore, 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 (Table 3). In Thiruvettakudy village, for the 577 soil samples taken from 209 fragments, EC values ranged from 0.01 to 0.96, implying normal soils (Table 4).

Having shown that soils in both control and treatment villages were not saline in the pre-shrimp period, the next step in our analyses was to compare pre-shrimp farming soil salinity with current salinity in the two villages. The soil samples taken from cultivated lands and fallow lands in Poovam in 2006 show EC values ranging from 0.02 to 6.60. In areas adjacent to the shrimp farm, EC levels were very high ranging from 4.95-15.89. In the cultivated lands, the EC ranged from 0.02 to 2.13.

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6. Comparing Paddy Cultivation

The chief difference between the paddy economics of the two villages is seen in the net returns figures: per hectare net returns of Rs 6,265 for Thiruvettakudy's farmers versus a loss of Rs 5,400 per hectare for Poovam's farmers. Although the variable cost per hectare is higher in Thiruvettakudy (Rs 19,000 as against Rs 16,784 in Poovam) it is the large gap in the productivity between the two villages that makes the significant difference. In Thiruvettakudy the yield is 3,973 kg per hectare, which is 87% more than Poovam's 2,124 kg per hectare. The details on input use, productivity, cost and returns from transplanted paddy (TP) and direct sown paddy (DS), along with the descriptive statistics of variable inputs obtained from survey of farm households are furnished in Tables 5 and 6.

In general, TP is more input intensive and hence the cost of cultivation is high as compared to DS farms. Also productivity is significantly higher for TP farms. In Poovam the average yield was higher for TP at 2,124 kg ha^{-1} as compared to only 1,670 kg ha^{-1} for DS. Similarly, TP farms in Thiruvettakudy recorded a higher average yield of 3,973 kg ha^{-1} while in DS farms yield was 3,016 kg ha^{-1}.

7. Estimation of externality cost

An externality exists when the consumption or production choices of one person or firm enters the utility or production function of another entity without that entity's permission or compensation (Kolstad 2000). Shrimp farming in agricultural lands causes two kinds of externalities: (i) An externality borne by the current generation due to decline in crop yields caused by increasing salinisation 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 minimised; (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 salinisation 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, fertilisers, 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 the change in productivity method by a comparison of salinity affected and unaffected paddy villages. In the next section, we estimate a production function for paddy and examine whether and how soil salinity affects yields in the control and treatment villages.

8. Factors Causing Soil Salinity

What is the link between salinity in soil and shrimp farming? Finding answers scientifically help us decide whether salinity is primarily caused by shrimp farming or whether other factors too are responsible. In general, the intensity of salinity is influenced by factors like soil type, topography and location of fields. In the study area, the soil type varies from sandy to sandy clay but the sub-surface texture is sandy throughout. There are no variations in slope and therefore for our analysis the location of fields was the most important factor. The location of paddy farms was identified by measuring the vertical distance from key hydro-geological structures in the village - the tertiary canal, shrimp farms and drainage shutters – to the mid-point of each farm fragment in the sample. Each fragment in the dataset is comprised of a number of plots which ranged between one and five in Poovam and tended to be slightly more in Thiruvettakudy. To examine the link between soil salinity in the farm fragments and shrimp farms, mean EC was regressed on distance variables and a village dummy. Linear, log-log and semilog models were attempted. The log-log form is reported in Table 7, which was chosen taking into account the signs and significance levels of the coefficients of explanatory variables. All the distance variables were highly collinear, hence, in the final model, all distance variables were dropped other than distance to shrimp farm. The salinity regression analysis shows that mean EC is positively and significantly influenced by distance from shrimp farms and the village dummy. The significance of the dummy variable for Poovam suggests farms in Poovam are more saline than farms in Thiruvettakudy. This supports the hypothesis that Poovam is affected by shrimp farms given that both villages had the same salinity in the period before shrimp farming was introduced to the region and given that Thiruvettakudy is actually a bit closer to the sea. However, in terms of the significance of the shrimp farm distance variable, there is a caveat to be recorded. The coast runs almost parallel to the shrimp bund and therefore the variable measuring distance from the shrimp bund is highly correlated with distance from the coast. Hence, part of what the distance from shrimp farms variable may be picking up is distance from saline sea waters.

9. Production Function Analysis

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

$$Y = \alpha X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} e^u \text{ ....(1)}$$

where,
Y = Paddy yield (kg ha^{-1})
X_1 = Human labour cost (Rs ha^{-1})
X_2 = Machinery cost (Rs ha^{-1})
X_3 = Quantity of Urea + DAP (Diammonium Phosphate in kg ha^{-1})
X_4 = Mean EC (dS m^{-1})
e^u = error term
â's are regression coefficients of respective variables.

In order to estimate the production function, pooled regressions of paddy yield in both control and treatment villages on the input variables were used. In these regressions, yield is measured as kg of paddy per hectare. The variable inputs - urea and DAP fertiliser - are expressed in physical units as kg ha^{-1}. For labour input, wages are the same for a particular operation in all farms while transplanting and weeding are done on a contract basis. Labour cost has been calculated per hectare. In the case of machinery, the unit cost of machinery per ploughing per acre is the same for all farms in a village and so total machinery cost per hectare was included based on number of hours of machinery used.

Three different specifications are used to test the hypothesis that salinity has a significant effect on paddy yield. Model I estimates a Cobb-Douglas production function and includes all the variable inputs identified in equation 1 in log form. Also included is a village dummy, which is defined as being equal to 1 if the farm is a Poovam (shrimp-affected) farm and 0 if the farm is from Thiruvettakudy. Model II includes all the variables used in Model 1 as well as an additional interaction term of the log of the fertiliser variable interacted with log mean EC. This model tests whether there is a synergistic effect between fertiliser use and salinity: if increased salinity in combination with fertiliser use contributes to increased productivity. Model III takes into account a possible exponential relationship between salinity and paddy production. Thus, in this regression mean salinity is not logged.

The results of estimated pooled production functions for paddy farms are given in Table 11. In model I, the elasticity of output with respect to variable inputs, human labour, machinery cost and fertiliser are positive and significant. The coefficient of mean EC is -0.0628 and significant at the 5 per cent level. This suggests that a one per cent increase in salinity *ceteris paribus* reduces paddy yield by 0.06 per cent.

In model II, the coefficient of the interaction variable of fertiliser x mean EC is positive but not statistically significant, which indicates that increased fertiliser use does not counteract salinity, and that fertiliser use in combination with salinity does not affect yield. The coefficients of the other variables are similar to in sign to those obtained in model I.

Model III assumes an exponential relationship between salinity and yields and the coefficient of salinity is significant at the 5 per cent level. The other variables behave in a manner similar to Model 1.

All three models show that there is a significant effect of salinity on paddy yield. Using different specifications simply strengthens the robustness of the analyses. The estimates show that there is non-linear relationship between salinity and land productivity explained by either logarithmic or exponential functions.

10. Welfare Gains from Salinity Reduction

Next, we estimate the welfare gains from decreases in salinity or the welfare losses suffered by villagers as a result of increased salinity. Table 12 provides estimates of welfare losses from increased salinity using different methods of estimation. Methods I, II and III use the three estimated production functions given in Table 11. Method IV provides an estimate of productivity loss by comparing productivity in affected and unaffected villages.

Based on scientific evidence, soil salinity level is considered to be safe if it is equivalent to 1; any higher values of mean EC are considered unhealthy. Table 12 (methods I, II and III) presents productivity levels for salinity equal to 1 and the maximum salinity observed in the affected village, which is 3. 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 kg of paddy per hectare. With the production function considering the synergistic effects of fertilisers 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 results in a gain of 837 kg per hectare. These estimates show a complicated non-linear relationship between farm productivity and the land salinity and it must at the same time be noted that these are gains attributed to a decrease in the mean level of salinity from 3 to 1, and that they represent the maximum gains possible.

Method IV estimates the gains that would accrue if salinity decreases by comparing the productivity in the controlled farms with those affected by salinity. The predicted per hectare yield of unaffected and affected farms are 3,252 and 1,606 kg respectively. These estimates are obtained by substituting the mean values of input variables for the unaffected and affected villages into the estimated Cobb-Douglas production function. The mean values for the input variables are obtained from Tables 9 and 10, which provide descriptive statistics for the affected and un-affected villages. Using this method, the average per hectare gain from reducing salinity is estimated to be 1,647 kg.

Table 12 suggests that there are indeed welfare gains to be had by reducing soil salinity. These gains can range between Rs 1,000 and Rs 5,000 per hectare depending on the specification of the production function. Conversely, an examination of the controlled salinity level means in the affected and un-affected villages suggests that the losses could be as high as Rs 10,000 per hectare.

The analysis shows that there are challenges associated with estimating welfare loss for an agricultural community in which paddy cultivation is dominant, and for an individual farming household. These challenges have to do with the underlying assumptions about the physical relationship between salinity and productivity and the methodology used for estimating welfare.

11. Conclusions

Our study examines the externality effect of shrimp-induced salinity on the productivity of paddy. The data collected shows that the soil salinity status was normal in both Thiruvettakudy and Poovam villages in the period before shrimp farming, which is 1994-95. Also, an analysis of soil samples taken during 2006 shows that soil salinity is in the normal range in the unaffected village (Thiruvettakudy). In Poovam however, a spatial pattern in soil salinity is observed. In the lands adjoining shrimp farms, the mean EC level is very high and ranges from 4.95 to 15.89 dSm^{-1}, while cultivated lands have an EC range of 0.02 to 3.0 dSm^{-1}.

How have farmers responded? Shifting to direct sown paddy technology has emerged as a coping strategy for dealing with salinity and to manage water scarcity. The shift in paddy production technology is more evident in Poovam, the salinity-affected village. DS paddy constitutes 65 per cent of the total paddy area in this affected village while it accounts for 59 per cent of the total paddy area in Thiruvettakudy. The analysis of farm budgets shows that the returns in Poovam are negative: net losses of Rs 5,400 per hectare and Rs 4,743 per hectare respectively for transplanted paddy and direct sown paddy. Such losses can certainly not be sustained by Poovam's farmers and their choosing DS over TP is a means to reduce these losses. The comparison with Thiruvettakudy is telling: in this village returns per hectare are Rs 4,000 (DS) and Rs 6,000 (TP). This situation has forced a 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 1 per cent percent increase in EC is associated with a 0.063 percent decrease in paddy yields. The estimates of gains in paddy yield from reduced salinity increase with the more non-linear specifications of production function.

How can the farmers of Poovam gain from a reduction in soil salinity to safe levels? Data from the cropped areas in Poovam show a maximum salinity level of 3, and for those farms that are growing paddy despite being near this salinity level, the average gain would be Rs 1,000 to Rs 5,000 per hectare depending on the specification of the production function. This average gain is based on an increase in yield of 172 to 836 kg per hectare. No doubt many farms have not reached this level of salinity, but if conditions do not change then with continued exposure to the effects of being near shrimp farms, they may well reach this level. There is good reason for this expectation, which unfortunately may further burden Poovam's farmers. Some of the lands in Poovam which are not cropped at present may previously have been agriculturally active, with farmers having allowed them to lapse into the current state of permanent fallows given their high value (6.60) of maximum salinity.

A key agent of change in Thiruvettakudy has been responsible for transforming the village into an agriculturally prosperous community. This is the Farmer's Irrigation Society, an institution that has brought in farmers' participation in salinity management. This institutional model could serve Poovam as also other agricultural communities in the coastal tracts of Tamil Nadu and Puducherry.

Salinity control measures like rainwater harvesting, the application of amendments like gypsum based on soil tests, the maintenance and regulation of sluice gates, leaching and drainage can all be employed to lower salinity in Poovam. Regular monitoring is critical to prevent an increase in salinity over the long term, and will rely on more frequent and regular soil testing by the authorities.

Is there a case for the region's shrimp farmers to internalise the costs of increased land and water salinity in their neighbourhood, which is an externality they have generated? A variety of economic instruments exist that can be used for reducing such externalities. Direct compensation may not be feasible, but a regulatory framework for taxing externalities can be developed which will pull the farmers of Poovam out of a cycle of losses, and bring long-term sustainability to their agricultural effort.

12. Acknowledgements

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TABLES

Table 1: Land Use and Cropping Characteristics of Paddy Villages (in hectares)

S.No.	Particulars	Before shrimp farming (1990-'92)		Shrimp farming period (1993-'95)		After shrimp farming (2001-'03)	
		Poovam	Thiruvettakudy	Poovam	Thiruvettakudy	Poovam	Thiruvettakudy
1.	Geographical area	207.40	549.00	217.89	558.00	217.89	558.00
2.	Current fallows	31.40 (15.14)	62.27 (11.34)	45.23 (20.75)	131.30 (23.53)	15.66 (7.18)	18.23 (3.26)
3.	Other fallows	10.23 (4.93)	14.80 (2.69)	8.83 (4.05)	13.37 (2.39)	24.68 (11.33)	33.18 (5.94)
4.	Cultivable waste	7.17 (3.46)	36.53 (6.65)	6.90 (3.17)	38.67 (6.93)	57.12 (26.22)	170.0 (30.46)
5.	Net sown area (NSA)	121.93	347.00	107.83	278.50	66.70	222.29
6.	Gross cropped area (GCA)	146.07	445.40	121.37	326.53	66.73	230.52
7.	Paddy area	70.50	265.63	60.13	223.60	32.37	192.29
8.	Per cent of paddy area to GCA	48.26	59.64	49.54	68.47	48.50	83.41
9.	Per cent of NSA to total area	58.78	63.20	49.48	49.91	30.61	39.83
10.	Per cent of GCA to total area	70.42	81.12	55.70	58.51	30.62	41.31
11.	Cropping intensity (%)	119.79	128.35	112.55	117.24	100.04	103.70
12.	Irrigation intensity (%)	100.14	101.41	100.00	100.61	100.00	100.32
13.	Productivity of paddy (kg ha-1)+	4000-4500	4000-4500	-	-	-	-

Source: Village Annual Crop Abstracts, Directorate of Economics and Statistics, Karaikal (Data was not available for the period 1996 to 2000)

+As told by farmers through recall and figures in parentheses indicate percentage to village panchayat, or local self-government, area.

Pre-shrimp period denotes average for the triennium ending 1992-93. Shrimp period and post-shrimp periods denote averages for triennium ending 1995-96 and 2003-04, respectively.

Table 2: Soil Salinity during pre-shrimp farming period (1994-95)

Soil status	Soil EC (dS m^{-1})			
	Min	**Max**	**SD**	**Mean+**
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 = o.461

EC: Electrical Conductivity in deci Siemens per metre.

Table 3: 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		
a)	Distance of 100 ft	18	5.64 - 15.89
b)	Distance of 200 ft	28	4.95 - 11.09
	Total soil samples	314	0.02 - 15.89

Table 4: 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

Table 5: Descriptive Statistics for Transplanted Paddy

S.No.	Items	Poovam (n=23)		Thiruvettakudy (n=110)		t test p-value
		Mean	CV %	Mean	CV %	
1.	Seeds (Kg ha^{-1})	141.29	45.66	124.54	12.54	0.228
2.	Organic manure (Kg ha^{-1})	9153.18	123.74	6619.52	39.38	0.298
3.	Urea fertiliser (Kg ha^{-1})	303.41	126.57	380.58	99.06	0.386
4.	DAP fertiliser (Kg ha^{-1})	85.99	122.01	121.71	71.29	0.138
5.	MOP fertiliser (Kg ha^{-1})	115.76	167.02	31.71	220.03	0.051
6.	Plant protection cost (Rs ha^{-1})	434.26	124.66	117.04	344.56	0.013
7.	Human labour (Rs ha^{-1})	8546.01	36.03	9617.11	27.20	0.131
8.	Machinery charges(Rs ha^{-1})	1955.39	56.30	2614.72	54.77	0.018
9.	Variable cost (Rs ha^{-1})	16784.98	39.11	19000.43	25.53	0.137
10.	Productivity of paddy (Kg ha^{-1})	2124.77	44.31	3973.06	47.98	0.000
11.	Price (Rs kg^{-1})	5.37	7.41	6.30	11.15	0.000
12.	Gross returns (Rs ha^{-1})	11384.22	44.03	25266.03	53.96	0.000
13.	Net returns (Rs ha^{-1})	-5400.77	170.37	6265.60	196.34	0.000

CV % = Standard deviation/ Mean x 100

Table 6: Descriptive Statistics for Direct Sown Paddy

S.No.	Items	Poovam (n=25)		Thiruvettakudy (n=99)		t test p-value
		Mean	CV %	Mean	CV %	
1.	Seeds (Kg ha^{-1})	137.50	33.35	130.30	17.01	0.452
2.	Organic manure (Kg ha^{-1})	9072.73	60.83	4455.82	89.18	0.000
3.	Urea fertiliser (Kg ha^{-1})	185.15	70.74	211.84	62.14	0.369
4.	DAP fertiliser (Kg ha^{-1})	52.26	119.56	115.76	108.05	0.000
5.	MOP fertiliser (Kg ha^{-1})	54.39	94.47	54.69	273.25	0.987
6.	Plant protection cost (Rs ha^{-1})	146.99	131.76	47.31	273.21	0.021
7.	Human labour (Rs ha^{-1})	6571.20	47.00	7829.59	39.37	0.077
8.	Machinery charges(Rs ha^{-1})	1818.69	69.18	2109.25	51.14	0.297
9.	Variable cost (Rs ha^{-1})	12966.81	36.43	14630.63	47.33	0.162
10.	Productivity of paddy (Kg ha^{-1})	1670.71	53.59	3016.15	28.02	0.000
11.	Price (Rs kg^{-1})	5.47	8.81	6.25	11.70	0.000
12.	Gross returns (Rs ha^{-1})	8223.07	63.46	18959.29	29.82	0.000
13.	Net returns (Rs ha^{-1})	-4743.75	-116.44	4328.66	205.97	0.000

CV % = Standard Deviation/ Mean x 100

Table 7: Estimated Log-Log Function of Salinity on Distance Parameters (Dependent variable Log of mean EC in dS m^{-1})

Variables	Regression coefficients	Standard error
Intercept	-2.968***	0.128
DIS SHR	0.032*	0.019
Village dummy	1.211***	0.137
R^2	0.241***	
Adj R^2	0.235	
F	40.28	
N	257	

*** , * denote significance at 1 percent and 10 per cent levels.

Table 8: Descriptive Statistics of Affected Farms

Variable	Observation	Mean	Std Deviation
Yield	48	1888.281	936.4028
Urea Dap	48	310.2431	307.8608
Meanec	48	.4397917	.6329044
labcst	48	7517.462	3209.589
machcst	48	1884.2	1174.844

Table 9: Descriptive Statistics of Unaffected Farms

Variable	Observation	Mean	Std Deviation
Yield	209	3519.79	1571.638
Urea Dap	209	419.6686	342.6793
Meanec	209	.0866986	.1093913
labcst	209	8770.385	2977.17
machcst	209	2375.286	1298.826

Table 10: Descriptive Statistics of Combined Sample

Variable	Observation	Mean	Std Deviation
Yield	257	3215.073	1604.298
Urea Dap	257	399.2312	338.5818
Meanec	257	.1526459	.3198046
labcst	257	8536.376	3054.878
machcst	257	2283.566	1288.731

Table 11: Estimates of Production Function

Dependent Variable LnY	Model I		Model II		Model III	
Independent Variable	Coefficient	T Statistics	Coefficient	T Statistics	Coefficient	T Statistics
Ln X1	0.1372*	1.827	0.1340*	1.788	0.1343*	1.790
Ln X2	0.0949	1.424	0.1086*	1.613	0.1094*	1.629
Ln X3	0.1422***	3.986	0.1838***	3.894	0.1305***	3.517
Ln X4	-0.0628**	-2.031	-0.1952*	-1.889	--	--
D	-0.4860***	-6.297	-0.4765***	-6.158	-0.4953***	-6.600
X4	--	--	--	--	-0.1981**	-2.084
X5 = Ln X3 * Ln X4			0.0244	1.343	--	--
Constant	5.1194	7.414	4.829	6.683	5.294	7.670
R2	0.3963		0.4007		0.3968	
Adjusted R2	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
Y = Paddy yield (kg ha^{-1})
X_1 = Human labour cost (Rs ha^{-1})
X_2 = Machinery cost (Rs ha^{-1})
X_3 = Quantity of Urea + DAP (kg ha^{-1})
X_4 = Mean EC (dS m^{-1})
D: Village dummy variable (1=affected village)
X_5 = Quantity of Urea + DAP (kg ha^{-1}) x Mean EC (dS m^{-1})

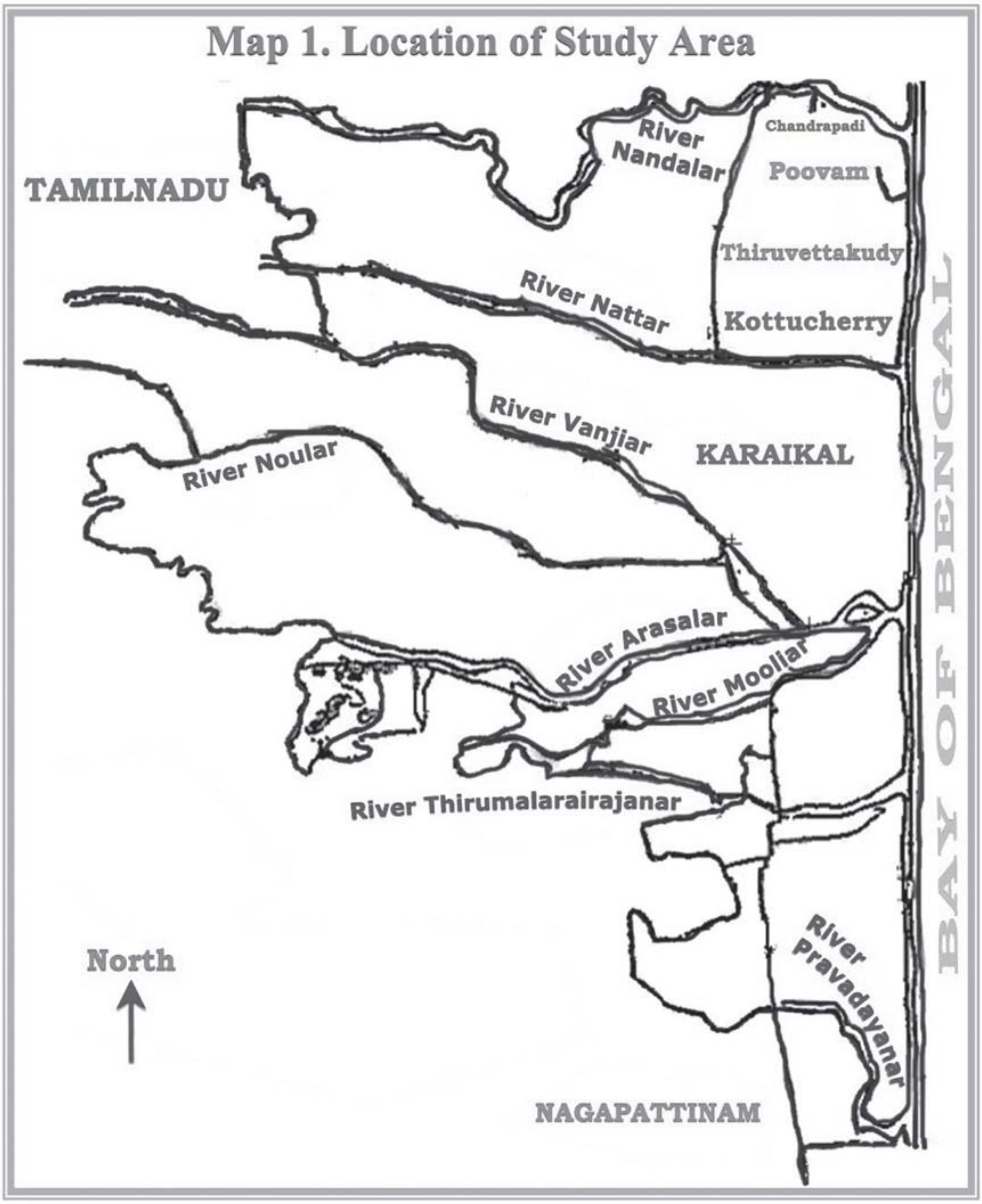
Table 12: Estimates of losses per hectare from increased salinity obtained using different methods

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 (kg)	Loss per hectare (Rs)
I	2582	2410	172	1008
II	2681	2540	141	826
III	2557	1721	836	4899
IV	-	-	1647	9651

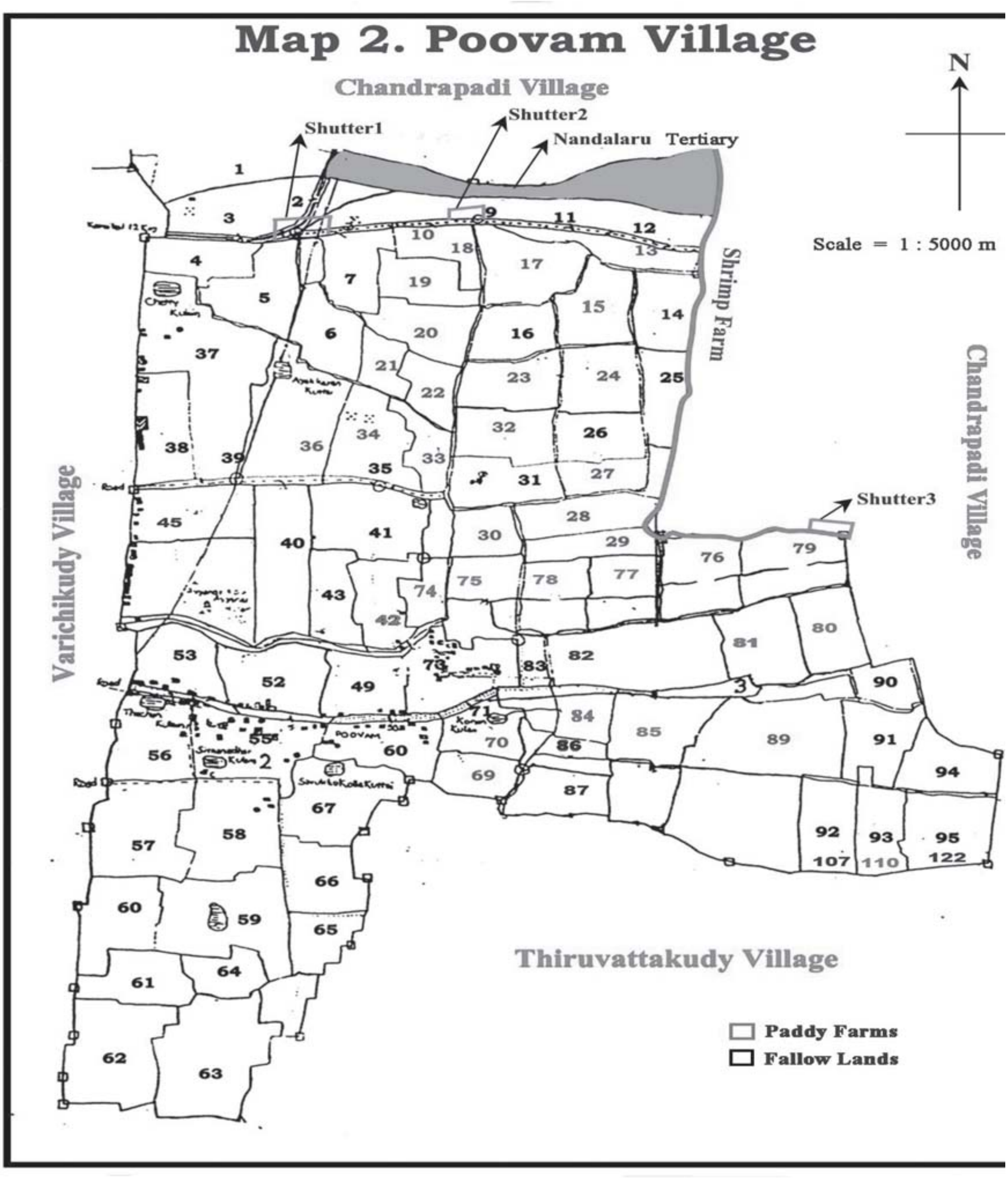
Note: Estimates I, II and III use different production function specifications and the estimate IV is obtained by comparing farm productivity of affected and unaffected villages. Losses in Rs are calculated by assuming an average paddy price of 5.86 per kg.

MAPS

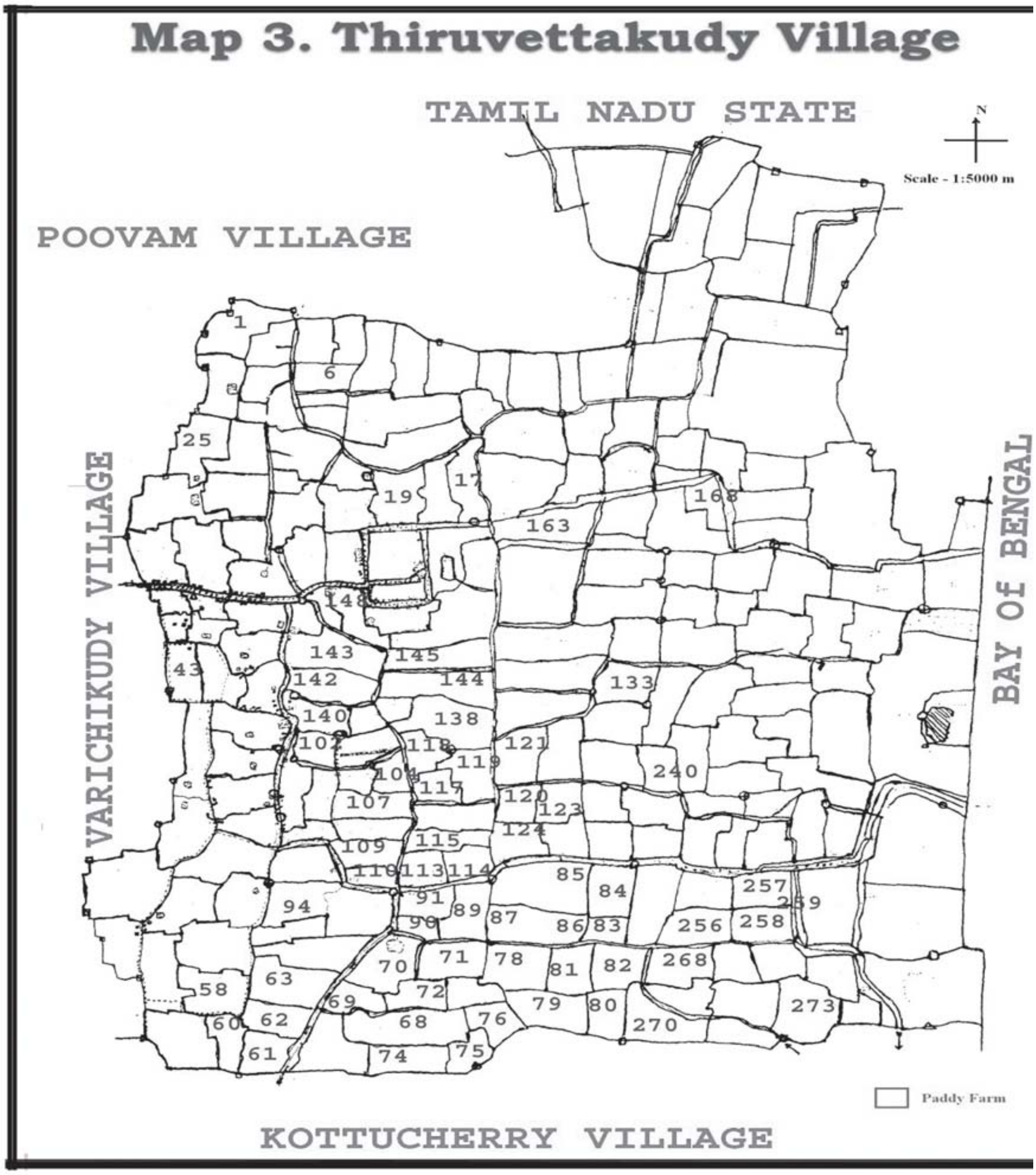
Map 1: Map of Poovam Village



Map 2: Map of Thiruvettakudy Village



Map 3: Map of Thiruvettakudy Village



FIGURES

Figure 1: Externality Effect of Decline in Soil Quality