Impact of shrimp farming on the soil characteristics of Vellar Coleroon estuary complex, Tamil Nadu

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Impact of shrimp farming on the soil characteristics of Vellar Coleroon estuary complex, Tamil Nadu

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ABSTRACT

Assessment of changes in soil characteristics in and around shrimp farms will be helpful to evaluate the impact of aquaculture on the surrounding environment. Satellite data of IRS-1C, LISS III of 2003 were used to estimate the areal extent and spatial distribution of aquaculture farms in the Vellar Coleroon estuary complex based on satellite image processing softwares such as ERDAS Image and ARC VIEW. Sampling stations were fixed based on the spatial distribution of aquaculture farms using Global Positioning System (GPS). Soil samples were collected in and around the farms at various depths and analyzed. Electrical conductivity which varied from 5.75 to 5.81 dS/m and 8.45 to 9.19 dS/m before and during the culture period respectively, indicated the increase in salinity by 46-58 % in shrimp ponds. Soil salinity decreased as the distance from the farm increased up to 100 m. Soil pH (7.85 to 8.37) and organic carbon (0.88 to 1.46%) registered higher values in the shrimp ponds, than surroundings. Shrimp culture did not influence porosity, water retention capacity and texture. There was no significant difference in soil properties of the surrounding environment before and during culture. Surface soil had higher pH, electrical conductivity, organic carbon and porosity than the sub surface soil. The water retention capacity and clay content increased with the depth of soil. The present study has shown that the development of aquaculture in Vellar Coleroon estuary did not have any adverse impact on the soil quality of the nearby environment.

Introduction

Commercial shrimp culture has gained global attention not only because of the role it played in strengthening the economy of a country but also by the sudden collapse the industry registered in certain countries. According to Food and Agriculture Organization (FAO), total aquaculture production of aquatic animals (excluding aquatic plants) increased from 6.7 million tonnes in 1984 to 42.3 million tonnes in 2003 and India's contribution to world aquaculture production was 6.2 %. Aquaculture has transformed from traditional activity to commercial farming of high profit in the early nineties. The area under aquaculture increased from 60,235 ha in

1989 - 1990 to 2,21,250 ha in 2003-04 (MPEDA, 2005). This rapid expansion of aquaculture in India has led to the growing concern about its impact on the environment. Since brackishwater is generally used for prawn culture, it enhances the levels of salt in soils, making them saline (Dwivedi and Sreenivas Kandrika, 2005). Salinization of agricultural lands nearer to aquaculture farms due to the seepage of water from shrimp ponds has become one of the major environmental issues. Many reviews led to the conclusion that aquaculture has both positive and negative impacts and occasionally negative impacts have received wide publicity (Csavas, 1994).

Nature of the pond bottom soil is of great importance in brackishwater aquaculture. There is increasing evidence that the condition of pond bottom reflects the exchange of substances between soil and water (Boyd, 1995). Characteristics of soils suitable for earthen shrimp pond construction include: adequate clay content, low organic content, proper soil texture and proper pH (Howerton, 2001). Environmental impacts have been linked to major outbreak of shrimp diseases, degradation of resources and conflicts with other coastal users. The impact of shrimp farms on salinization of agricultural lands is not documented based on the shrimp farm area developed in the nearby regions which is essential for areas with intense agricultural activity in proximity to shrimp farms. Evaluation of impacts of shrimp farming will be useful in reducing the adverse impacts if any and also to shape the project to suit local environment. There is a necessity to assess the soil characteristics in and around the shrimp farm with reference to the realistic area of shrimp farms and other resources. The present study was undertaken to assess the impact of aquaculture development on soil characteristics in Vellar Coleroon estuary complex.

Materials and methods

Study area

The study area (Fig.1) lies between 79°45' - 79°50'E and 11°20'- 11°30' N, in Cuddalore district of Tamil Nadu which consists of Pichavaram, a well-known place for luxuriant growth of mangroves. This area was declared as reserve forest in 1897. *Avicennia marina* and *Rhizophora* sp. are the dominant species of mangroves with a total area of 1358 ha (Selvam *et al.*, 2005). Major portion of the study area was under paddy cultivation and aquaculture has developed in a large scale in early nineties. Shrimp farmers practised improved/modified extensive farming of tiger shrimp with a stocking density of 4-10 PL/m^2 with two crops per year.

Assessment of aquaculture area

Indian Remote Sensing Satellite IRS 1C Linear Imaging Self Scanning (LISS) III Sensor digital data was used to delineate the areal extent and spatial distribution of aquaculture farms. The digital data was imported to ERDAS Image format and enhanced with different enhancement (spatial, spectral and radiometric) techniques. The digital image was geo-referenced using the resampled toposheet 58M/15 to its corresponding geographic coordinates by assigning 40 ground control points and resampled to 23.5 x 23.5m pixel dimension. The land use classes were identified based on the image characteristics developed by Space Application Center, Ahmedabad. The sampling stations were fixed based on the distribution of shrimp farms (Fig.1) and the latitudes and longitudes were measured using Global Positioning System (GPS).

Analysis of soil characteristics

In order to assess the impact of shrimp farming on the soil characteristics in and around the shrimp farms, samples were collected from three ponds of each shrimp farm and away from each farm at a distance of 0, 50, 100 and 250 m during every month of the culture period of summer crop of 2003 and 2004. Ten locations were selected for the study and the samples from each farm were collected at 6 points in zig zag fashion and from other points at 0-10, 10-20, 20-30, 30-40 and 40-50 cm depth with soil auger. The samples were air dried, powdered, sieved through 80 mesh sieve and analyzed for pH (1:2.5 soil: water suspension), electrical conductivity (EC - 1:2.5 soil: water suspension), organic carbon (OC), water retention capacity (WRC), porosity and soil texture following standard procedures (Piper, 1966; Jackson, 1967).

Statistical analysis

The results were subjected to oneway ANOVA and the treatment means were compared with Duncan's multiple range test at 0.05 probability. Correlation tests were performed to assess the relationship among the soil properties. The mean soil properties before the start of culture and during the culture period were compared with 'Student's t test' (Gomez and Gomez, 1984).

Results and discussion

The land use categories identified from the satellite data were aquaculture farms, mangroves, agricultural lands, fallow land, sand, settlements, mud flats, agricultural plantation and forest plantation. From the satellite data, the

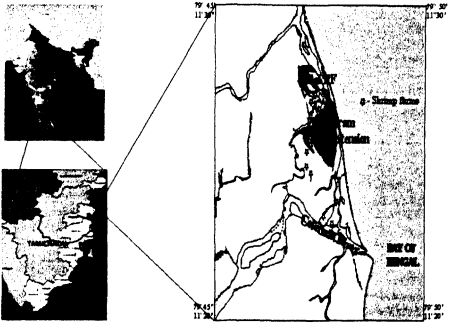

Fig. 1. Study area map and the location of shrimp farms

area under shrimp farming was estimated as 346.78 ha and the aquaculture farms were developed nearer to agricultural fields (Fig.2), which indicated the possible conversion from earlier agricultural lands for aquaculture. The sampling stations were fixed from the resultant map for the uniform distribution and realistic interpretation of soil characteristics.

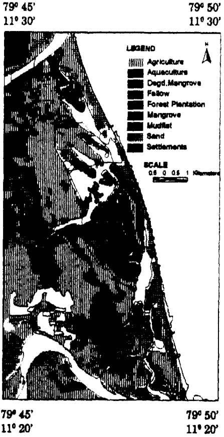

Fig. 2. Land use in and around Pichavaram in 2003

Average soil pH in the shrimp ponds and the surrounding environment ranged from 7.83 to 8.15 and 7.65 to 7.81 before the start of culture (Table 1). During the culture period, pH ranged from 7.85 to 8.37 and 7.85 to 8.01 in shrimp farms and surrounding environment respectively on the surface soil (Table 2). The pH values in all farms were in optimum range (6.5 to 8.5) for shrimp farming. The pH in shrimp ponds were slightly higher than the surrounding environment (Fig. 3) and

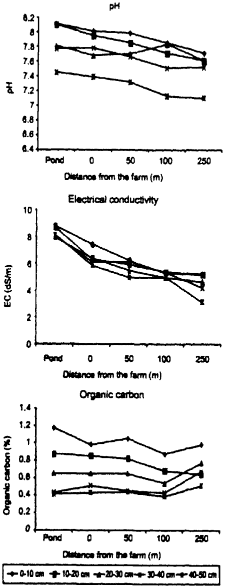

Fig. 3. Chemical properties of soil in and around the shrimp farms

TABLE 1: *Soil characteristics in and around shrimp farms before the culture period*

Parameter	Distance away from shrimp farm (m)				
	Pond	0	50	100	250
pH	7.99±0.16^{a}	7.81±0.01^{ab}	7.65±0.72^{b}	7.77±0.10^{b}	7.69±0.20^{ab}
EC (dS/m)	5.78±0.03^{b}	4.89±0.22^{b}	5.29±0.31^{b}	5.01±0.06^{b}	4.49±0.62^{c}
Organic carbon (%)	0.71±0.06^{c}	0.93±0.11^{ab}	0.99±0.48^{ab}	0.91±0.20^{b}	1.02±0.25^{a}
Porosity (%)	52.81±1.42^{a}	51.68±0.63^{d}	52.19±1.49^{c}	51.27±0.98^{b}	54.31±0.97^{a}
WRC (%)	51.28±1.84^{a}	50.17±0.78^{c}	49.35±1.01^{bc}	52.31±1.43^{b}	51.8±1.82^{a}
Sand (%)	57.45±1.80^{b}	55.10±1.05^{a}	54.52±0.85^{ab}	57.60±1.32^{ab}	56.15±2.15^{b}
Silt (%)	15.40±0.90^{bc}	18.10±2.05^{a}	17.55±2.00^{a}	13.85±3.07^{c}	15.65±2.15^{ab}
Clay (%)	23.25±0.35^{a}	24.85±.2.10^{b}	24.00±0.80^{b}	25.20±1.44^{a}	25.25±0.55^{b}

Note: Values with similar superscript alphabets are not significant ($P \geq 0.05$)

TABLE 2: *Surface soil characteristics in and around shrimp farms during the culture period*

Parameter	Distance away from shrimp farm (m)				
	Pond	0	50	100	250
pH	8.11±0.26^{a}	8.01±0.23^{ab}	7.98±0.33^{b}	7.85±0.28^{b}	8.01±0.32^{ab}
EC (dS/m)	8.82±0.37^{a}	7.85±0.22^{b}	6.25±0.49^{b}	5.29±0.18^{b}	5.27±0.96^{c}
Organic carbon (%)	1.17±0.29^{a}	0.98±0.21^{ab}	1.05±0.24^{ab}	0.87±0.18^{b}	0.98±0.16^{a}
Porosity (%)	57.51±1.29^{a}	55.63±1.35^{d}	56.34±1.73^{c}	56.93±1.20^{b}	58.91±1.68^{a}
WRC (%)	49.27±2.31^{a}	47.20±1.61^{c}	48.97±1.54^{bc}	48.29±2.10^{b}	49.81±2.95^{a}
Sand (%)	58.95±2.80^{b}	59.15±1.80^{a}	58.25±1.25^{ab}	59.65±2.55^{ab}	57.90±3.45^{b}
Silt (%)	16.25±1.95^{bc}	16.60±1.45^{ab}	15.90±3.05^{a}	13.75±4.35^{c}	16.35±3.05^{ab}
Clay (%)	25.75±1.50^{a}	24.25±2.25^{ab}	25.85±1.60^{b}	26.60±2.35^{ab}	25.75±0.95^{ab}

Note: Values with similar superscript alphabets are not significant ($P \geq 0.05$)

there was a decrease in pH as depth of sampling increased. There was not much variation in pH of the surrounding environment. In ponds with low or high soil pH, the quality of water above the sediment may deteriorate and negatively impact survival and growth of the cultured species (Banerjea, 1967).

Before the start of culture, EC ranged from 5.75 to 5.81 dS/m in the ponds and 4.49 to 5.29 dS/m in the surrounding environment. The average EC values were significantly high in farm ponds (8.45 to 9.19 dS/m) and influenced the soil salinity up to a distance of 100 m in the surrounding environment during the culture period. The EC values decreased (Fig.3) to 5.29 dS/m at 100 m from the pond and after that did not vary much as the distance increased. High EC values in shrimp ponds are due to the stagnation of brackishwater (25 – 35 ppt) during the culture period and the optimum EC for shrimp culture was >4 ds/m (Boyd,1995). The soil salinity in the shrimp pond was 46 - 68 % higher than the surrounding environment. In the study area, the nature of the soil was saline (Soil Survey Report, 1978) before the start of aquaculture. EC values are decisive in the deterioration of soil properties due to the stagnation of brackishwater (Dwivedi and Sreenivas Kandrika, 2005). Adjacent location of shrimp farms and agricultural lands had indicated that salinisation is not a problem at present. However, contribution of shrimp culture to the built up of soils through secondary salinisation process cannot be ruled out in the long run.

Organic carbon ranged from 0.73 to 0.85 % before the start of culture and 0.88 to 1.46 % during culture period in the shrimp farms. The applications of organic manure and feed have increased the organic matter load on the pond surface due to accumulation of uneaten feed and dead plankton. In the surface soil of the surrounding environment, it varied from 0.91 to 1.02 % and 0.87 % to 1.05 % before and during the culture period respectively. The organic carbon values did not vary much in surrounding areas as the major activity was agriculture in the adjoining areas. The organic carbon content was significantly high on the surface soil and decreased with increase in depth (Fig. 3). Higher concentrations of OC in the uppermost few millimetres of soil layer in all farms may be due to the solids in the flocculent layer, which settle on to the soil surface. Microorganisms easily decompose the organic carbon input in the aquaculture ponds as they have low concentrations of fibre and low C: N ratio (Boyd, 1995). Hence, the organic carbon in pond soils due to ageing is more or less the same. There was no evidence of development of adverse soil quality in older ponds (Munsiri *et al.*, 1995). It could be attributed that the distribution of organic carbon content in the surrounding soils vary with activities/vegetation on the surface horizon. Organic matter content was high during summer due to decomposition of organic bearing materials (Adhikari *et al.*, 1987). It was also observed that the farms with high clay content had high value of organic carbon as these were located close to the mangrove areas.

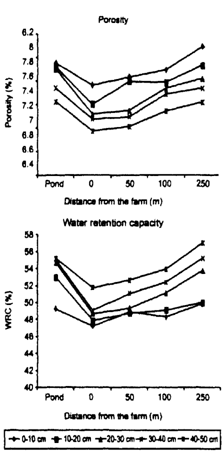

Fig. 4. Physical properties of soil in and around the shrimp farms

The porosity varied from 51.39 to 54.23 % and 51.27 to 54.31 % in shrimp ponds and surroundings respectively before the start of culture. During culture period, porosity of the surface soil ranged from 52.22 to 58.80 % and 55.63 to 58.91 % in the shrimp farm and surrounding environment (Table 2). There was not much change in porosity with the increase in distance from the pond (Fig. 4), as the textural separates and land based activities were not varying much. Porosity was high in the surface horizon of the soils, due to comparatively high content of organic matter in the surface horizon. Shrimp culture did not influence

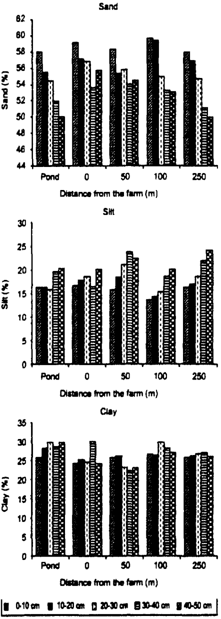

Fig. 5. Soil texture at different depths in and around shrimp farms

porosity of the soil and the changes were due to high void ratio naturally present in the soil. These findings corroborated with Munsiri *et al.* (1995) and Painuli and Pagliai (1996).

The WRC varied from 49.44 to 53.12 % in shrimp farms and 49.35 to 52.31 % in surroundings before the start of culture. It ranged from 46.96 to 51.58 % (Fig. 4) and 47.2 to 49.81 % in shrimp farms and surroundings respectively during culture period. The variation in WRC between the pond soil and the surrounding environment could be attributed to accumulation of organic matter in ponds due to uneaten feed and faecal matter, which might have acted as binding materials. Soils with high water retention capacity (more than 40%) can make good earthen pond construction by preventing losses due to seepage. Texture, bulk density, organic matter and specific gravity determine the water retention by soil to a large extent. Water retention properties of soil determines the seepage rate (Boyd, 1995), which influences the movement of water to the adjoining lands. In a well constructed pond, if seepage is minimized, water loss occurs only through evaporation. Reducing seepage in a pond after it is built is often difficult and expensive. Materials such as bentonite and clay can be applied in the pond bottom, or in extreme cases synthetic liners can be installed (Teichert – Coddington *et al.*, 1989) during the process of construction.

The texture of soil has direct bearing on the productivity of ponds. Soil texture varied with 55.65 to 59.25 % sand, 14.50 to 16.30 % silt and 22.90 to 23.60 % clay in the shrimp ponds and 56.1 to 57.60 % sand, 13.85 to 18.10 % silt and 24.00 to 25.25 % clay in the surrounding environment before the start of culture. During culture period, the texture varied with 56.15 to 61.75 % sand, 14.30 to 18.20 % silt and 24.25 to 27.25 % clay and 57.90 % to 59.65 % sand, 13.75 % to 16.60 % silt and 24.25 % to 26.60 % clay in shrimp ponds and surroundings respectively.

TABLE 3: *Correlation matrix of soil properties in the shrimp ponds*

	Depth	pH	EC	OC	Porosity	WRC	Sand	Silt	Clay
Depth	1								
pH	-0.945*	1							
EC	-0.786*	0.766*	1						
OC	-0.970**	0.867*	0.857*	1					
Porosity	-0.945**	0.913*	0.575*	0.857*	1				
WRC	0.885*	-0.756*	-0.864*	-0.957**	-0.700*	1			
Sand	-0.996**	0.923*	0.740*	0.967*	0.953**	-0.883*	1		
Silt	0.849*	-0.779*	-0.444*	-0.772*	-0.957**	0.574*	-0.866*	1	
Clay	0.774*	-0.715*	-0.804*	-0.821*	-0.554*	0.925**	-0.762*	0.338	1

**- Significant level P ≤ 0.01 * - Significant level P ≤ 0.05

TABLE 4: *Correlation matrix of soil properties in the surrounding environment adjacent to shrimp farms*

	Depth	pH	EC	OC	Porosity	WRC	Sand	Silt	Clay
Depth	1								
pH	-0.845*	1							
EC	-0.558*	0.412	1						
OC	-0.906**	0.799*	0.394	1					
Porosity	-0.770*	0.644*	0.193	0.702*	1				
WRC	0.741*	-0.673*	-0.776*	-0.561*	-0.210	1			
Sand	-0.771*	0.598*	0.603*	0.627*	0.377	-0.825*	1		
Silt	0.667*	-0.667*	-0.339	-0.441	-0.547*	0.578*	-0.509*	1	
Clay	0.092	0.193	-0.288	-0.034	0.228	0.311	-0.363	-0.214	1

**- Significant level P ≤ 0.01 * - Significant level P ≤ 0.05

The shrimp culture did not influence the soil texture as there was not much change before and during the culture. There was not much difference among the textural separates *viz.*, sand, silt and clay in shrimp ponds and in the nearby environment. The sand content decreased with increase in depth of soil profile. The texture of the soil was sandy clay loam. Since finer particles are more active than coarse ones, the magnitude of activity of the soil phase is determined largely by its textural composition. Textural and chemical properties of pond soils vary with pond depth, clay and organic matter accumulate in deeper areas of ponds (Boyd, 1995). A clayey soil rich in organic matter encourages growth of benthic blue green algae, which along with the associated microorganisms form the main food of most of the brackishwater animals (Boyd, 1995). A high clay content reduces the seepage of water, thereby preventing or reducing the possible salinisation in nearby areas.

The correlation matrix among the soil properties and depth of sampling in shrimp ponds and in the surrounding environment during culture period (Tables 3 and 4) indicated that soil pH, EC, porosity, sand content ($P \leq 0.05$) and organic carbon ($P \leq 0.01$) were negatively correlated, whereas WRC, silt ($P \leq 0.05$)

and clay content were positively correlated with the depth of soil profile. WRC was negatively correlated ($P \leq 0.05$) with sand and positively correlated with silt and clay content because coarse textured soils are porous and water seeps very fast and reaches the ground water aquifer. In shrimp ponds, a significant difference was observed with electrical conductivity and organic carbon whereas in the surrounding environment, there was no significant difference in soil properties before and during the culture period. Considering the influence of aquaculture on the electrical conductivity of soil up to a distance of 100 m from the shrimp farms, it is necessary for lining of shrimp farms in sandy areas and creation of buffer zone of 100 m between aquaculture farms and agricultural fields, for the long term sustainability of the environment and aquaculture.

References

Adhikari, M., P. P. Chakraborthy, D. Ghosh and K. Dey 1987. Physico-chemical properties of coastal saline soils of Sunderban, West Bengal. *J. Indian Soc. Coastal Agric. Res.*, **5** : 43-48.

Banerjea, S. M. 1967. Water quality and soil condition of fish ponds in some states of India in relation to fish production. *Indian J. Fish.*, **14**: 113-144.

Boyd, C. E. 1995. *Bottom soils, sediments and pond aquaculture*. 16 pp. Chapman and Hall, New York.

Csavas, I. 1994. Important aspects in the success of shrimp farming. Soc. *World Aquacul.*, **25** (1): 34-56.

Dwivedi R. S. and Sreenivas Kandrika 2005. Delineation and monitoring of aquaculture areas using multitemporal space – borne multispectral data. *Current Sci.*, **89**(8) : 1414-1421.

Gomez, K. A. and A. A.Gomez 1984. *Statistical Procedures for Agricultural Research*, 2nd edn. John Wiley and Sons, New York.

Howerton, R. 2001. *Best management practices for Hawaiian aquaculture*. 32pp. Centre for tropical and subtropical publications, No.148, Waimanalo, HI.

Jackson, M. L. 1967. *Soil Chemical Analysis*, 3rd edn. 489 pp. Prentice Hall of India Pvt. Ltd., New Delhi.

MPEDA, 2005. *Status of shrimp farming* Marine Products Export Development Authority, Cochin, India.

Munsiri, R., C. E. Boyd and B. F. Hazek 1995. Physical and chemical characteristics of bottom soil profile in ponds at Auburn, Alabama, U.S.A. and a proposed system for describing pond soil horizon. *J. World. Aquacul. Soc.*, **26**: 346-377.

Painuli, D. and M. Pagliai 1996. Changes in porosity of three different soils induced by water infiltration. *J. Indian Soc. Soil Sci.*, **44** (3): 361-364.

Piper, C. S. 1966. *Soil and plant analysis*, p. 81-89. Hans publications, Bombay.

Selvam, V., K. K. Ravichandran, L. Gnanappazham and M. Navamuniyammal 2003. Assessment of community-based restoration of Pichavaram mangrove wetland using remote sensing data. *Curr. Sci.*, **85** (6): 794-798.

Soil Survey Report 1978. *Soil Survey and Land Use Organization*, Department of Agriculture, Chidambaram taluk, Govt. of Tamil Nadu.

Teichert – Coddington, D. R., M. Peralta and R. P. Phelps 1989. Seepage reduction in tropical fish ponds using chicken litter, *Aquacul. Eng.*, **8**: 147-154.

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