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Management of Fish Ponds Built on Acid Sulfate Soils in Buguma Creek, Niger Delta, Nigeria

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ABSTRACT: An experiment on the use of tidal flushing as a management technique for fishponds constructed in mangrove swamp of the Niger Delta was carried out at the NIOMR/ARAC brackish water fish farm, Buguma, Rivers State, Nigeria. The soils are highly acidic. pH in the wet state ranged between 6.75 and 7.70 but on air-drying, values went down to as low as 3.1. The soil acidifies the overlying pond water rapidly to pH less than 4.0 but upon tidal flushing the acidity was reduced remarkably with pH increasing to 7.1. The experiment revealed the effectiveness of tidal flushing in improving pond water quality and fish yield in brackish water ponds to about 1.25mt/ha/yr @ JASEM

Aquaculture in the mangrove swamp of the Niger Delta has gained importance in the last two decades with an estimated potential of 1.3 million Mt (Tobor 1991). Despite this great potential, brackish water aquaculture contributes very little to National fish production in Nigeria. The under utilization of mangrove swamps for aquaculture is mainly due to problems associated with the acidic nature of the soils, their reclamation and management (Dublin-Green and Ojanuga 1988). Actual and potential acid sulfate soils cover about 1 million hectares of unclassified wetlands of mangrove swamp in the Niger Delta (Pillay 1965, Brady 1981, Nsirimah and Ojanuga 1985). This zone lies between a narrow strip of beach ridges and a fairly extensive zone of fresh water swamps (Fig.1). Acid sulfate soils are naturally occurring soil and sediment containing iron sulfides. Left undisturbed, acid sulfate soils are not dangerous to the existing fauna and flora,but disturbance by excavation or drainage exposes the sulfidic compounds in the soil to atmospheric oxidation, thus producing large quantities of sulfuric acid (Muhrizal and Shamsuddin 2002). The formation of acid sulfate soils in mangrove swamps has been well documented by Brinkman and Pons 1972, Pons 1973 and Gaviria et al 1986. Problems associated with fishponds built on acid sulfate soils include; acidification of pond water, low production of phytoplanktons, poor fertilizer response, slow fish growth, low fish yield and high fish mortality. The reclamation and management of acid sulfate soils for aquacultural purposes in the Niger Delta have received very little attention. This paper is on a study carried out on the use of tidal flushing in the management of fish ponds built on acid sulfate soils in the mangrove swamp of the Niger Delta.

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MATERIALS AND METHODS

The experiment was conducted at the NIOMR/ARAC brackish water fish farm located in an extensive mangrove swamp of the Buguma Creek, Buguma, Rivers State. The tides in the creek are semi-diurnal with a mean tidal range of 1.5m. The high tidal range makes it possible to fill the ponds at high tide and drain at low tide. This process is known as tidal flushing. The mean annual rainfall in Buguma is about 2,025mm. The red mangrove *Rhizophora spp.* dominates the vegetation. Salinity of creek water varied between 9.2‰ in the rainy seasons and 19‰ in the dry season.

The fish farm consists of fifteen production and seven nursery ponds of various sizes ranging from 0.2 - 1 ha. The 1 ha ponds were under rehabilitation, while some of the smaller ponds were used for oyster and shrimp culture experiments. Soil tests conducted during the construction of the ponds revealed that severe acid sulfate soil conditions prevailed in the fish farm. A pH of 5 was recorded for wet soils from the nursery ponds (Pillay 1965), while Dublin-Green (1986) recorded a pH of 4.5 in the newly constructed production ponds. Two production ponds K and J (0.5 ha each) were used for the experiment. The effectiveness of repeated flushing using tidal water to remove acidity from the soil was determined. Pond K was managed by using tidal flushing while, pond J served as control.

At the beginning of the experiment, four soil samples (i – iv) were collected along a transect from each pond and analysed for the following parameters according to McKeague (1978). pH, particle size, organic carbon, total nitrogen, available phosphorous, Exchangeable acidity, Cation Exchangeable Capacity (CEC), cations (Ca, mg, K) and sulfate-sulfur ions. The ponds were reclaimed and prepared for stocking

by draining and repeated flushing with tidal water, while organic fertilizer (chicken manure) was applied before stocking.

In the laboratory, soil pastes (1:1 soil: water ratio) were prepared for immediate measurement of soil pH using a glass-electrode pH meter. Sub samples were air-dried and pH monitored at 5-day interval for 40 days till a constant pH was achieved. Particle size analysis was determined by the pipette method following the removal of organic matter. Organic carbon was determined by the oxidation method of Walkley and Black, while total nitrogen was analysed using the semi-micro Kjeldal method. The available phosphorous of the soil was extracted with Bray-1-solution and the phosphate in solution assayed by the ascorbic acid-molybdenum blue colour method. Exchangeable acidity was extracted with IM KCl solution and the extract titrated with 0.1M NaOH solution. Cation Exchange Capacity (CEC) was determined by Sodium acetate (NaOAc) method. The exchangeable cations; Ca^{2+}, mg^{2+} in the sodium acetate extract was determined using EDTA titration, while K^{+} was determined by flame photometry. Sulfate-S was extracted by KH_2PO_4 method and ions in the extract determined by turbidimetric method. Details of procedures are in accordance with McKeague (1978). Two species of herbivorous fish – *Tilapia guineensis* and *Sarotherodon melanotheron* fingerlings were stocked in each pond at a stocking density of $5/m^2$ and $2/m^2$ respectively. The average weight of stocking was 25.10g, with weight varying from 20.3 – 30.4 g. The fish were fed with a 30% crude protein diet made of shrimp waste, brewers yeast and palm kernel meal in the ratio of 3:1:1. During the six-month grow-out period, pond K was flushed weekly with tidal water from the creek, while Pond J was left unflushed. Physico-chemical parameters such as; pH, dissolved oxygen and alkalinity of the water in the two ponds were monitored daily. At the end of the six months experimental period, the ponds were drained and the fish harvested.

RESULTS

Physical and Chemical Properties of Soil

Texturally, the ponds' soils ranged from loamy sand to silty loam. The soils have low bulk density due to high amount of fibrous roots and other partly undecomposed organic matter. pH of wet and dry soil showed the tendency of all the soil samples to develop extreme acidity on air-drying. The pH in the wet state ranged from 6.75 – 7.70, but on air-drying, the pH went down to less than 3.7 in all the samples. Table 1 shows some of the physical properties of the pond soils.

Table 1: Physical and Chemical Properties of Pond Soil from the NIOMR/ARAC Fish Farm, Buguma

Sample Location (Ponds)	TX	pH		OC %	TN %	AP ppm	Exch. Acidity meq/100g Soil	CEC meq/100g Soil	K meq/100g Soil	Ca meq/100g Soil	Mg meq/100g Soil	SO_4 – S ppm
		Wet	Dry									
K (i)	LS	7.50	3.20	4.12	0.13	1.55	11.96	29.10	0.59	2.78	7.10	2,565
K (ii)	LS	7.60	3.40	4.17	0.07	1.15	12.08	29.25	0.60	1.25	2.83	1,100
K (iii)	LS	7.70	3.60	4.08	0.07	1.10	11.99	29.32	0.62	1.01	2.98	1,182
K (iv)	LS	7.60	3.50	4.03	0.06	1.25	15.01	29.86	0.62	0.86	2.88	1,000
J (i)	SS	7.10	3.50	4.38	0.35	1.40	18.20	30.05	0.65	9.10	30.20	2,765
J (ii)	SL	6.95	3.10	4.27	0.05	1.40	17.78	30.90	0.62	9.79	26.21	3,000
J (iii)	SL	7.00	3.10	4.35	0.12	1.25	18.05	29.95	0.60	11.14	26.45	2,835
J (iv)	SL	7.20	3.40	4.21	0.14	1.28	16.96	30.70	0.52	7.44	31.49	2,700

** i – v: Four samples collected along a Transect in Pond K and J: LS: Loamy Sand: SL = Sandy loam: SS = Silt loam: TX = Soil Texture: OC = Organic carbon: TN = Total nitrogen: AP = Available phosphosous*

Oxidisable organic matter expressed as carbon content in the soil was greater than 4%. Total nitrogen was low, values ranged from 0.06 –0.14%. Available phosphorous was low in all the samples, values ranged between 1.40 to 1.55ppm. Exchangeable acidity and cation exchangeable capacity (CEC) were high with values ranging from 11.96 – 18.20 and 29.1 – 30.9 meq/100g of soil respectively. Exchangeable cations; Mg, Ca and K in the soil samples were moderately high with Mg ions dominating the complex. High values of sulfate-sulfur (SO_4 – S) were recorded for all samples, values ranged between 1,000 to 2,765 ppm. The lime requirement was determined; results indicate the need for approx. 4.1 tonnes of agricultural lime per hectare for neutralization. Result of chemical analysis of pond soil is presented on Table 1.

Physico-Chemical Properties of Pond Water

Result of the experiment in Pond K showed that the pH of pond water decreased rapidly from 7.3 to 4.0 in the first six days of the experiment, but upon tidal flushing the acid exported from the acidic soil diminished rapidly with pH increasing to 7.1 (Fig. 2). The pH of water in the control pond J decreased rapidly from 7.1 to 3.8 during the first six days of the experiment. This was followed by a gradual decrease to 3.5 at the end of the experiment. Alkalinity and dissolved oxygen in Pond K were high, values ranged from 53.50 to 60.67 mg/l and 9.20 to 10.00mg/l respectively. For Pond J values for alkalinity and dissolved Oxygen ranged between 43.30 – 36.10 mg/l and 5.7 to 6.2 mg/l. A comparison of alkalinity and dissolved oxygen in ponds K and J is presented in Fig. 3.

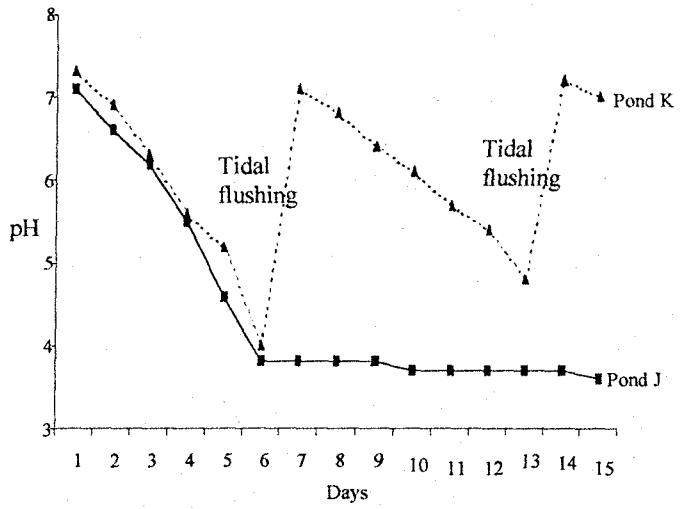

Fig.1 Effect of Tidal Flushing on pH of Pond K.

Fish Production

Data on fish production in the ponds are presented in Table 2. The survival rates for *Tilapia guineensis* and *Sarotherodon melatheron* in Pond K were 82 and 85% respectively, while in Pond J, survival rates for the two species were 40 and 58% respectively. Average weights *of T. guineensis and S. melanotheron* in Pond K at harvest after the six months experimental period were 156.0 and 84.0g respectively with weights ranging from 80.0 to 240.0 and 50.0 to 150g. 18% of *T. guineensis* weighed above 100g, while 9% of *S. melanotheron* weighed above 100g. For Pond J, the average weights of the two species at harvest were 80.0 and 62.5g respectively, with weights ranging from 68.0 to 155.0g and 50.0 to 110.0g. 4.2% of *T. guineensis* weighed Table 2 above 100g, while 2.1% of *S. melanotheron* weighed above 100g. Final fish yields in Ponds K and J at the end of the six months experimental period were 628 and 225kg/ha respectively (1.25mt/ha/yr and 0.45mt/ha/year).

Table 2: Data On Fish Production In Ponds K And J

Cultured Fish Species	Initial Wt. At Stocking (g)		Survival Rate %	Final Wt. At Harvest (g)		Yield kg/ha
	Mean Weight	Range of weight		Mean Weight	Range of Weight	
Pond K						
Tiliapia guineensis	25.00	20 – 30	82	156.0	80 – 240	275. 50
Sarotherodon melanotheron	25.10	20.3 – 30.4	85	84.0	50 - 150	352.50
Pond J						
Tiliapia guineensis	26.50	20 – 30	40	80.0	68 – 155	85.00
Sarotherodon melanotheron	26.00	20.5 - 30	58	62.5	50 – 110	140.00

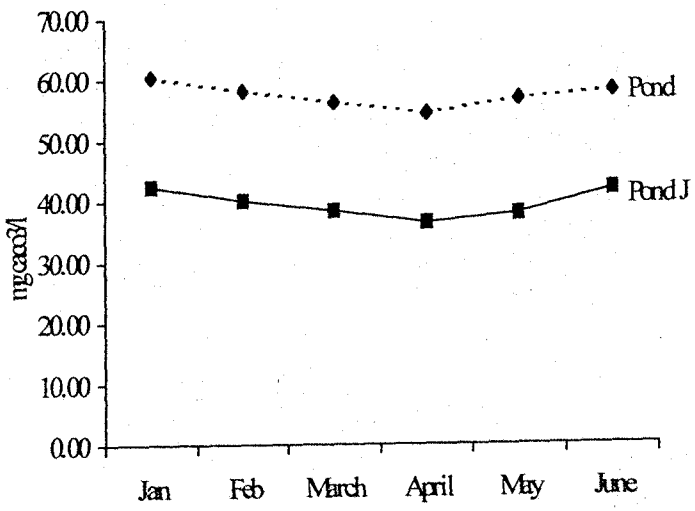

Fig.2a: Comparison of monthly mean values of Alkalinity in Ponds K and J

DISCUSSION

Results of soil analysis showed that the soil of the NIOMR/ARAC fish farm Buguma is highly acidic. Oxidation of the soil produces acid which acidifies the overlying pond water resulting in very low pH. The acidification of pond water causes poor fertilizer response, low production of phytoplanktons, slow fish growth, fish mortalities and low fish yields. This is reflected in the production level of the control pond of 0.45mt/ha/yr compared with the experimental pond of 1.25mt/ha/yr. The experiment has revealed the effectiveness of tidal flushing for removing acidity from the soil and also improving pond water quality. The pH, dissolved oxygen and alkalinity in Pond K which was subjected to regular tidal flushing were considerably higher than those recorded in the control pond J. The effects of tidal flushing on fish production as shown in Table 2 revealed that fish survival rates and fish yields were much higher in Pond K. This improvement is attributable to the regular tidal flushing.

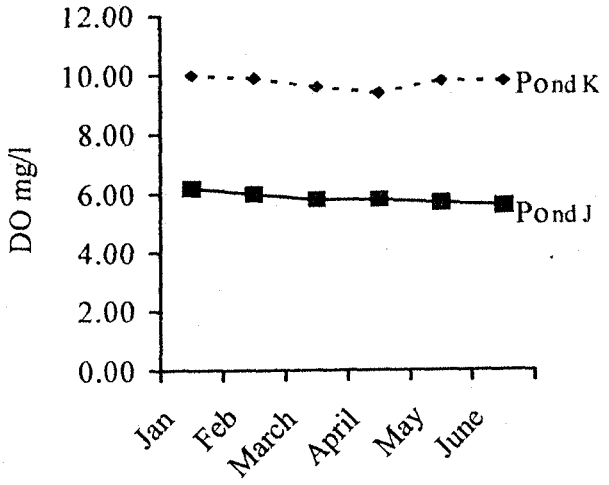

Fig. 2b: Comparison of monthly mean values of Dissolved oxygen in Ponds K and J

The most common management technique used in reducing soil acidity is by extensive use of agricultural lime. This has however proved uneconomical and also compounded by the problem of overliming and loss of phosphorous from pond water through the formation of insoluble compounds such as aluminium phosphate. Two general approaches have been proposed for development and management of fish ponds built on acid-sulfate soils. The first approach (Singh 1980) recommended the traditional Southeast Asian pond design. The ponds are tidal, management approach involved repeated flushing with seawater and addition of organic fertilizer. Production level of 1.25mt/ha/yr achieved in Pond K may possibly increase by the combination of flushing with minimal application of lime as recommended by Singh (1980).

The second approach (Simpson 1983, Simpson and Pedini 1985, Kwei-Lin 1998) advocates minimal excavation in order not to expose acidic soil layers. Dykes should not be massive, while the use of pumps to fill and drain ponds rather than by tidal exchange was recommended. This approach has been found to be capital intensive and not feasible in the study area due to lack of necessary infrastructure such as electricity. The findings in this study has suggested that fish production in the mangrove swamp of the Niger Delta may be substantially increased to bridge the wide gap between fish demand and supply through the management technique of tidal flushing combined with minimal application of lime. Utilization of about 100,000 ha of Niger Delta mangrove swamp will translate into 125,000mt of fish per annum.

Conclusion: Based on the result of this study and the various approaches reviewed from literature, the following measures are suggested for the reclamation and management of fishponds built on acid sulfate soils of mangrove swamp in the Niger Delta: -
Large-scale excavation of soil should be avoided during fishpond construction to prevent the exposure of sulfidic layers. Pond preparation for fish culture should include drying of pond bottom followed by repeated flushing with tidal water until a pH of 7.0 is achieved for pond water. Regular monitoring of pond pH should be carried out and tidal flushing embarked upon as soon as pH decreases to 5.0. Production practices to raise fish yields should adopt a combination of regular flushing of pond water, low rates of liming and low organic fertilizer application. It is also important that older and heavier fingerlings than usual should be used for stocking.

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