Reclamation and management of brackish water fish ponds in acid sulfate soils: Philippine experience

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1 Summary

The rapid reclamation technique described by Brinkman and Singh in the last Acid Sulfate Soils Symposium in 1981 was applied in several experimental and commercial fish ponds in Panay and Negros Islands in the Philippines. The basic concept in this technique was to remove the source of acidity from the upper 15 cm pond bottom soil and preventing further diffusion of acids, and aluminium and ferrous salts from the sub-soil to the pond water during fish rearing period. To do so, it required a repeated sequence (4-5 times) of drying, tilling, flooding and draining of the pond bottom, and leaching of relatively big dikes. Subsequently, a small amount of lime (< 500 kg/ha) was also needed to counteract the diffusion of acidity from underneath.

The results obtained from this study have been very encouraging and successful both in terms of improving soil and water quality, and fish yields. Based on the results obtained, a technology package was prepared and disseminated for the use of farmers. Because of its simplicty, practicality and high effectiveness at economic costs, many farmers in Panay and Negros islands, and elsewhere in the country have adopted this technique and benefitted from it.

After reclamation, soil properties indicated a general decrease in the concentrations of sulfates (from 6145 to 630 ppm), aluminium (160 to 12 ppm) and pyritic iron (3300 to 1800 ppm) and an increase in pH of dry soil by about 1.1 to 1.4 units (from 3.5 to 4.8). Similar improvements were also recorded in water properties. The pH increased form 3.9 to 6.5 and alkalinity from 22 ppm to 47 ppm while the levels of aluminium, iron and sulfate decreased to 0.18, 1.35 and 773 ppm from 2.9, 3.5 and 1800 ppm, respectively.

In all crop seasons, the growth of fish-food organisms (Lab-Lab) in reclaimed ponds was four times more than in unreclaimed ones, although both received similar productions inputs. Likewise, milkfish and prawn production in reclaimed ponds was five times higher (530 kg/ha milkfish and 32 kg/ha prawns) than in unreclaimed ponds (112 kg/ha milkfish and no prawns). In reclaimed ponds fish mortalities were less and weight gains/fish were higher than in unreclaimed ponds.

After the first season, there was further improvement in the soil and water quality and fish production in reclaimed ponds. Details of these results and economic analysis of reclamation, are presented and discussed in the paper.

Résumé

La technique d'assainissement rapide décrite par Brinkman et Singh lors du dernier symposium sur les sols sulfaté-acides, tenu en 1981, a été employée dans plusieurs viviers à poissons de types expérimental et commercial à Panay et Negros Islands, aux Philippines. Le concept sur lequel repose cette technique consistait à éliminer la source d'acidité présente dans la couche supérieure de sol – d'une épaisseur de 15 cm – du lit du vivier et à empêcher toute autre remontée d'acides et de sels aluminiques et ferreux du sous-sol dans l'eau du vivier, pendant la période d'élevage des poissons. Pour ce faire, il fallait procéder à des séances répétées (4 à 5 fois) de séchage, de labour, d'inondation et de drainage du lit du vivier, ainsi qu'au lessivage de digues de taille relativement importante.

Ensuite, il fallait appliquer une petite quantité de chaux (500 kg/ha) afin de contrecarrer la diffusion d'acides contenus dans les couches inférieures du sol.

Les résultats obtenus à la faveur de cette étude ont été très encourageants et on fait leurs preuves en termes d'amélioration de la qualité des sols et de l'eau et de rendements dans la production de poissons. A partir des résultats obtenus, on a donc préparé, puis disséminé un ensemble de techniques à l'usage des paysans. Cette technique étant simple, pratique et hautement efficace, a séduit de nombreux pisciculteurs de Panay et des Negros Islands pour ensuite être adoptée dans d'autres régions du pays, où elle porte ses fruits.

Après l'assainissement, les caractéristiques des sols indiquaient une régression générale de la concentration de sulfates (de 6145 à 630 ppm), d'aluminium (de 160 à 12 ppm) et de fer pyritique de (3300 à 1800 ppm), et une augmentation du pH du sol sec de l'ordre de 1,1 à 1,4 unités (de 3,5 à 4,8).

Des améliorations similaires ont également été constatées dans les caractéristiques de l'eau. Ainsi, le pH a augmenté, passant de 3,9 à 6,5 unités et le taux d'alkalinité de 22 à 47 ppm tandis que les niveaux d'aluminium, de fer et de sulfate ont baissé, passant respectivement de 2,9 unités à 0,18, de 3,5 à 1,35 et de 1800 ppm à 773.

Dans toutes les campagnes de production, la croissance de la biomasse alimentaire (Lab-Lab) dans les viviers a été de quatre fois supérieure à celle qui a été observée dans les viviers non-assainis et ce bien que les uns comme les autres aient reçu les mêmes intrants de production. De même, la production de 'milkfish' et de crevettes dans les viviers assainis a été de cinq fois supérieure (530 kg/ha de 'milkfish' et 32 kg/ha de crevettes) à celle des viviers non-assainis (112 kg/ha de 'milkfish' et pas de crevettes du tout). Dans les viviers assainis, le taux de mortalité des poissons a été inférieur et le gain pondéral à l'unité de poisson supérieur à ceux qui ont été relevés dans les viviers non-assainis.

Après la première campagne de production, on a constaté une nouvelle amélioration tant de la qualité des sols et de l'eau que de la production de poissons dans les viviers assainis. Les détails concernant les résultats de cette enquête et de l'analyse économique de l'assainissement sont présentés et discutés en détail dans la présente étude.

2 Introduction

Acid sulfate soils develop strong acidity upon drainage and drying. They are common in brackish water mangrove tidal swamp areas. With the rapid expansion of fish ponds, in potential and actual acid sulfate soil areas, the problems of high acidity,low productivity, poor fertilizer response, fish kills and high levels of iron, aluminum, sulfate and in some cases manganese, have become acute and more pronounced.

Whenever these soils are subjected to oxidation by excavation or by drainage and drying, the two inevitable operations in establishing and managing fish ponds, the result is strong acidity with the above mentioned adverse effects. The problems have been commonly observed in many countries in Southeast Asia, Africa and in Latin America. In the Bangkok symposium on acid sulphate soils of 1981 the phenomena involved were analysed in detail and presented by Brinkman and Singh (1982), Singh (1982 a and b). Brinkman and Singh (1982) reviewed the earlier reclamation efforts and prepared a rapid reclamation technique for brackish water fish ponds in acid sulfate soils. Since then this technique has been tested and adjusted in several experimental and commercial fish ponds in Panay and Negros islands, Philippines and the results have been very encouraging.

After two years of verification, a technology package was prepared and disseminated for the use of farmers. Because of its simplicity, practicality and high effectiveness at economic costs many farmers in these islands and elsewhere in the country, have adopted the technique and benefitted from it. The details of reclamation results are presented and discussed in this paper.

3 Nature and magnitude of problems in fish ponds with acid sulfate soils

Various problems faced by farmers in fish ponds with acid sulfate soils have been summarized by Potter (1976), Singh (1980), Brinkman and Singh (1982), Poernomo (1983), and Singh and Poernomo (1983).

3.1 General

The most common phenomena observed in the ponds are poor fertilizer (especially-P) response, dark brown or clear brown water with little and poor natural fish food production, slow growth of fish, soft shelled prawns, in severe cases fish kills especially during heavy rain after long dry periods and erosion of pond dikes.

Fish mortalities are also observed in the canals that receive water drained form acidic ponds or acid sulfate areas.

3.2 Algae growth and fertilizer response

The growth of algae is observed to be restricted or inhibited by low pH, low phosphate concentration (Figure 1) and high aluminium and high iron (Figure 2) content. At

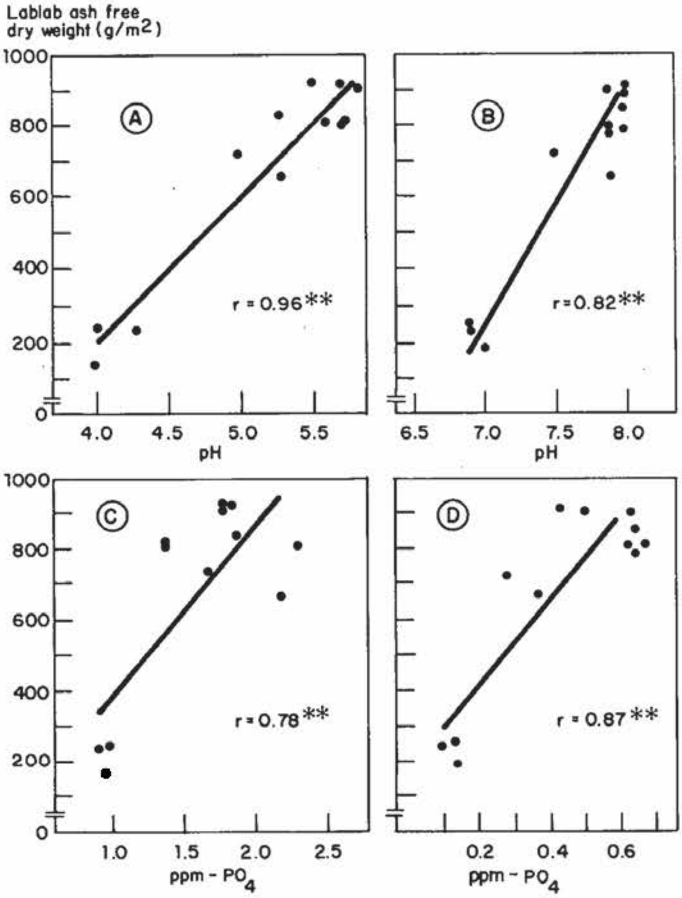

Figure 1 Relationships of Lab-lab production with soil pH (A) water pH (B), soil available-P (C) and dissolved-P in water (D)

low pH the solubility of aluminum, iron, and sulfate is high (Figure 3). These high concentrations of aluminium and iron render the phosphate unavailable (Figure 3) as it is fixed into insoluble aluminum and ferric-posphate compounds. This leads to severe phosphate deficiency for algae growth.

Stum and Morgan (1970) reported that high concentrations of aluminium and iron render silicates and molybdenum unavailable which affect nitrogen metabolism and cellular function in algae. The high concentration of iron and aluminium are also reported to inhibit cell division (Clarkson 1969) and disrupt the activities of protenaceous enzymes in the cell wall (Woolhouse 1970). However, other than the general decrease in biomass production and changes in species composition of the biomass, directly observable effects (symptoms) of acid sulfate on algae have not been established.

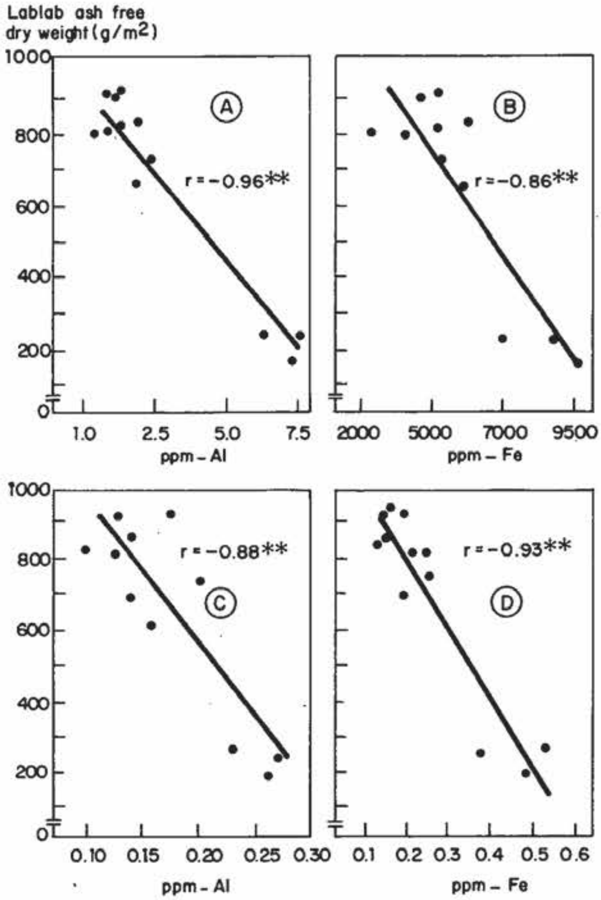

Figure 2 Relationships of Lab-lab production with soil-A1 (A), soil active- Fe (B), aluminum in water (C) and iron in water (D)

3.3 Fish health

High concentrations of aluminum and iron together with low pH become toxic to fish and result in fish kills. This is more pronounced and evident when there is a sudden influx of acid water washed down from the dikes during the early rainy season. In most fish ponds with acid sulfate soils, the concentrations of iron and aluminium reach beyond the tolerance limit to most fishes. The tolerance limits for iron and aluminium to most fishes are reported to be 0.2 and 0.5 ppm, respectively (Nikolsky 1973).

In less severe cases, marginal for fish health, these elements create chronic stress trough ionic imbalance in the fish body and as a result fish becomes more susceptible to diseases and parasites.

Prawns grown in these situations face an even worse problem; besides being soft-shelled due to lack of calcium and other essential elements for shell formation their gills are clogged with finely suspended ferric oxides and hydroxides.

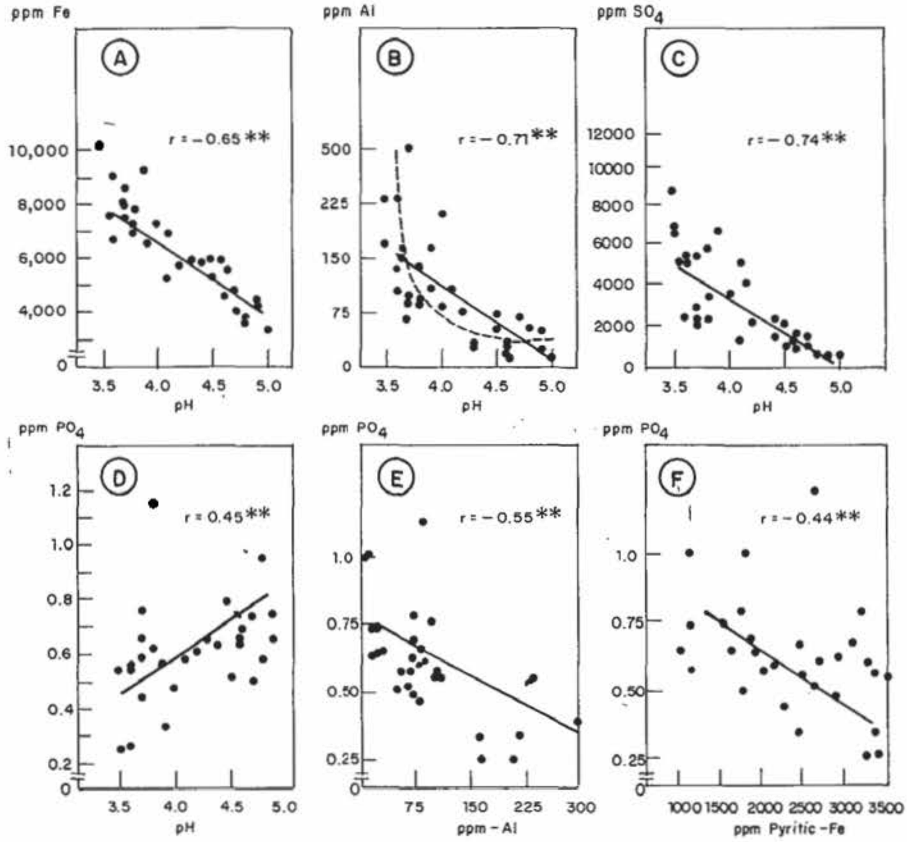

Figure 3 Relationships of soil pH with active-Fe (A), exchangeable-Al (B), sulfate (C) and available-P (D), and soil available-P with exchangeable-Al (E) and pyritic-Fe (F)

3.4 Dike erosion and pond siltation

A lesser problem due to the lack of vegetative cover is the very rapid erosion of dikes and siltation in the pond. Grasses hardly survive on the acidic dike soil. Thus, aside from being detrimental to the pond biota (fish and fish food organisms), acid sulfate soil conditions add to the cost of physical maintenance of dikes and pond desiltation.

4 Reclamation of acid sulfate fish ponds in the Philippines

4.1 Reclamation procedures

The basic concept in this technique is to remove the source of acidity by oxidizing the pyrites from the upper 15 cm. pond bottom soil and preventing further diffusion of acids, and aluminium and ferrous salts from the sub-soil to the pond water during fish rearing periods. This requires a repeated sequence (4-5 times) of drying, tilling, flooding and draining of the pond bottom, and leaching of relatively big dikes. Subsequently, a small quantity (500 kg/ha.) of finely ground (60-100 mesh) agricultural lime is also needed to counteract possible diffusion of acidity from underneath. The details of this procedure can be read in Brinkman & Singh (1982).

In the last five years this procedure has been applied in several experimental and commercial fish ponds in Panay and Negros island, Philippines. Depending on the prevailing conditions like weather (mainly rainfall), amount and distribution of pyrites, texture, structure and moisture in the soil and the presence of compounds like calcium carbonate, the entire reclamation work is completed in about 3-4 months. Leaching of dikes is done only in a few cases where primary dikes were relatively big or where large secondary dikes surround nurseries and fingerling ponds of relatively small size.

Reclamation in considerably easier in a distinct monsoon and dry climate than in perennially even climatic conditions. The maximum effect of reclamation is expected if carried out in the dry season with soil moisture of about 30-40%.

Heterogeneous distribution of pyrites in the soil has to be taken into account . In the large root remnants pyrite concentrations are oxidized relatively fast due to easy access of oxygen. The acid formed upon oxidation is also leached rapidly. With limited sponge structure on the other hand in soil the oxidation front moves downward very slowly after drainage so that soluble acids are also leached out slowly. Tilling the pond bottom thus creates a situation in which the greater surface area exposed after tilling leads to faster oxidation and the wider pore space facilities the leaching of oxidation products.

Pyrite sediments rich in $CaCo_3$ do not give rise to acid sulfate soil conditions when their lime content matches the equivalent acidity potential of the pyrite. Smaller amounts of lime may slow down the initial oxidation of pyrite and the completion of the reclamation operation.

4.2 Management of reclaimed fish ponds

In the experimental and commercial fish ponds that were reclaimed with the described method, preparation for growing natural fish food (benthic algae and other microorganisms that grow in the pond bottom, locally called lab-lab) and fish rearing was started immediately after completing the reclamation. The lime application as recommended earlier was done at the rate of 500 kg/ha after completing reclamation or just in the beginning of pond preparation. Growing of fish food (lab-lab) was practised by following the standard pond preparation and management practices. Only milkfish was grown in the first season. The prawns were tried in poly/mix culture with the milkfish in the second season and thereafter also by following the standard fish growing techniques.

All fish pond operations except the fertilizer management were carried out in the usual manner as that practised in normal fishponds. A total of 48 kg N and 60 kg P_2O_5/ha was applied in six bi-weekly split applications during the entire fish growing period which ranged from 90-120 days. The fertilizer management and other suggestions for reclaimed fish ponds in acid sulfate soils are presented in another paper of this symposium (Singh et al. 1986).

5 Reclamation experiences and results

The results of fishpond reclamation with the described technique at different locations in the Philippines have been very encouraging and successful. Similar satisfactory results have also been reported from trials conducted at experiment stations and privately owned fish ponds by Poernomo 1983, Poernomo and Singh 1982, Bantala 1983, Singh and Darvin 1983, Singh and Poernomo 1984, Neue and Singh 1984, Soveyanhadi 1985 and Singh 1985.

Based on these results a technology package has been prepared and disseminated for the use of farmers. In the following the results of a specific representative case are presented and reviewed.

The properties of the pond bottom and dike soil and pond water before and after reclamation are shown in Tables 1, 2 and 3. The results of lab-lab and fish production are shown in Table 4.

5.1 Soil properties

In the beginning the low pH (3.6) combined with high concentrations of exchangeable Al, (160 ppm) active Fe, (7800 ppm) and acetate soluble SO_4 (6100 ppm) (Table 1) indicate extremely acidic condition. Because of the intense oxidation of pyrites, the dike soil was even more acidic than the pond bottom.

The concentrations of aluminium and iron in the pond soil due to low pH are very high and are far beyond the tolerance limits for most fishes, which generally are about 0.5 ppm and 0.2 ppm, respectively (Nikolsky 1973). The extremely low concentration of available phosphorus (0.30 ppm) in the pond bottom soil is attributed to the high binding capacity of excess amounts of aluminium and iron (Table 1).

Table 1. Some properties of pond bottom soil before and after reclamation and after the harvest of first crop (after Singh 1985)

Property*	Before reclamation		After reclamation		After harvest	
	Control	Treated	Control	Treated	Control	Treated
pH – Wet	5.8	5.7	5.6	6.0	5.8	6.8
pH – Dry	3.7	3.6	3.7	4.8	3.8	5.7
Eh (mV)	230	220	70	10	–120	–150
Exch. Al	160	135	85	12	63	10
Active Fe	7845	7600	7910	3630	7670	2960
Pyritic Fe	3350	3320	3140	1865	3200	1620
Active Mn	15	16	12	10	7	0
Acetate sol. SO_4	6145	5612	2075	630	2000	700
Avail. PO_4	0.30	0.25	0.66	1.03	1.13	1.43

* Except the pH and Eh, all others are in ppm (mg/kg)

In the tilled pond bottoms vigorous oxidation resulted in the formation of bright-red ferric-oxides and brown ferric hydroxide with an efflorescent film of aluminum sulfate. These colorations became clearly visible in two days after shallow flooding (2.5 cm).

The formation of colored deposits gradually decreased with repeating the sequence of drying, tilling, flooding and rush draining. At the end of the reclamation, no reddish coloration was noticeable in the reclaimed ponds. In contrast the bottom of unreclaimed ponds remained evenly red throughout. The red color in control ponds was evident even after harvesting the first fish crop. During and after reclamation there were significant improvements in soil quality.

After 3 months reclamation both potential and actual acidity had decreased as expressed (Table 1) in decrease of pyritic iron (from 3320-1865 ppm) acetate soluble sulfate (6100-630 ppm) and exchangeable aluminium (160-12 ppm) and by the increase of pH of dry soil with 1.2 units (3.6-4.8). The available PO_4 in treated ponds increased from 0.25 to 1.03 ppm. In contrast, there was little change in the pH and other properties of control ponds and such change this was due to superficial washing by rains.

The dry soil pH (4.8) attained after reclamation (Table 1) was enough to maintain and ideal pH wet (6.8) of the submerged reduced pond bottom soil and (7.0 to 8.5) of pond water during lab-lab and fish growing. The lab-lab growth further helped in maintaining these pH levels. This situation in turn was optimal for the solubility and availability of phosphate for lab-lab growth; fixation of phosphorus is known to be minimal at these pH levels.

In the control ponds where the concentrations of aluminium and iron were high and the soil pH low, phosphate fixation was apparently vigorous. That is why in these ponds even just after fertilizer application the levels of phosphate remained constantly low. Singh (1982 a) and Soveynhadi (1985) noted that after application of 100 kg P_5O_5/ha., the available P level in acid sulfate soils was almost gone in about 2 days; while in neutral and reclaimed soils applied with the same rate, it remained above 2 ppm for several weeks. A similar trend in the changes of soil properties was also observed for dike soil (Table 2).

After fish harvest from the reclaimed and control ponds both treated with chicken manure and 48 kg N and 60 kg P_2O_5 per ha as a standard operation practice the analytical results indicated that the reclaimed pond soils attained a higher dry pH (5.7); and also had lower concentrations of aluminium (10 ppm), active and pyritic iron (2960 ppm and 1920 ppm, respectively), and sulfates (700 ppm) than the control ponds in

Table 2. Some properties of dike soil before and after reclamation (after Singh 1985)

Property*	Before reclamation		After reclamation	
	Control	Treated	Control	Treated
pH – Wet	3.6	3.6	3.6	4.1
ph – Dry	3.0	3.1	3.6	4.1
Eh (mV)	370	360	340	290
Exch. Al	360	330	250	118
Active Fe	9850	9650	9160	5285
Pyritic Fe	2330	3120	1770	1360
Active Mn	17	15	11	6
Acetate sol. SO_4	9440	8720	7000	1080
Avail. PO_4	0.40	0.40	0.55	0.80

* Except pH and Eh, all others are in ppm (mg/kg).

which these concentrations were at least twice as high (Table 1). In the treated ponds the level of available phosphorus (1.43 ppm) was higher than in the control ponds (1.13 ppm).

5.2 Water properties

Before reclamation the chemical properties of water in both the control and treated ponds, had similar magnitudes. Water pH was 3.9, alkalinity 22 ppm, aluminum 3.5 ppm, iron 9.3 ppm and sulfate 1800 ppm (Table 3). Due to low pH and high aluminum, iron and sulfate levels, the dissolved phosphorus in water was essentially zero. These conditions indicate a very highly acidic and unfavorable situation for growing milkfish and prawns.

After the 3 months reclamation period, the water quality in ponds improved significantly. The water pH increased to 6.5, alkalinity to 47 ppm (Table 3) and the levels of aluminum, iron and sulfate decreased to 0,18 ppm, 1.30 ppm and 770 ppm, respectively (Table 3). Dissolved phosphorus improved from 0.0 to 0.02 ppm. Slight improvements also occurred in the control ponds but these were mainly due to occasional overflow of water from previously dried ponds because of heavy rains during the reclamation period (Table 3).

Table 3. Some properties of pond water in acid sulfate soils before and after reclamation and after harvest of first crop (after Singh 1985)

	Before reclamation		After reclamation		After harvest	
Property*	Control	Treated	Control	Treated	Control	Treated
pH	3.9	3.9	4.2	6.5	6.9	8.0
Alkalinity	20.3	23.1	23.1	47.3	49.0	98.5
Aluminium	2.9	4.1	1.7	0.18	0.04	0.02
Iron	9.3	9.3	3.9	1.35	0.40	0.16
Sulfate	1720	1930	1060	770	1070	680
Phosphate	0.0	0.0	0.01	0.02	0.02	0.20

* Except pH, all others are in ppm (mg/l).

During the fish growing period and thereafter, water quality in the reclaimed ponds further improved significantly. After harvesting the fish grown in the control as well as reclaimed ponds (both had received the same fertilizer and other inputs) the improvement in water quality of the reclaimed ponds was remarkably better than that in the control. Aluminium and iron in reclaimed ponds decreased to negligible levels, sulfate decreased considerably and pH, alkalinity and phosphorus levels increased significantly (Table 3).

5.3 Lab-lab and fish production

5.3.1 Lab-lab

The significantly lower production of lab-lab in the control ponds (Table 4) compared with that in reclaimed ones is attributed to the constantly low concentration of the available phosphorus. In the reclaimed ponds, fixation of phosphorus by the soil seems to have been much less because of high pH and reduced concentrations of aluminium and iron.

Table 4. Lab-lab production (ash free dry wt. g/m^2), fish survival (%), weight gain (g/fish) and yield (kg/ha) in control and reclaimed ponds with acid sulfate soils (after Singh 1985)*

Treatment	Lab-lab production g/m^2	Milkfish Survival %	Milkfish Weight gain g/fish	Milkfish Yield kg/ha	Prawn Survival %	Prawn Weight gain g/prawn	Prawn Yield kg/ha
First season							
Control	198	43	108	112	–	–	–
Reclaimed	672	93	124	442	–	–	–
Second season							
Control	230	45	110	150	2	8	3
Reclaimed	780	90	178	500	15	13	32
Third season							
Control	248	50	107	150	7	10	15
Reclaimed	800	90	175	550	28	18	60

* Lab-lab and milkfish values are over a period of 90 days, while those for prawns over a period of 120 days; prawns were not stocked in the first season. In control ponds they are generally soft shelled.

The growth of lab-lab in control ponds in all seasons was about four times less than that in the reclaimed ponds (Table 4) although both received the same amount of fertilizer and other management inputs. Even in the second and third seasons after reclamation the growth of lab-lab in reclaimed ponds was significantly higher than that in control ponds, although the total amount produced remained almost the same as in the first season.

The lab-lab mat which grew evenly on reclaimed pond bottom seems to have acted as a barrier and prevented the phosphorus fixation into the soil. After establishing lab-lab growth, subsequent application of fertilizer also provided ideal condition for utilization of P by lab-lab because the fertilizer ultimately settled on the lab-lab and in the water column. Lab-lab growth in all the reclaimed ponds was so thick that thinning was done to avoid the danger of sudden decomposition.

The dominant component species of lab-lab in the reclaimed ponds were different from those in the control ponds. In reclaimed ponds dominated Nitzachia, Anabaenopsis, Oscillatoria, Lyngbia, Rotatoria, Copepods and Nematodes. In the control ponds Pleurostigma and Gyrostigma were the dominant species of lab-lab.

5.3.2 Milkfish

Despite of equal inputs reclaimed ponds produced more milkfish (442 kg/ha in the first season) than the control ponds (112 kg/ha, table 4).

Twice in the first season there were mortalities in the control ponds leaving only 43% survival. The survival in the reclaimed ponds was 93%. Also in the succeeding seasons, the number of fish that died in control ponds was about twice that in the reclaimed ones.

Theoretically, fishes in the control ponds should have gained more weight than in the reclaimed ones (because of fewer fish and less competition in the controls as a result of high mortality), buth the results were otherwise. The fish in the reclaimed ponds weighed about 50 g more (av. 160 g/fish) than the ones in the control (av. 110 g). This indicates that the supply of natural food in the control pond was not sufficient and the water quality was poor. This observation was further confirmed by the length-weight analysis. Fish production in both treatments was significantly correlated with lab-lab growth.

5.3.3 Prawns

In the first season after reclamation prawns were not stocked in any of the ponds. In the second and third season they were stocked together with milkfish. This was done in both the reclaimed and control ponds.

They were not fed with any artificial/synthetic feed.

The survival of prawns in the second season was rather low in both ponds but it was significantly higher (15%) in reclaimed ponds (Table 4) than in the control ones (2%). Again, even with the poor survival the weight of prawn was lighter than normal. In control ponds it averaged 8g/ prawn in the reclaimed ponds 13 g/prawn. At the end of the culture period, total production in the control ponds was only 3 kg/ha; while in the reclaimed ponds it was 32 kg/ha.

In the third season after reclamation i.e. the second season of prawn growing, the survival, weight gain and production of prawns increased markedly in the reclaimed ponds to 28%, 18 g/prawn and 60 kg/ha, respectively (Table 4); against only 7% 10 g/prawn and 15 kg/ha in the control ponds.

Besides low survival and production, prawns in the control ponds were soft shelled apparently due to the lack of calcium and phosphorus, as normally observed in acid sulfate soils.

5.4 Effects of forced leaching of dikes

The technique of fishpond reclamation includes forced oxidation and leaching of larger dikes with potential acid sulfate soil material, to prevent contamination of pond water by acids washed from the dike body in the rainy season. The effect of preventive dike leaching on the lab-lab and fish production was not apparent in the first season of fish growing. It became significant and more pronounced in the subsequent growing seasons especially during distinct rainy periods. The ponds with unleached dikes showed higher fish mortality and lower production than the ponds with leached dikes even if the bottoms of both were reclaimed. The unleached dikes had more acidic water seeping out, thus, represented more potential hazards of fish kills.

6 Returns

Based on an improved fish yield of 330 kg/ha per crop over control, gross revenue increased by $215.8 (Table 5) for the first season after reclamation. The net income in the first season increased by about $124.40/ha equal to a return of $1.35 per dollar invested in the reclamation. It should be noted however,that the cost of reclamation is incurred only once while the benefits of reclamation are expected to last several fish growing seasons or forever. At present it is the sixth season after reclamation and there is no indication of reoccurrence of the problem. The cost of reclamation therefore, should be amortized over at least six fish growing seasons.

Moreover, the results indicate that in the succeeding seasons after reclamation there is further increase in production especially of prawns. Therefore, the returns are supposed to increase further and the cost benefit-ratio of reclamation to improve.

Table 5. Cost and returns* of reclaiming fishponds in acid sulfate soils for one fish growing season (after Singh and Darvin 1983)

Particulars		Value ($/ha).
Cost of reclamation**		
– Tilling of the pond bottom (three times at $12 each)		36.00
– Construction of levees at the top of dikes ($0.05/m)		20.00
– Fuel cost to run a water pump for dike leaching (three to four times)		15.36
– Labor cost (8-10 men days at $2/day)		20.00
	Sub total	91.36
Returns		
– Increase in Gross returns: increase in fish production (in reclaimed less in control = 330 kg/ha) multipield by price of fish ($0.65/kg)		214.50
– Net returns: increase in gross returns minus the cost of reclamation (214.50 – 91.36)		123.14
– Benefit-cost Ratio***		1.35

* All computations are based on the data from first season after reclamation.

** Except for the reclamation other costs were same in control and reclaimed ponds.

*** The benefits of reclamation appear higher in the subsequent seasons after reclamation.

Based on these results, the application of this reclamation procedure seems not only practical but economically highly feasible and profitable as well. The cost of reclamation is only about $90.0/ha with a return of 150% in one season.

7 Conclusions

Acid sulfate soils are undoubtedly detrimental when excavated for fishponds, but they can be rapidly improved to become productive pond bottom soils with the proper method of reclamation.

A repeated sequence of drying, tilling and flushing (with sea water or brackish water) of the pond bottom combined with leaching of relatively big dikes preferably during the dry season, is a cheap, fast and economically feasible method of reclamation for areas with a distinct monsoon and dry climate.

A moderate and low rate application of powdered lime (500 kg/ha) broadcast on the pond bottom immediately after reclamation or during pond preparation would help speed up soil reduction, and suppress the concentrations of aluminum, iron and acids that may be released into the soil. This would also reduce the fixation of phosphate into the acid sulfate bottom soil. Application of waste materials like mudpress from sugar mills and burnt rice hulls on the wet pond bottom are also effective in reducing phosphate fixation.

To further avoid excessive phosphate fixation in pond bottom soil,small weekly dressings of preferably slow release fertilizers, are recommended.

Instead of prefingerling, post fingerling size of milkfish or other hardy fishes should be stocked in the first or second season after reclamation. Prawns should be tried afterwards in polyculture with milkfish on an experimental basis before embarking on the intensive commercial monoculture after several years.

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