Original Research Article

RELATIONSHIP BETWEEN THE PRODUCTIVITY AND NUTRIENT PROFILE OF BOTTOM SOILS OF SELECTED REGULAR AND INTEGRATED FISH PONDS IN IBADAN, NIGERIA

ABSTRACT

Water quality management has been considered one of the most important aspects of pond aquaculture for many years, but less attention has been given to the management of pond bottom soil. The quality of pond bottom soils greatly impacts the productivity of ponds with respect to fish production. The objective of this study is to explain the nutrient profile of bottom soils of selected regular and integrated ponds in the Ibadan metropolis, Oyo State, Nigeria. Bottom soils and water samples of three regular and three integrated ponds in Ibadan metropolis, Nigeria were sampled. In each pond, soil samples were sampledfrom two different points at three depths each (inlet and outlet) of 0-10cm,10-20cm and 20-30cm. Soil samples were also analysed for; pH, organic carbon, organic matter, nitrogen, phosphorous and potassium. The productivity of the ponds was evaluated using the measured parameters in line with standard procedures. The data obtained were analyzed using descriptive statistics, one-way analysis of variance, correlationand regression analysis. The organic carbon of all the ponds indicated that they were all suitable for aquaculture production with average values ranging from 0.82% to 2.66%. Three of the ponds' bottom soil were of mineral soils having medium organic carbon of mean values 1.81%, 1.73% and 2.66% for integrated pond 3, regular ponds 1 and 3 respectively while the three other ponds were of organic soils having high organic carbon concentration of mean values 1.06%,0.82% and 1.01% for integrated ponds 3and 2 and regular pond 2. The pond soils were all neutral except two of the regular ponds with average values ranging from 7.00 to 9.60. All the mean values of phosphorous in the soil indicated that the soils were of high productivity and highly suitable for aquaculture production. Mean soil phosphorous concentration values 0.33%, 0.30%, 0.26%, 0.27%, 0.28% and 0.34% of integrated ponds 1 to 3 and regular ponds 1-3 respectively showed that the ponds were highly suitable for fish culture with respect to ability to synthesize phytoplankton and zooplanktons. The organic carbon concentration and the phosphorous concentration of all the ponds showed high productivity. The pH and the nitrogen concentration of all the ponds showed high productivity. Generally, the evaluation of the ponds in line with the three standard procedures indicated that the integrated pond soils was more productive for fish culture than the regular pond soils.

Key words : Fish culture, water quality, pond productivity, pond soil.

INTRODUCTION

Fish ponds or fishing enclosure are controlled, artificial lakes, or reservoir that are stocked with fish and used for fish farming, recreational fishing and ornamental purposes. In the modern day fish farming systems, most fish production from culture fisheries rely heavily on especially earthen ponds which can be either an embankment or excavated pond (Ajani *et. al*., 2011). "Sediment is a naturally occurring material that is broken down by processes of weathering and erosion, and is subsequently transported by the action of wind, water, or ice and/ or by the force of gravity acting on the particles. Aquaculture production in earthen ponds is one of the most common types of fish production system. The ponds are either dug with hand or with the use of heavy equipment, it varies in shape depending on the shape of the land where it is constructed. Earthen ponds can be embankment ponds, excavated ponds or barrage ponds. Earthen ponds are easier to manage and production is usually faster because of the addition of natural foods to supplement the feed given to the fish. The ponds are however prone to predators if not properly managed which can reduce production drastically" (Omitoyin, 2007). "When aquaculture fish ponds are constructed, one or more of the upper terrestrial soil is usually removed, and subsoil is exposed to water when ponds are filled. All fish pond bottom soil become covered with sediment (mostly organic components), and this sediment can be considered aquaculture pond soil. In describing various physical, chemical and biological processes occurring in the pond bottom, it is convenient to refer bottom deposit as sediment. However, the sediment layers in the bottom of an aquaculture pond are referred to as pond soil" (Avnimelech*et.al.*, 1984; Boyd, 1995)."Fish is an essential food requirement being a good and cheap source of high quality animal protein considered as very vital for growth, good health, and very much acceptable to man. It is generally believed that bottom soil quality in ponds deteriorates over time because of sediment accumulation, declining pH, and increasing organic matter concentration but much less effort has been devoted to the condition and management of freshwater pond bottoms" (Limsuwan and

Chanratchakool 2004). One of the most important parts of fish farming is finding the right place for the pond. The history of aquaculture farming projects all over the country and world has led to the conclusion that the right selection of sites is probably the most important factor that determines the feasibility of viable operations. Even though many years of painful efforts and new technology have turned some farms on poor sites into productive units, many have been abandoned after a considerable investment of money and effort. So there is no underestimating the basic importance of selection of the sites which are most suitable for successful and profitable aquaculture farming activity.

"The success of fish production relies greatly on the habitat provided.The quality of soil is important in pond farms, not only because of it influenced the productivity and quality of the overlying water, but also because of its suitability for dike construction; the ability of ponds to retain the required water level is also greatly affected by the characteristics of the soil. It is therefore essential to carry out appropriate soil investigations when selecting sites. Such investigations may vary from simple visual and tactile inspection to detailed subsurface exploration and laboratory tests. Because of the importance of soil quality, detailed investigations are recommended particularly when large scale farms are proposed. An adequate supply of good quality water that is rich in oxygen, nutrient and free from pollutants must be available all year round. The success of an aquaculture pond depends greatly on the good management of the pond soil" (Aruleba and Agbebi, 2010)."Moreover, some pond water quality variables are strongly influenced by pond bottom characteristics. Fish do not grow well in ponds with acidic water, which usually are located on acidic soils however, acidity in ponds can be corrected by liming. Water quality management has been considered one of the most important aspects of pond aquaculture for many years, but less attention has been given to the management of pond bottom soil quality. There is increasing evidence that the condition of pond bottom soil and the exchange of substances between soil and water strongly influence pond water quality" (Boyd, 1995). Pond soil plays an important role in regulating the concentration of nutrients; the soil carbon or organic matter acts as a source of energy for bacteria and other microbes that release nutrients through various biochemical processes in the pond water for pond productivity. Soil characteristics should be given primary concern in the selection of sites for pond aquaculture (Hajek and Boyd 1994), and the application of good bottom soil management is necessary for the long-term operation of ponds. Moreover, attention to soil quality improves pond water quality, which in turn, favors both good productivity and enhanced effluent quality (Boyd, 1995). There is a need for more attention to be devoted to the study of pond soils to use the knowledge of pond soil characteristics to help potential farmers toselect good sites for fish farming and also to develop efficient management practices that will boost production both in commercial and in homestead fish farming. "Pond soil classification is based primarily on the sediment that accumulates in the pond bottom and in direct contact with the pond water rather than upon the original soil from which the pond was constructed, because as soon as pond is constructed the characteristics of the pond bottom begins to change, these changes result from erosion, sorting, sedimentation of particles from within or from outside the pond and accumulation of organic matter from easily decomposable organic matter such as simple carbohydrates, protein and other cellular constitutes" (Boyd *et.al.*, 2002).

MATERIALS AND METHODS

Three integrated and three regular ponds from different farms in Ibadan metropolis, Oyo State Nigeria were sampled. Soil and water samples were collected. Soil samples were taken at three depths; 0-10cm, 10cm-20cm and 20-30cm at inlets and outlets of the ponds respectively.

Ibadan is located in southwestern Nigeria in the southeastern part of Oyo State about 120km east of the border with the Republic of Benin in the forest zone close to the boundary between the forest and the savanna. It is within Latitudes $7^{o}23'47$ N and Longitude $3^{o}55'0$ E. The city ranges in elevation from 150m in the valley area, to 275m above sea level on the major north-south ridge which crosses the central part of the city. The city's total area is 1190 sq mi(3,080 km^2). The city is naturally drained by four rivers with many tributaries; Ona Rivers in the North and West ; theOgbere River towards the East ; Ogunpa River flowing through the city and theKudeti River in the Central part of the metropolis. Ogunpa River , a third- order stream has a channel length of 12.76 km and a catchment area of 54.92 km^2 . The annual rainfall is approximately 1600mm, most of which falls between April and October giving a predominantly dry season from November to March.

Bottom soil samples were taken with a bucket soil auger and cylindrical core .The samples were collected and stored in black waterproof bags which were properly labelled and kept air tight. The auger was made of iron and it is about 90cm long . It has a hollow like enclosure at thebottom which has two crab like claws (18cm long). The claws collect the samples when turning the auger in a clockwise and anti-clockwise direction during sample collection. This was done at the inlets and outlets of three depths within the ponds. Thirty-six soil samples in all were taken from the six ponds.

The collected soil was analyzed in the laboratory and evaluated for pH, organic carbon, organic matter, nitrogen, phosphorous and potassium in line with the methods by Murphy and Riley,(1962), Blake and Hartge(1986). Descriptive analysis was used to determine the mean, standard error, standard deviation and one way Analysis of variance(ANOVA) was used to determine if there is any variation among the parameters. The pond productivity of the study sites was evaluated using three productivity measure models (Table 2,3 and 4) stating the soil quality requirements.

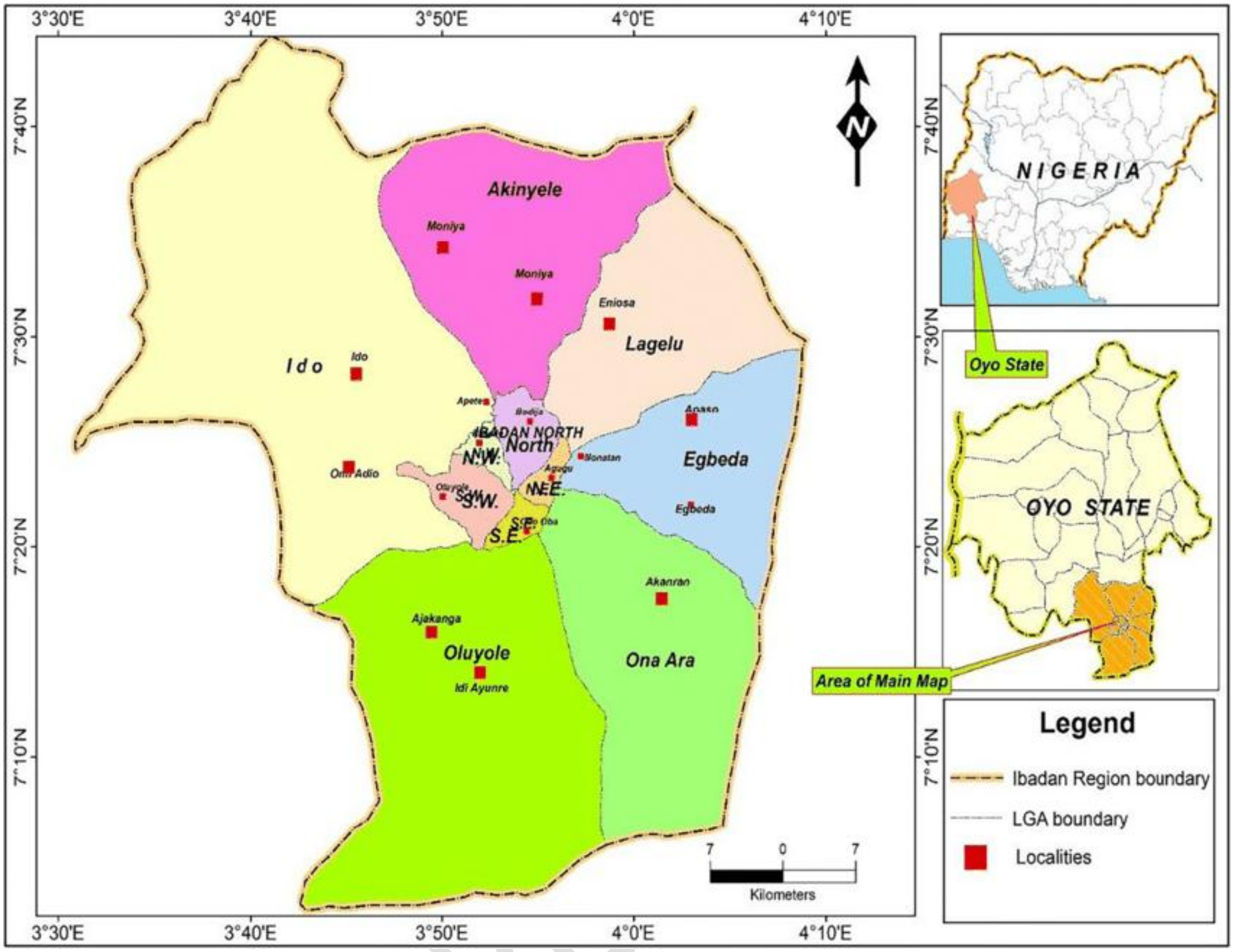

Figure 1: Map of Ibadan showing major communities

Source: Fashae *et.al.*,2020

Table 1: General Demographic Information on the Selected Ponds Used for the Study

Farm	Pond type	Location	Altitude Above msl(m)	Average Dimension(LxBxD)
UI	Integrated (I_1)	07◦26.409N 003◦53.996 E	205m	10m x 15m x 0.75m
	Regular(R_1)	07◦26.475N 003◦53.982E	206m	15m x 30m x 1.75m
ISI	Integrated(I_2)	07◦26.121N 003◦53.763E	208m	13m x20m x 1.50m
Nikol	Regular(R_2)	07◦ 28.529N 003◦58.002E	234m	27m x 17m x 0.75m
Adewoyin	Integrated(1_3)	07◦ 31.032N 003◦58.24E	257m	10m x 20m x 1.75m
	Regular(R_3)	07◦31.032N 003◦58.242E	258m	13.5mx 13.5mx 0.75m

Table 2: Basic soil fertility requirement for pond productivity

Productivity level	pH	N mg/1000gm soil	Organic carbon(%)	P_2O_5(mg/1000gm)
High	6.6- 7.5	50	1.5	6-12
Medium	5.5-6.5	25-49	0.5-1.4	3-5
Low	<5.5	<25	<0.5	<3

Adapted from Sarma and Kalita (2006).

Table 3 : Soil quality requirement for pond productivity

Parameter	Critical level	Least/Not suitable	Marginally suitable	Moderately suitable	Highly suitable

Clay(%)	20	<5	10	11-19	>20
Bulk.D(g/cm^3)	1.4	>1.2	1.25-1.4	1.4	>1.4
pH	7.5	<6.8	6.8	6.9-7.5	>8
P(mg/kg)	8	<6	6-7	7-8	>8
N(%)	0.15	<0.08	0.08-1.0	0.1-0.13	>1.5
Org.C(%)	1-2	<1	1-2	2-3	>3
Soil texture	SCL,L	LS,S	L	SL,SCL	CL

Adapted from Aruleba and Agbebi (2010).

Table 4: General nutrient status for pond productivity

Productivity level	Organic carbon(%)	Nitrogen(ppm)	Phosphorous(ppm)
Low productivity	<0.5	<250	30
Medium productivity	0.5-1.5	250-500	30-60
High productivity	1.5-2.5	>500	>60

Adapted from Adhikari (2003).

RESULTS AND DISCUSSION

The results of the various analyses on the pond bottom soils are summarized in table 5.

Soil pH, organic matter and organic carbon of evaluated ponds

The soil pH in the integrated pond 3 and regular pond 3 were the highest with values of 7.60 and 9.60 respectively while integrated pond 2 and regular pond 1 are the lowest mean values of 7.00 and 7.08 respectively(Table 5). There is a significant difference ($P < 0.05$) between the pH of the integrated ponds and the regular ponds with the pH in the regular ponds being higher than that of the integrated ponds .The average values of organic carbon,1.81% and 2.66% were recorded in integrated pond 3 and regular pond 3 respectively which were the highest and 0.82% and 1.01% were recorded for integrated pond 2 and regular pond 2 respectively which were the lowest across the ponds. However, the average organic carbon concentration did not differ ($P > 0.05$) between the two culture systems. Concentration of organic matter averaged 3.11% and 4.57% for integrated pond 3 and regular pond 3 respectively was recorded as the highest while mean values of 1.40% and 1.72% for integrated pond 2 and regular pond 2 respectively were recorded to be the lowest across the ponds. Organic matter concentrations did not differ($P > 0.05$) between the two culture systems. The soil pH average value among the ponds ranges from 7.00 to 9.60. The best pH for pond soils is considered to be 6.5 to 7.5, and pH 5.5 to 8.5 is considered acceptable (Banerjea and Ghosh, 1970). Based on Banerjae's scale, all the soils had acceptable pH except regular ponds 2 and 3 which were alkaline (Table 5). The optimum pH range for aquaculture pond soils is 7.5 to 8.0, for microbial activity is most rapid in this pH range (Boyd and Pipoppinyo 1994). Microbial decomposition of organic matter recycles nutrients and prevents the accumulation of large amounts of organic matter in pond bottoms. The mean pH value of the regular ponds is significantly greater than in the integrated ponds and they do not have large reserves of inorganic carbon to support phytoplankton photosynthesis unlike the integrated ponds. pH very often acts as an index for reflecting conditions associated with the release of nutrients, physical conditions of soil and potency of toxic substances. Pond soil with less than 0.5% organic carbon and considered unproductive while those in the range 0.5-1.5% and 1.5 – 2.5% have medium and high productivity respectively. Organic carbon content of more than 2.5% may not be suitable for fish production, since it may lead to an excessive bloom of microbes and oxygen depletion in the water(Adhikari,2003).According to Adhikari,(2003) and Boyd *et al*.,(2002) Integrated ponds 1 and 2 and regular pond 2 are of medium productivity which indicates that they are mineral soils and integrated pond 3 and regular ponds 1 and 3 have high organic carbon content which indicates that they are organic soils. According to Boyd *et al*.,(2002) organic soils have 15 to 20% organic carbon (about 30 to 40% organic matter). Such soils are not good for pond aquaculture and should be avoided. Soils with less organic matter are known as mineral soils, organic matter in mineral soils is considered to be labile if microorganisms can decompose it readily or refractory if it decays slowly. When feed input is high and phytoplankton blooms are dense, enough fresh organic matter may accumulate on the pond bottom as a flocculent layer to cause anaerobic conditions at the sediment water interface (Munsiri *et al*., 1995). This scenario apparently was occurring in the integrated ponds because sediment was dark coloured (anaerobic) with soil organic carbon concentration below 3%. Sedimentation of fresh organic matter in uneaten feed, feces, and dead plankton onto the bottom in large amounts can temporarily spoil soil quality in ponds where the upper layer of bottom soil contains less than 1 percent organic carbon. Soil organic carbon (or organic matter) concentration is useful in determining if the sediment is becoming highly organic. Certainly, bottom soils with more than 3 or 4 percent organic carbon are likely to be highly anaerobic throughout the culture period regardless of the intensity of aquaculture in the pond (Boyd,1995). The integrated ponds have low concentration of organic carbon, and bottom soil increase in organic carbon because of the large concentration of organic matter from aquacultural activities and microbial degradation of organic matter because of waterlogged conditions as in the regular ponds.

Soil nitrogen, phosphorous and potassium

The average values of nitrogen in integrated ponds 3 and 2 of 0.07% and regular pond 3 of 0.11% were recorded to be the highest while integrated pond 1 of 0.05% and regular pond 2 of 0.04% were recorded to have the lowest mean values. Soil phosphorous averaged 0.33% and 0.34% of integrated pond 1 and regular pond 3 respectively were recorded as the highest while 0.26% of integrated pond 3 and 0.27% of regular pond 1 were recorded as the lowest mean values across the ponds (Table 5). However average phosphorous concentration did not differ ($P > 0.05$) between the integrated and the regular ponds. Soil potassium concentrations 0.02% of all the ponds except regular pond 1 were recorded as the highest mean value across the ponds while 0.01% of regular pond 1 was recorded as the lowest mean value across the ponds(Table 5).

However, there is no difference ($P>0.05$) between the potassium concentration of the integrated ponds and the regular ponds.

According to Adhikari (2003), pond soils with less than 0.025% available nitrogen are considered to have low productivity, concentrations in the range of 0.025-0.05% have medium productivity while above 0.05% are considered to be highly productive, integrated pond 1 and regular ponds 1 and 2 are recorded to be of medium productivity while integrated ponds 2 and 3 and regular pond 3 are recorded to be of high productivity. Low concentrations of nitrogen are normal in soils with low organic matter concentrations because nitrogen is present in pond soil primarily as a component of organic matter. Pond soils with low carbon: nitrogen ratios tend to have highly decomposable organic matter and anaerobic conditions at the soil-water interface may be a common problem(Boyd *et al*., 2002). The evaluated integrated ponds had lower carbon: nitrogen ratio compared to the regular ponds. All the ponds were stated not suitable for aquaculture due to low nitrogen concentration except in regular pond 3 which was stated moderately suitable for aquaculture as reported by Aruleba and Agbebi(2010). Low nitrogen content in an integrated pond may be due to the fact that nitrogen in the ponds were used up as nutrients by the rice plants in the ponds. This would invariably limit the phytoplankton growth. This can be enriched by adding fertilizer, manure and feeds to the pond. Fertilizer nitrogen usually is in the form urea or ammonium and urea quickly hydrolyses to ammonium in pond water. Ammonium may be absorbed by phytoplankton converted to organic nitrogen and eventually transformed the nitrogen of fish protein organic nitrogen in plankton and in aquatic animal feaces may settle to bottom to become soil organic nitrogen. All the mean values of phosphorous indicate that they are of high productivity and highly suitable for aquaculture as reported by Adhikari(2003) and Aruleba and Agbebi(2010). This might be due to the high clay content in the ponds soil as reported by Boyd and Munsiri(1996). Increasing phosphorous concentrations in pond soils favour greater potential for fish culture. Nevertheless, if pond soils become saturated with phosphorous, they will no longer remove phosphorous from pond water (Banerjea and Ghosh, 1970). Potassium concentration in the integrated pond likely resulted from potassium entering the ponds from the poultry houses or from chicken manure applied to the ponds and otherwise in the regular ponds.

Table 5: Mean values of selected nutrient profile of the ponds bottom soil

Parameters(unit)	Integrated			Regular		
	I_1	I_2	I_3	R_1	R_2	R_3
pH	7.25±0.27	7.00±0.00	7.60±1.00	7.08±0.20	8.65±0.65	9.60±2.21
Organic carbon(%)	1.06±0.29	0.82±0.53	1.81±0.45	1.73±0.78	1.01±0.47	2.66±1.33
Organic matter(%)	1.78±0.45	1.40±0.92	3.11±0.78	2.97±1.33	1.72±0.77	4.57±2.28
Nitrogen(%)	0.05±0.02	0.07±0.02	0.07±0.03	0.05±0.01	0.04±0.01	0.11±0.03
Phosphorous(%)	0.33±0.19	0.30±0.19	0.26±0.05	0.27±0.07	0.28±0.13	0.34±0.07
Potassium(%)	0.02±0.00	0.02±0.00	0.02±0.01	0.01±0.00	0.02±0.01	0.02±0.00

Note: Each value represent the mean ± SD.

Productivity of ponds

The soil quality requirement tables were used to evaluate the productivity potential of all the ponds according to the soil qualities obtained from each sample. Tables 2, 3 and 4 showed the pond soil requirement for pond productivity and Table 6 showed the observed pond soil qualities of the selected sites. The clay content and phosphorous concentration of all the ponds shows that they are highly suitable for productivity with respect to ability to synthesize phytoplankton and zooplanktons. The bulk densities of all the ponds are highly suitable for productivity except regular pond 3 which is marginally suitable for productivity. Nitrogen is least in all the ponds except regular pond 3 in which the nitrogen concentration is moderate. Soil texture of all the ponds are moderately suitable the pH of integrated ponds 1 and 2 and regular pond 1 are also moderately suitable while the pH of integrated pond 3 and regular ponds 2 and 3 are highly suitable for productivity.

The organic carbon of integrated ponds 1 and 2 and regular pond 2 are marginally suitable, regular pond 1 is moderately suitable while integrated pond 3 and regular pond 3 are highly suitable for productivity as presented in Table 7. The organic carbon concentration and the phosphorous concentration of all the ponds show that they are all of high productivity. The nitrogen concentration integrated pond 1and regular ponds 1 and 2 are of medium productivity while integrated ponds 2 and 3 and regular pond 3 has high productivity. The soil qualities showed that all the selected pond's productivity is either high or medium productivity across the parameters as presented in Table 8. The pH and the nitrogen concentration of all the ponds showed that they are all of high productivity. The organic carbon concentration of integrated ponds 1 and 2 and regular pond 2 are of medium productivity while integrated pond 3 and regular ponds 1 and 3 are of high productivity as presented in Table 9. All the ponds except regular pond 3 are the least suitable in terms of productivity with the soil nitrogen as the major limitation similar to the assessment done by Aruleba and Agbebi(2010).

Table 6: Pond fertility, soil quality and nutrient status related parameters obtained in the evaluated ponds

Parameters (unit)	Integrated			Regular		
	I_1	I_2	I_3	R_1	R_2	R_3
Pond Fertility						
pH	7.25±0.27	7.00±0.00	7.60±1.00	7.08±0.20	8.65±0.65	9.60±2.21
N(mg/1000gm soil)	500±200	700±200	700±300	500±100	400±100	1100±300
Organic carbon(%)	1.06±0.29	0.82±0.53	1.81±0.45	1.73±0.78	1.01±0.47	2.66±1.33
Soil Quality						
Clay(%)	31.53±1.84	38.27±2.49	36.97±1.03	34.73±4.26	38.27±3.22	34.39±2.15
Bulk.D(g/cm^3)	1.49±0.14	1.71±0.08	1.45±0.10	1.71±0.03	1.64±0.02	1.32±0.02
pH	7.25±0.27	7.00±0.00	7.60±1.00	7.08±0.20	8.65±0.65	9.60±2.2
P(mg/kg)	3261.05±1931.13	3000.40±1896.48	2551.90±460.95	2681.25±696.76	2796.30±1330.74	3362.45±656.39
N(%)	0.05±0.02	0.07±0.02	0.07±0.03	0.05±0.01	0.04±0.01	0.11±0.03
Org.C(%)	1.06±0.29	0.82±0.53	1.81±0.45	1.73±0.78	1.01±0.47	2.66±1.33
Soil texture	SCL	SC	SCL	SCL	SC	SCL
Nutrient Status						
Organic carbon(%)	1.06±0.29	0.82±0.53	1.81±0.45	1.73±0.78	1.01±0.47	2.66±1.33
Nitrogen(ppm)	500±200	700±200	700±300	500±100	400±100	1100±300
Phosphorous(ppm)	3261.05±1931.13	3000.40±1896.48	2551.90±460.95	2681.25±696.76	2796.30±1330.74	3362.45±656.39

Values are mean± SD

Table 7: Soil quality for pond productivity of evaluated pond

Parameter	I_1	I_2	I_3	R_1	R_2	R_3
Clay(%)	S1	S1	S1	S1	S1	S1
Bulk.D(g/cm^3)	S1	S1	S1	S1	S1	S3
pH	S2	S2	S1	S2	S1	S1
P(mg/kg)	S1	S1	S1	S1	S1	S1
N(%)	S4	S4	S4	S4	S4	S2
Org.C(%)	S3	S4	S3	S3	S3	S2
Soil texture	S2	S2	S2	S2	S2	S2

Key: S1- Highly suitable, S2- Moderately suitable, S3- Marginally suitable, S4- Least/Not suitable in line with Aruleba and Agbebi,(2010).

Table 8: Nutrient status for productivity of the evaluated ponds

Sites	Organic carbon(%)	Nitrogen(ppm)	Phosphorous(ppm)
I_1	MP	MP	HP
I_2	MP	HP	HP
I_3	HP	HP	HP
R_1	HP	MP	HP
R_2	MP	MP	HP
R_3	HP	HP	HP

Key: HP- High productivity, MP- Medium productivity, LP- Low productivity in line with Adhikari,(2003).

Table 9: Fertility for productivity of the evaluated ponds

Sites	pH	N mg/1000gm soil	Organic carbon(%)
I_1	High	High	Medium
I_2	High	High	Medium
I_3	High	High	High
R_1	High	High	High
R_2	High	High	Medium
R_3	High	High	High

In line with Sarma and Kalita,(2006).

CONCLUSION

Generally, the productivity of the pond was checked using three models and the soil in each of the study sites had a high level of productivity. The evaluation of the ponds in line with the three standard procedures indicated that the soil of the integrated pond was more productive for fish culture than the regular ponds soil.

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