Water loss, sediment deposition, and pond age relationships in Lagos State, Nigeria

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Abstract: The issue of sediment in aquatic environments has been a topic of concern for many decades because it harbouring pathogen and decrease water depth. The investigation was carried out to identify and proffer solutions to some environmental and management problems that have hitherto affected fish production sub-sector of the economy, using Lagos State, (Western) Nigeria as a case study. Both surveying and experimental methods were used. The results indicated that of water loss from ponds resulting from evaporation and seepage ranged from 2.5-4.6 mm day^{-1}. Percentage reduction in pond water depth during dry season ranged from 70%-81% as compared to the observed percentage increase during rainy season with a range of values as, 17%-34%. The mean rise and fall in water depth were 24.7±3.8% and 47.6±11.7% respectively. The fall in water depth during dry season was almost twice its rise during rainy season. The degree of variation among ponds was found to be significant ($t=2.11$ at $p=0.05$). The mean rate of soft sediment depth was 10.5±1.8 cm yr^{-1}, while the soft sediment depth in silty sand ponds doubled those from mixed sandy ponds. The predictive equation indicated that soft sediment accumulation was found to increase with year of pond operation. The results showed a significant correlation ($p = 0.05$) between soft sediment and year of pond operation.

Keywords: Sediment, water depth, water loss, pond age, seepage

Citation: Omofunmi, O. E. 2019. Water loss, sediment deposition, and pond age relationships in Lagos State, Nigeria. Agricultural Engineering International: CIGR Journal, 21(1): 34–39.

1 Introduction

The issue of sediment in aquatic environments has been a topic of concern for many decades. In assessing sedimentation, evaluation of environmental change will help to identify other factors such as precipitation, discharge, shear stress, or a change in channel pond or geometry that may also accompany the sedimentation changes (Boyd, 2009). Other factors of importance in determining sediment impacts are the temporal variations of sediment yield especially stream or river sources of water for pond impoundment (Singh, 2007). The matrix bed load is often referred to as "sediment" by fisheries biologists and is the size class that is of most interest and concern in fisheries studies such as suspended load (Boyd, 2009).

Received date: 2018-03-15 **Accepted date:** 2018-09-21

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Subaqueous plants will be significantly affected by increased suspended sediment loads because primary plant production is reduced with increases in turbidity (Shaw and Maga, 2003). It also decreases in benthic organism diversity and density because of a limited food supply (Statzner and Higler, 2006).

Fish production from culture fisheries have been all time low in Nigeria (Ajana, 2003). Omofunmi (2010) highlighted that fish ponds are faced many problems among which are seepage, high water table, and sediment accumulation. The sediment- water interface in aquatic system, including aquaculture ponds, was a bridge connecting bottom sediments with the overlying water column. Nutrient concentrations in pond bottom soil are typically two to four orders of magnitude higher than in water (Ram et al., 2007; Lee, 2005; Boyd, 2009); that was, the amounts of most chemical components in a 1-cm surficial pond soil layer are generally higher than those present in 1 m of overlying water (Lee, 2005). Materials settling from the water column to the sediment can be derived from two sources. First, particulate organic matter, consisting of biogenic material with specific gravities greater than water such as senescent algae, fish excreta, and feed residues, continuously settle from the water column. In some cases, sedimentation from the water column includes suspended matter imported with water supply. Particles resuspended from the pond bottom are a second source of sedimenting material. Ponds have external and internal sediment loads. Freshwater ponds filled by runoff from denuded watersheds and brackish water ponds filled from estuaries are laden with suspended soil particles. Internal sediments result from turbulence that erodes pond bottom soils, levees and suspended particles. Sources of turbulence are wind action, aquatic animal activity. Mechanical aeration and harvest operation. Long residence time favours sedimentation of suspended particles and ponds behave as sediment basins. Studies on the soil as they affect fish pond performance and productivity have been carried out by researchers such as Sinha and Ramachandran (2001), Jhingram (2002) and Kumar (2004). Climatological data are classified into meteorological and hydrological data. The important of climatological data was highlighted by Coche (2006) that it helps in the estimation of height, size and capacity of dike and also influences the choice of pond depth and pond location. In the coastal area, the presence of vegetation has sometimes been used for the assessment or an indicator of soil property. Evaporation rates, temperature and wind velocity are among climate parameters that are important in pond design and operation. Coche (2006) suggested that addition of annual evaporation allowance of 1250 mm to the water budget for pond operation. Evaporation contributes to the fall in water depth, rise in water temperature and reduction in dissolved oxygen content of the pond (Huet, 2000; Kumar, 2004). According to Boyd (2009) most ponds are static water system, while others are characterised by copious water exchange. Water seldom exceeds 20%-30% of pond volume per day and it is usually much less. Physical problems identified by Sinha and Ramachandran (2001), Jhingram (2002), Coche (2006) and Kumar (2004) include, seepage, piping flood hazard, leakage of dike. Rot (corrosion) of construction materials, siltations, cracking of dike and drying of pond. Sinha and Ramachandran (2001) estimate indicated about 20% rises in normal water depth in ponds sited in swamp areas of India attributed to seepage. Similarly, Jhingram (2002) findings indicated about 20%-60% fall in normal water depth of ponds sited in swamp areas and also stated that about 5% loss in fish farm investment was attributed to seepage. Flood effects in the pond performance have been examined by several investigators such as Kumar (2004), Huet (2000) and Pillay (2003). They reported that the flood accelerated the erosion of ponds, aid the quick collapse of pond structures, introduce predator to ponds, increase the cost of maintenance of ponds, enhance siltation (sediment deposition) and increase loss of fish pond investment. Sediment is a resource out of place whose dual effect is to deplete the land from which came and impair the quality of the water it enters. Sediment accumulations apart from harbouring pathogens (bacteria) and chocked fries and eggs, it also decreases water depth and leading to temperature variations especially during dry season (Boyd, 2009). The bacteria found in sediments, dependent on the content of organic substances and the particle size of the sediment. The smaller the particle size, the higher the bacterial counts. With the expansion of pond culture system in Nigeria, the importance and crucial role of engineering expertise cannot be over-emphasized. Planning for the site selection, design, and construction of a pond is one of the most important steps in the pond management process (Whitis, 2002). Common design and construction mistakes can result in pond seepage. Poor selections of sites, lack of hydrological data and defective design and construction of pond structures have often been the cause of failures of fish pond (Coche and Muir, 2002). The objective of this study was to conduct a diagnostic survey of some selected fish farms in Lagos State, Nigeria, with a view to identifying some of the factors that could be accountable for observed low production from the culture fisheries sub-sector.

2 Materials and methods

2.1 Study Area

Lagos State, southern Nigeria falls within longitudes 03°50′E and 03°38′E and latitudes 06°20′N and 06°38′N. It has an area of 3,577 km^2 with about 20% of this covered by lagoon and associated creeks. The area is characterized by humid climate with distinct dry and wet seasons lasting November to March and April to October respectively (Figure 1).

Figure 1 Map of Lagos State showing the study area

2.2 Field survey and data collection

Forty-five fish ponds were chosen for this study .The rationale for the choice of ponds was predicated on the assumption that such ponds are sited in geographical areas fairly represented of the soil and climate characteristics in Lagos State. Monthly trips were made to the selected ponds during the rainy and dry season respectively. Primary data collections for the study were based on both on-the-spot assessment of selected fish farms and administration of structured questionnaire designed for fish farm operators. Secondary data on climatology were collected from associated government agencies. Data on temperature and evaporation are presented in Tables 1 and 2 respectively. Pond water depth was determined by sounding technique employing an improved 5m long graduated bamboo pole fitted at the base with a wooden disc of 5cm diameter. The results of the measurement are presented in Table 3. Simultaneously; sediment accumulation was measured with the same device, but a 10 cm diameter disc. The results are presented in Table 4.

2.3 Data analysis

Data were analyzed using descriptive statistics. Student's t-test was applied to determine the differences between soft sediment deposition and length of pond operation and also change in water level amongst the ponds.

3 Results and discussion

3.1 Mean daily temperature and evaporation in the study area

The maximum temperature in the study area ranged between 27.6°C and 31.8°C in February, while the minimum temperature ranged between 23°C and 26.8°C with the least being in July (Table 1).

Table 1 Mean daily minimum and maximum temperature (ºC) the period (1982-2013)

Month	Minimum temp.(ºC)	Maximum temp. (ºC)	Average temp. (ºC)
January	24.0	30.9	27.5
February	24.8	31.8	28.3
March	25.5	31.4	28.5
April	25.0	28.2	26.6
May	24.9	27.6	26.3
June	23.4	28.7	26.1
July	23.1	27.0	25.1
August	23.2	27.3	25.3
September	23.3	27.9	25.6
October	23.6	29.1	25.7
November	24.5	30.5	27.5
December	24.4	30.9	27.7

Table 2 Mean daily evaporation (mm) the period (1982-2013)

Month	Maximum evaporation. (mm)	Minimum evaporation (mm)	Average evaporation (mm)
January	6.1	2.8	4.0
February	5.4	4.0	4.8
March	4.7	4.1	4.5
April	4.2	3.4	3.8
May	3.7	3.4	3.5
June	3.1	2.8	2.9
July	2.9	2.1	2.8
August	2.7	2.2	2.6
September	2.6	2.2	2.5
October	3.0	2.6	2.8
November	3.9	3.2	3.8
December	3.6	3.5	3.6

3.2 Water depth during the dry and rainy seasons in the study area

The mean rise in water depth in the rainy season was 24.7±3.8% with a range of 17%-34%, while the mean fall in water depth in the dry season was 47.6±11.7 % with a range of 70%-81% (Table 3). The fall in water depth during drought was almost twice its rise during rainy season and this is buttressed by the degree of variations among ponds which was found to be statistically significant (p = 0.05). The falls in water level during dry season was caused by seepage and evaporation; conversely, the rise in water level was caused by seepages as well as flood. Rapid change in water level appears to be serious in almost all the ponds in the study area (Table 3). Values of water loss from the ponds resulting from evaporation and seepage ranged from 2.5-4.6 mm day^{-1}. Our observation that the fall in water depth during drought was almost twice its rise during rainy season is in agreement with that of Jhingram (2002) who reported that fall in water depth during dry season is more severe compared with the rise in water level during the rainy season. However, our finding differs slightly from observations made by Sinha and Ramachandran (2001) which may be attributed to variability in installation modes. For the avoidance of doubt, Sinha and Ramachandran (2001) estimated about 20% rise in normal water depths in ponds sited in swampy area, while we obtained 24.7±3.8% with a range of 17%-34%. This difference may be due to different soil types, different degree of pudding or compaction especially during construction and level of treatment applied to the ponds. Besides, evaporation and seepage, the observed trends in the rise and fall in the pond water level in the study area and characterised by marked seasonal variations, may be attributed to such factors as, excessive fertilization with organic manure, soil types which allow for infiltration of water through the organic laden pond dikes and embankments, high insolation for most of the year which enhance high level of evapotranspiration in the height of the pond walls as a result of rapid decomposition of the material used. Organic sediments in the ponds originate primarily from plankton while other sources include; manure application, uneaten feed, aquatic animal manure and aquatic vegetation. An understanding of sediment sources and the principles of sedimentation are of practical value to pond managers.

Table 3 Water depth during rainy and dry seasons for selected ponds respectively in Lagos

CODE	Actual pond depth (m)	Rainy season depth (m)	Dry season depth (m)
001	1.60	1.92	0.80
002	1.50	1.90	0.60
003	1.50	1.95	0.75
004	1.50	2.01	0.41
005	1.60	1.95	0.81
006	1.50	1.60	1.20
007	1.80	2.30	0.95
008	1.60	1.93	0.92
009	1.50	1.94	0.91
010	1.60	1.88	0.91
011	1.60	1.94	0.83
012	1.60	1.93	0.78
013	1.60	1.95	0.46
014	1.60	1.93	0.78
015	1.55	1.92	0.81
016	1.50	1.95	0.62
017	1.51	1.88	0.83
018	1.50	1.92	0.58
019	1.50	1.89	0.83
020	1.60	1.93	0.84
021	1.60	1.96	0.74
022	1.60	1.92	0.85
023	1.50	1.88	0.83
024	1.53	1.92	0.29
025	1.51	1.92	0.81
026	1.60	1.95	0.76
027	1.60	1.89	0.78
028	1.59	1.95	0.75
029	1.50	1.88	0.81
030	1.51	1.92	0.88
031	1.50	1.94	0.75
032	1.50	1.75	0.11
033	1.51	1.85	0.99
034	1.50	1.88	0.95
035	1.60	1.95	0.96
036	1.50	1.96	0.98
037	1.50	1.90	0.96
038	1.60	1.98	0.94
039	1.50	1.95	0.96
040	1.50	1.85	1.20
041	1.51	1.95	0.88
042	1.50	1.88	0.74
043	1.60	1.98	0.76
044	1.50	1.93	0.74
045	1.50	1.89	0.69

Note: Coding: 1-10 : Badagry Location; 11-15: OjoLacation; 16-17: AjeromiIfelodun Location; 126-29: IbejuLekki Location; 41-45: Agege/Iju Location; 8-25, 30-40: Ikorodu/Majidun Location.

3.3 Relationship between soft sediment depth and year of pond operation

The mean rate of soft sediment depth was 10.5± 1.8 cm yr^{-1} (Table 4). The result shows significant relationship (p = 0.05) between soft sediment and deposition and year of pond operation. Equation (1) shows the predictive equation between soft sediment deposited and length of pond operation. Figure 2 shows a graphical representation of the relationship between soft sediment accumulation and years of pond operation.

A predictive equation for sediment deposition in a pond system

$$S = 9.3 + 7\,(Y - n) \tag{1}$$

where, S = Soft sediment depth (cm); Y = Year of pond operation; n = Sediment coefficient factor, was used with consideration for the soil types and their corresponding sediment coefficient factors (See Table 5).

Table 4 Relationship between soft sediment depth and year of pond operation of selected fish ponds in Lagos State

Code	Years of Operation (Yr)	Soft Sediment Depth (cm)
001	3	30.5
002	6	42.1
003	5	40.1
004	4	32.5
005	3	28.4
006	4	46.3
006	5	50.3
008	4	31.6
009	4	36.3
010	5	43.6
011	4	49.3
012	6	45.4
013	3	26.4
014	2	18.2
015	3	24.3
016	3	26.4
017	4	33.6
018	5	43.3
019	1.5	20.9
020	4	46.3
021	3	28.6
022	3	19.6
023	6	58.3
024	2	21.6
025	3	36.3
026	4	43.6
027	2	22.1
028	3	33.8
029	1.5	20.4
030	4	48.3
031	3	36.3
032	5	40.1
033	2	19.8
034	3	27.9
035	4	41.3
036	3	40.2
037	2	19.8
038	4	46.3
039	2	20.6
040	3	39.8
041	4	43.8
042	3	38.8
043	3	39.8
044	3	38.3
045	2	24.2

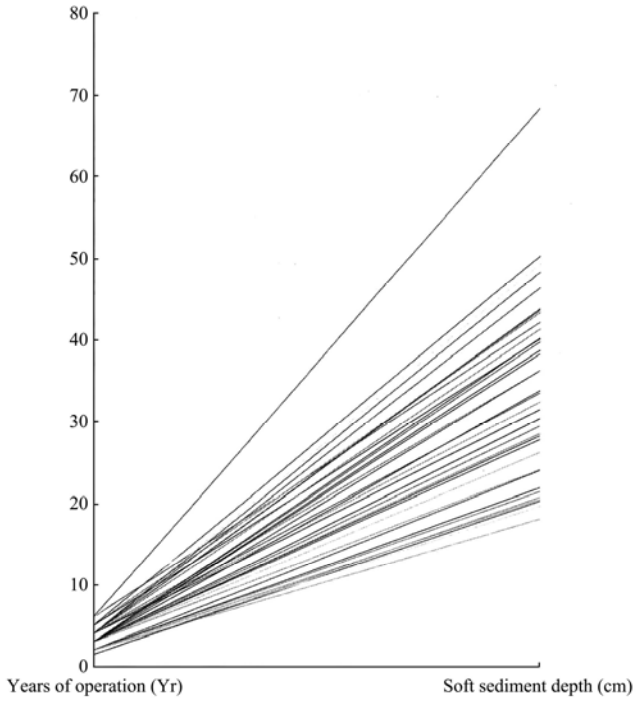

Figure 2 Graphical representation of the relationship between soft sediment accumulation and years of pond operation

Table 5 Sediment coefficient factors of soil types

Soil Type	Sediment Coefficient factor (*n*)
Mud bottom	-
Sandy bottom	1.0
Sandy clay	0.9
Loam	0.5
Loam clay	0.6
Clay	0.8

Over a period of several years, sediments can fill ponds and severely interfere with pond operation. Average sediment depth of 45 cm was observed for a five-year old shrimp pond in Ecuador (Boyd, 2009). This scenario in Ecuador is not too different from our result as a sediment depth of 43.4 cm for five-year old operations. This high value of sediment depth can be attributed to some fish ponds that are heavily treated with manure. Application rates normally ranges from 50-100 kg per month as extracted from the administered. It has been observed from structured questionnaires even though manure stimulates phytoplankton production, the life span of phytoplankton cells range from 1-2 weeks with resultant dead cells settling at the pond bottom. Most of the ponds investigated in this study have never been denuded since they came into operation, and this accounts for accumulation of silt with reduction in pond depth. In consequence, low level of dissolved oxygen can prevail because of high temperature resulting from quick light penetration of the shallow pond water besides high biological oxygen demand (BOD) occasioned by the degradation of the organic load. Long hydraulic residence time averaging 250 days in the ponds investigated, presupposed a semi-intensive method of fish culture, hence the high level of organic sedimentations. The predictive equation indicated that soft sediment accumulation was found increase with year of pond operation. The results showed significant correlation (p = 0.05) between soft sediment and year of pond operation.

4 Conclusion

The effects of seepage and soft sediment deposition on the biological, physical and chemical proportion of pond water can to a great extent affect fish production except appropriate management tools are employed. Excessive application of organic manure especially, poultry droppings by direct deposition in the pond as direct or indirect food by farmers should be discouraged.

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