Application of Geographic Information System and Remote Sensing to Aquaculture and Fisheries Potentials of Shiroro Lake, Niger State.

Ibrahim S.U[1], S.O.E Sadiku[2], Halilu A.S[3], Kolo R.J[4]

[1]-School of Preliminary and General Studies,
I.B.B. University Lapai, Niger State
[2&4] Centre for Climate Change and Fresh Water Resources,
Federal University of Technology, Minna
[3]Department of Geography
School of Science and Science Education
Federal University of Technology, Minna

Abstract

The study examines the Application of Geographic Information System and Remote Sensing to Aquaculture and Fisheries Potentials of Shiroro Lake, by integrating physico-chemical parameters into Geographic Information System database. This also involved identifying and estimating potential areas for aquaculture development. To provide focus for the study, five sampling sites (stations) were selected within the lake basin. Multispectral band satellites image was used to detect suitable areas of the lake for aquaculture,and fishery production. The suitability rating was established based on physico-chemical data obtained from previous survey, which identified station IV (River Dinya entering point) as the most suitable site for aquaculture, followed by station I (Dam Crest) as suitable, station V (River Munya entering point) moderately suitable, while station II (River Kaduna entering point) and station III (River Sarkin Pawa entering point) classified as unsuitable, based on the scale of the ideal ranges of all the physico-chemical parameters.

Introduction

Attempts to extrapolate spatial structure from aquatic environment relied on very limited data based primarily on catch information or fishermen "word of mouth" due to its dynamic nature, posing many challenges to officials in charge of sustainable fisheries management. But with the advent of such advanced technologies as Geographic Information System (GIS) and Remote Sensing, fisheries managers and commercial operators alike will have access to information that will help them to achieve their goals because data of inaccessible areas can now be obtained from both low and high resolution satellite images. A case study of the application of GIS for evaluating aquaculture and fisheries potentials of Shiroro lake, Nigeria is hereby presented.

Several survey studies have been conducted on Shiroro lake-Nigeria such as fishery survey carried out in December 1984 and April 1985. To evaluate the biological, physical, social and economic conditions for aquaculture development, Narescon. (1993). Kolo (1996) undertook a study on the limnology of the lake and its major tributaries, Shekari C. (2001) carried out a study on the biodiversity of fishes in Shiroro Lake. However, most of these surveys did not include systematic spatial data and planning activities that would cover the lakes aquaculture and fisheries potentials. A combination for these studies and GIS were useful for predicting aquaculture and fisheries potentials of the lake. This investigation is a pioneer effort in the use of this technology in Nigeria.

The objectives of the study is to identify the ecological potentials of the lake area and to develop a GIS database as a tool for the management of fisheries in Shiroro lake by integrating physico-chemical data with Geographic Information System (GIS) and Remote Sensing as a tool for identifying and estimating potential areas of the lake for aquaculture development.

Materials and Methods

Shiroro Lake with surface area of 31.200Ha and mean depth of 22.4m (Sado *et. al.* 1985) is the second largest man-made lake in Nigeria and is expected to provide favourable conditions for large scale fish production and aquaculture development (Fig.1).

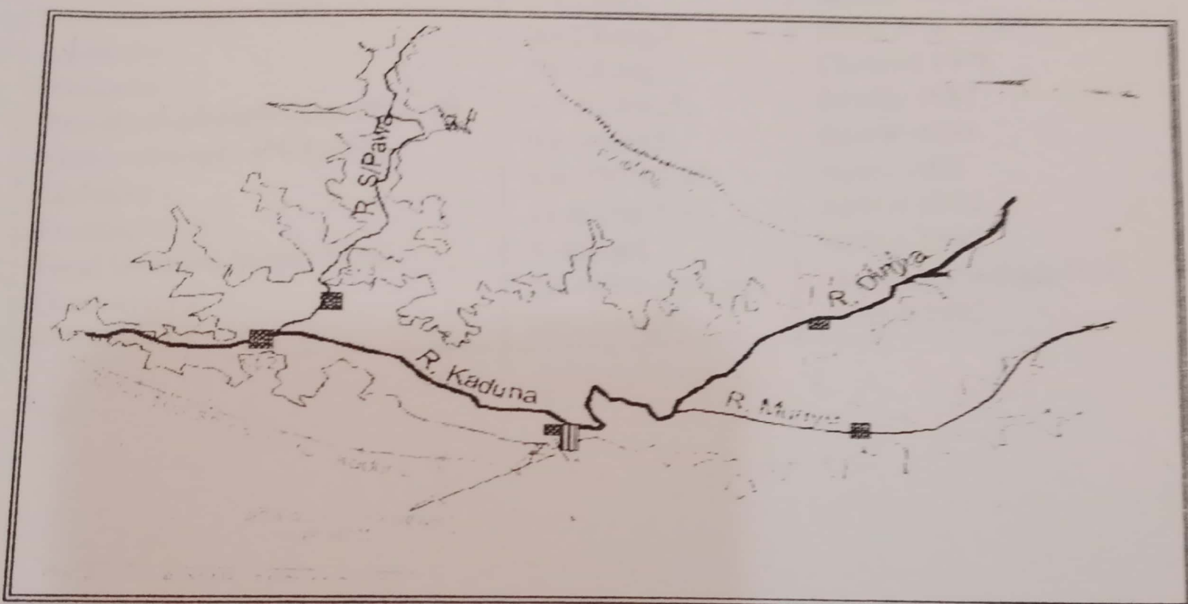


Fig.1: A Map Showing Shiroro Reservoir and Sampling Stations

The data used for this study were obtained from two sources, primary and secondary data. The primary data (directly sensed data) were generated through field surveys on the production functions which control the aquatic environment, using a digital camera, global positioning system, the water itself, fish in it, and fishing vessels.

The secondary data source which was an organised primary data were sourced from multi-spectral band satellite image and topographic map. GIS software used was Arcview GIS for Windows (version 3.2a) and Idrisi. The remote sensing image analysis was performed using the co-ordinates on topographic sheet 164 of 1967 at a scale 1:50,000 and 1:250,000. This was acquired from Niger State Ministry of Lands and Survey, Minna. Those from Global Positioning system (GPS), and aid for identifying area on satellite image were obtained from National Space Research Development Agency (NASRDA) Abuja, which is Nigeria Sat 1 image of 2003. Geo-referencing was carried out using Idrisi software, masked and exported to Arcview for digitisation. This was then built into geo-spatial data for query and result.

Result

Criteria for suitability of Shiroro lake for aquaculture and fisheries were based on thirteen physico-chemical parameters with suitable ranges and rating for fish yield. The interpretations of suitability classes for each parameter were classified on a scale of their ideal ranges (Table 1).

Table 1: The Ideal Ranges and Standards of physico-chemical parameters for aquaculture and fisheries production by various Authors

PARAMETERS	IDEAL RANGES	SOURCES
Temperature	20-25^{0}C	Dupree and Huner 1984
Hydrogen ions concentration pH	6.5-9.0	Ettis 1939
Dissolve oxygen (Do)	2-15mg/L	Beadle 1981
Alkalinity	20-200mg/L	Baird et al 1998
Hardness	20-300mg/L	Chakrof 1978
Phosphate-phosphorous (PO_4-P)	3.2-630mg/L	Beadle 1981
Nitrate-nitrogen (NO_3-N)	9.6-49mg/L	Beadle 1981
Turbidity	8.0-320 J.T.U	Henri 1992
Transparency	11.0-108.5cm	APHA 1992
Total Dissolve Solid (TDS)	5-40mg/L	APHA 1992
Conductivity	20-1600uhos/cm	Boyd and frobish 1990
BOD	60-120mg/L	APHA 1992

THE RANGE AND MEAN VALUES FOR THE PHYSICO-CHEMICAL PARAMETERS MEASURED AT DIFFERENT STATIONS OF SHIRORO LAKE

STATION S	TEMPT (^0C)	MEAN TEMP	AIR TEMPT (^0C)	MEAN AIR TEMPT	PH	MEAN PH	DO (mg/1	MEAN DO	BOD (mg/1)	MEAN BOD	COND (umohs/cm)	MEA N COND	HARD mg/1	MEAN HARD
1	15.6-33	24.6	20.4-30.7	26.5	5.6-82	6.8	1.7-18.3	7-9	13-8.7	3-4	46.0-98.0	69.6	12.0-80.0	28.6
2	16.1-34	27.0	20.8-32.8	27.6	5.6-7.5	6.8	2.6-20.5	9.1	0-21.8	4-8	45.0-235.0	76.7	8.0-70.0	30.7
3	16.5-34	26.6	20.3-31.9	27.8	5.7-7.7	6.8	1.7-19.1	8.2	0.8-8.7	3.3	38.0-114.0	71.1	13.0-96.0	3.1
4	16.0-33	26.0	18.0-32.7	27.7	6.0-7.5	6.7	2.6-18.3	9.1	0.9-7.0	3.7	42.0-92.0	66.7	14.0-75.0	28.8
5	16.3-32	25.7	18.0-32.0	26.5	5.9-9.4	6.7	2.6-20.1	9.3	0.00-10	3.8	48.0-88.0	68.9	13.0-72.0	30.6

ALK (mg/1)	MEAN ALK	TURB (Jtu)	MEAN TURB	CO_2 mg/1	MEAN CO_2	TRANS (m)	MEAN TRANS	TDS (mg/1)	MEAN TDS	PHOS (mg/1)	MEAN PHOS	NITR (mg/1)	MEAN NITR.
4.0-90.0	23.0	8.0-212	46	1.6-66.0	19.2	0.10-0.98	0.41	7.1-140	10.7	0.10-2.00	0.63	0.09-1.92	0.5
4.060.0	23.3	8.0-.320.0	89.8	0.8-48.0	13.1	0.10-0.85	0.35	6.9-363	11.8	0.18-2.40	0.77	0.12-1.82	0.52
4.0-50.0	21.1	8.0-258.0	78.1	1.2-44.0	12.1	0.10-0.80	0.37	5.8-17.5	10.9	0.12-1.88	0.69	0.09-1.28	0.49
4.0-50.0	215	8.0-1840	64.9	0.8-32.0	12	0.10-86	0.42	6.5-14.2	10.3	0.151-88	0.68	0.07-1.48	0.47
6.0-50.0	20.7	8.0-14.0	62.9	0.8-32.0	11.4	0.10-98	0.43	7.4-13.5	10.6	0.15-1.88	1.0	0.06-1.92	0.49

SOURCE: KOLO (1996)

Classification Criteria for Suitability Ranges for Fishery Potentials Analyses of the Reservoir

For analyses of the result, suitability ranges were . parameters:

Temperature

20-24.9 Suitable
25-29.9 Highly suitable
30-34.9 Suitable
≥20 Unsuitable

DO

2-4.9 Suitable
5-9.9 Highly suitable
10-14.9 Suitable
2≥15 Unsuitable

Alkalinity

20-99.9 Suitable
100-149.9 Highly suitable
150-199.9 Suitable
20≤200 Unsuitable

CO_2

6-20 Suitable
21-35 Highly suitable
36-50 Suitable
50≥6 Unsuitable

PO_4-P

3.2-4.2 Suitable
4.3-5.2 Highly suitable
5.3-6.3 Suitable
3.2≥6.3 Unsuitable

Transparency

11-43 Suitable
44-76 Highly suitable
77-109 Suitable
11≥109

pH

6-6.9 Suitable
7-7.9 Highly suitable
8-8.9 Suitable
6≥9 Unsuitable

Hardness

20-99.9 Suitable
100-199.9 Highly suitable
200-299.9 Suitable
20-≤300 Unsuitable

NO_3-N

10-19.9 Suitable
20-39.9 Highly suitable
40-50 Suitable
10-≥50 Unsuitable

TDS

5-16 Suitable
17-28 Highly suitable
29-40 Suitable
5≥40 Unsuitable

Turbidity

8-160 Suitable
161-240 Highly suitable
241-320 Suitable
320≤8 Unsuitable

Conductivity

42-560 Suitable
561-1081 Highly suitable
1082-1600 Suitable
1600≤42 Unsuitable

Source: Researcher's Compilation, 2004

Water Temperature

Logic query (i.e GIS result) was carried out based on range values for the water temperature to ascertain the suitability for possible fish yield. Based on ideal range, value greater than 35^0C or less than 20^0C were classified unsuitable for fish production. The result of the query shows that water temperature at station 1 and 4 with range of 15^0C-33.2^0C and 16.3^0C-32.8^0C respectively, are most suitable (Fig.1).

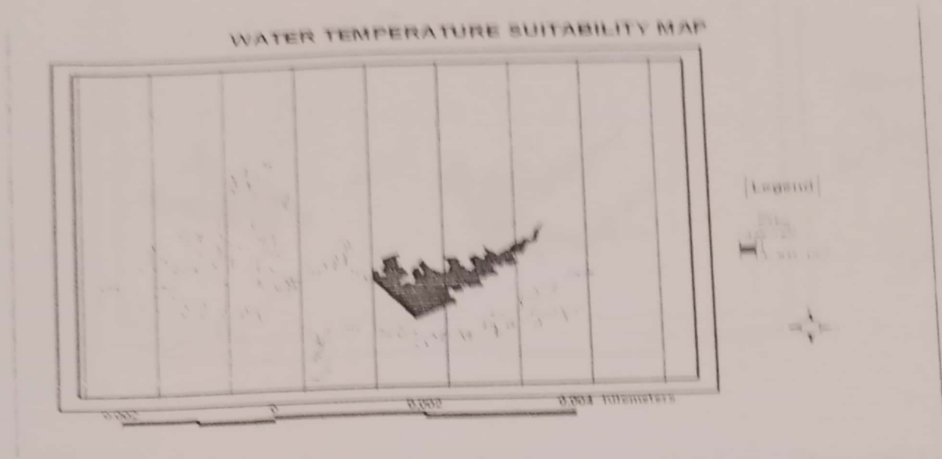


Fig. 1: The Water Temperature suitability map

Hydrogen Ion Concentrations (pH)

The result of the logic query performed on Hydrogen ion (pH) based on numeric values less than 6 is classified as unsuitable for fish production. This shows that station I, II, III and V were unsuitable while station IV was found to be highly suitable, hence all the ranges obtained from the data on the lake fall within the ideal range of 6.5-9.5. (Fig. 2).

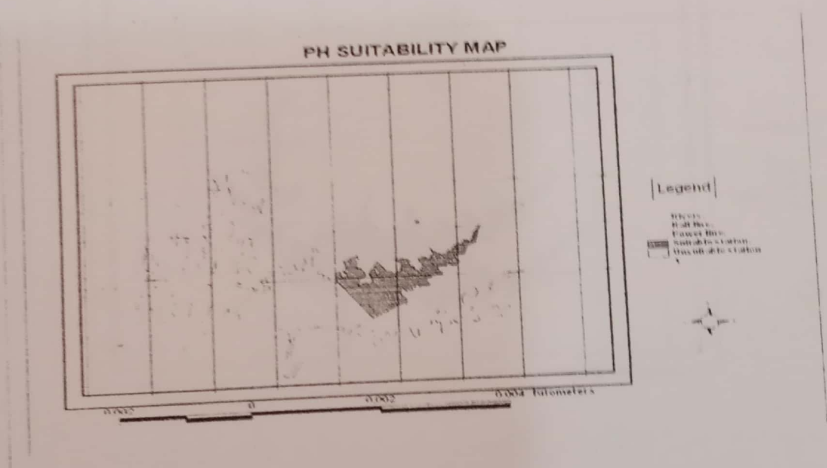


Fig. 2: The pH suitability map showing station IV as suitable

Dissolved Oxygen (DO)

For Dissolve Oxygen (DO), logic query was performed and areas greater than 15 were defined as poor area for fish to thrive very well. The result had showed that stations I and III were ideally suitable with range values of 1.7-8.3mg/l and 2.6-18.3mg/l respectively, while station II, IV, and V were not suitable; although all the ranges agreed with the recommended range of 2-15mg/l as classified by Beadle (1984).

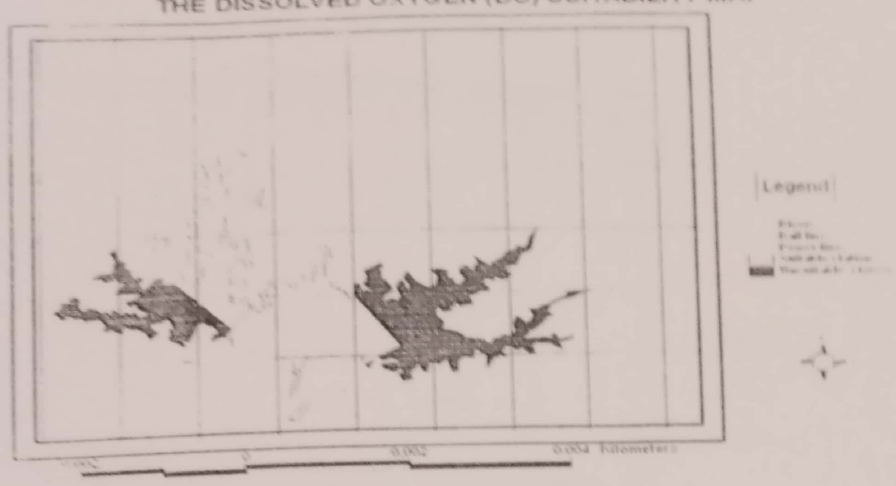


Fig.3: The DO suitability map showing station I and III as suitable

Turbidity

Logic query performed based on turbidity range of value less than 8.0mg/l and greater than 320mg/l depict station II as unsuitable for fish production (Fig.4). While others stations are suitable. Though, all the values fall within ideal range values of 8-320mg/l.

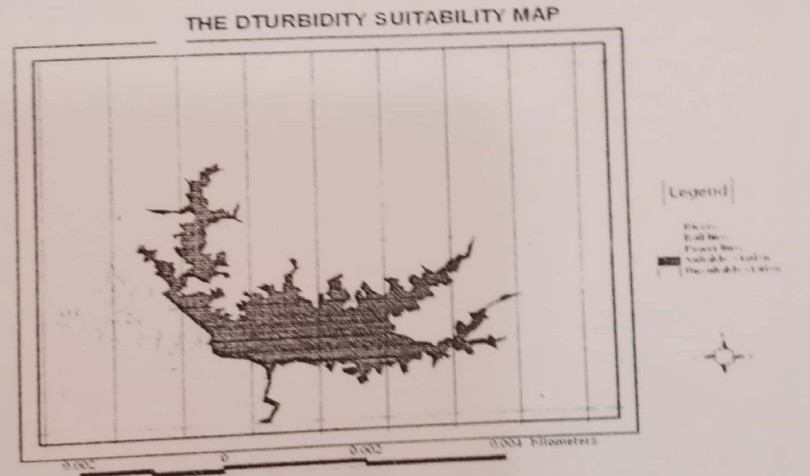


Fig. 4: The Turbidity suitability map showing station II as Unsuitable

Hardness

In respect of the suitability of the water for fish growth value less than 20mg/l or greater than 300mg/l is considered unsuitable for fish (Fig. 5). The analysis showed that station II is highly suitable while others unsuitable.

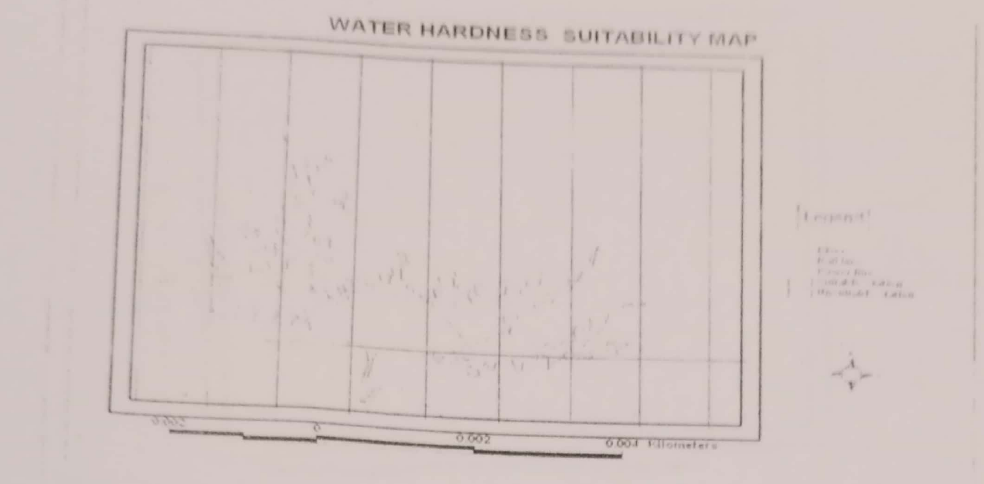


Fig. 5: Water hardness map showing station II as the area suitable for fishes

4.1.7 Conductivity

The ideal range of value for potential fish yield based on water conductivity is value less than 43uhos/cm. Base on this ideal range, the result shows that stations I, II, IV and V are all suitable for fish while III was found to be less suitable (Fig. 6).

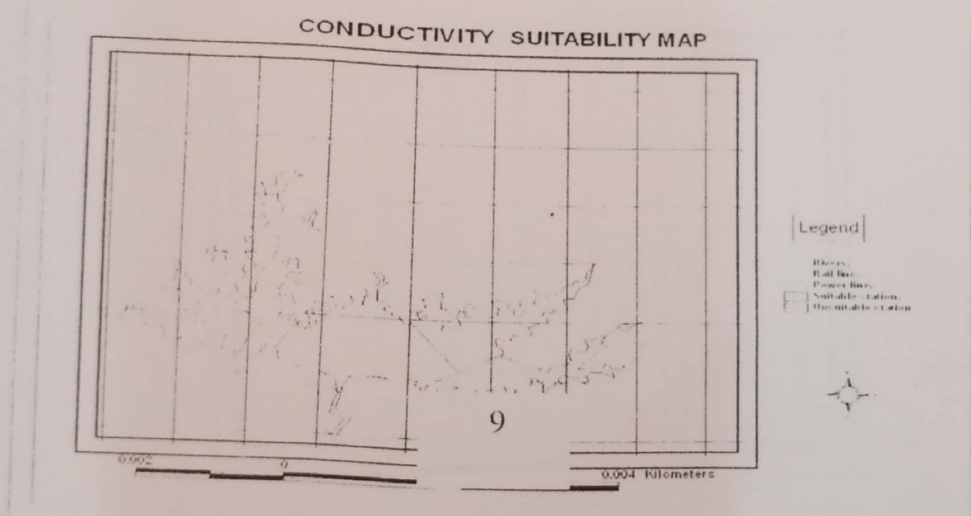


Fig. 6: The Conductivity suitability map showing station III as Unsuitable

Carbon dioxide (CO_2)

The result of the logic query performed based on Carbondiooxide (CO_2) range values of less than 48mg/l consider as unsuitable for fish production revealed that stations IV and V were suitable while stations I, II and III were unsuitable for fish production (Fig. 7).

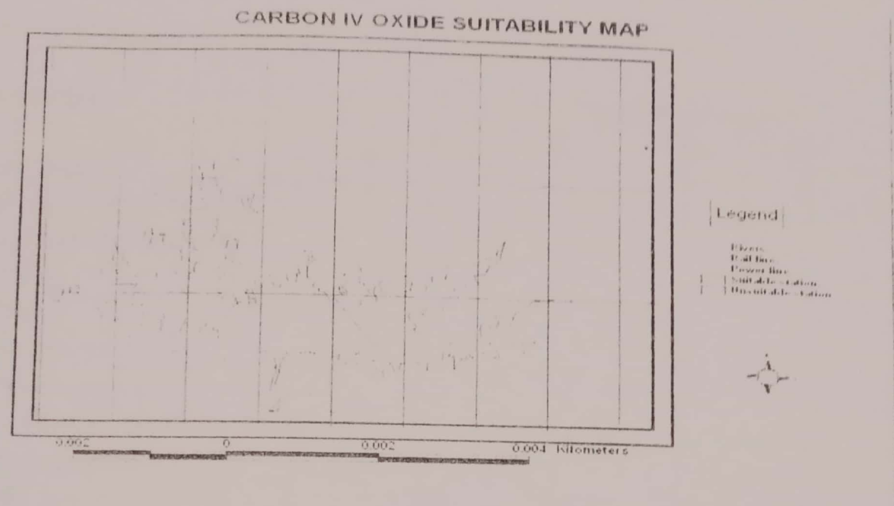


Fig. 7: Carbon dioxide suitability map showing station IV and V as Suitable

TDS, PO_4-P, NO_3-N, BOD, and Transparency

The logic query performed of the following physico-chemical parameters: TDS, PO_4-P, NO_3-N, BOD, and Transparency based on these ideal ranges: 5>40, 3.2≤630, 10–50, 50–120 and 11–109 respectively show that the entire lake is unsuitable for fish production. Below is a map of the query performed on Nitrate-Nitrogen showing this assertion (Fig. 8).

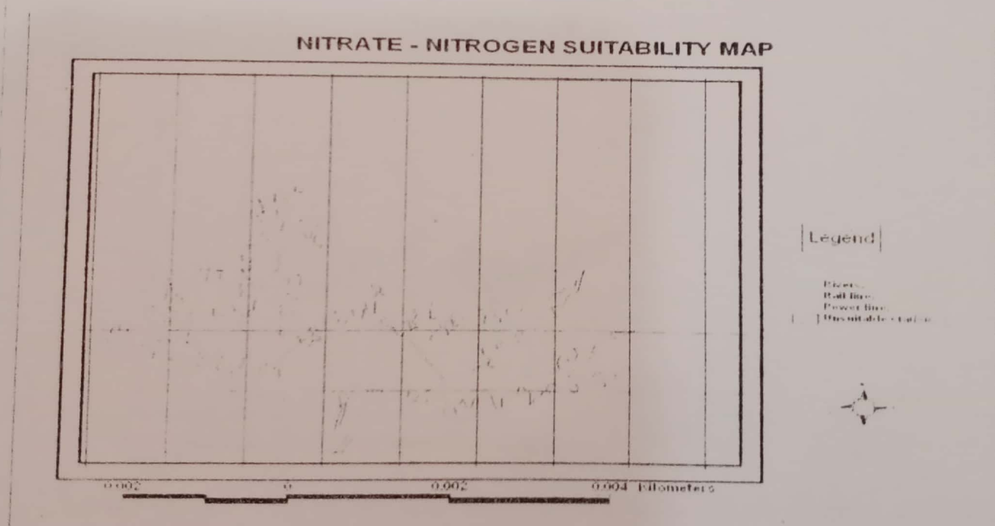


Fig. 8: NO_3-N suitability map showing all station as Unsuitable

Potential Site for Aquaculture

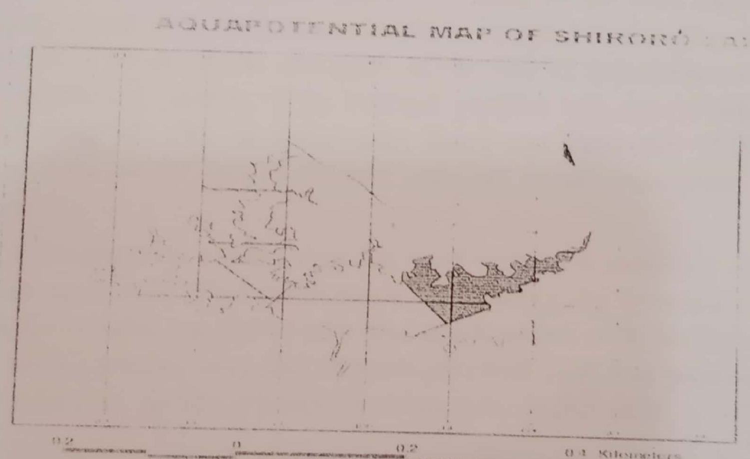
Putting all together, the result of the logic query on database of each physico-chemical parameter was ranked as five (5) scores for suitability and a zero (0) score for unsuitable for each station (table 3). Higher score values indicate more suitable stations for fish growth. Base on this, the final result depicts that station IV as the most suitable station for aquaculture purpose. This is followed by station I as suitable, moderately suitable cover station V, and not suitable covers station II and III (see Fig. 9, tables 3and 4).

Table 3: Showing station [illegible]

Parameter	Stations Scores I	II	III	IV	V
Temperature	5	0	0	5	0
Hydrogen ion conc (pH)	0	0	0	5	0
Dissolved Oxygen (DO)	5	0	5	0	0
Turbidity	5	0	5	5	0
Hardness	0	5	0	0	5
Conductivity .	5	5	0	5	0
Carbon iv oxide	0	0	0	5	5
TDS, PO4-P, NO3-N, BOD and transparency	0	0	0	0	0
Total	20	10	10	25	15

Table 4: Overall suitability Rating

Suitability Rating	Score	Stations
Most suitable	25	[illegible]
Suitable	20	[illegible]
Moderately suitable	15	[illegible]
Not suitable	10	II and III



Aquapotential map of the lake showing the range of the station suitability

Discussion

The logic query result (Fig. 1) of temperature which depicts that station I and IV are most suitable for fish to thrive could be as a result of dynamic changes of water quality at station I, and constant disturbance caused by power generation, less weathering and decay process, less water movements accounts for lower temperature. The greater depth at stations I and IV could also account for lower temperature, while other stations classified unsuitable could be as a result of higher temperature. Although optimal temperature for fish is specie specific. The recommended range for fishery activities as observed by Dupree and Hunner (1984) that warm water fish such as channel Catfish grow best at temperature between 25 – 32^{0}C. This is within the ideal range obtained from this waterbody.

The result of logic query based on pH shows that only station IV was suitable for fisheries and aquaculture (Fig. 2). This could be due to the site type characterized by [illegible] nature, low water volume, which brought about high concentration effect of ions. The pH range of 5.6 – 8.2 obtained from the range values (Table 2) agreed with recommended range of 6.5 – 9.0 most suitable for fish production by Ettis (1939), in all the stations.

Dissolved Oxygen based query indicates that stations I and II were ideally suitable (Fig. 3). **This could be as a result of the sites location and other factors. Station I, characterised by its** wood free vegetation and the greater depth effect, which resulted to lower temperature. This is in line with Heut (1972), that depending on the specific nature of the lake/stream, temperature tends to determine the amount of gases such as oxygen. Thus the higher the temperature of water body, the lower the dissolved oxygen and vice versa.

For Station III, that was also considered suitable, which one could have expected to be unsuitable due to its location, characterised by submerged woody vegetation, shallower depths and high water temperature. The suitability of the station could be as a result of swifter water movement, which might cause agitation of water mass to the bottom thereby aerating the water and sending more oxygen into the solution. Though all the ranges agreed with the recommended range of 2-15mg/L of Beadle (1984). In general, however, a minimum constant value of 5mg/l of dissolved oxygen is satisfactory for most species and stages of aquatic life (EIFACT/T19, 1973).

Fig. 4 depicts that only Station II is not suitable for fish production. This could probably be as a result of run off from catchment areas which also brought in heavier water overloaded with allochthonous materials that tends to flow underneath. Though the value obtained for these stations also falls well within the ranges suitable, the source of turbidity at Station II is not the type desirable for fish culture. Turbidity due to phytoplankton is more desirable than those due to inputs of allochthonous material (Henri, 1992).

Hard water are said to be more productive biologically than soft waters. Baird (1985), points out that total hardness concentration should be similar to the total alkalinity in most waters. The logic query result (Fig. 5) base on hardness revealed that station II is suitable for fish, this could be as a result of the closeness of the site to mountainous terrain which could enhance the weathering process of the bedrock coupled with run off which brought in much allochthonous material. This is inline with Rand and Petrocelli (1985) observation that mineralisation of the parent rock of the lake basin and lower temperature is known to enhance water hardness.

The high ionic conductivity values recorded in all stations is indicative of greater prospect of electric current generation. This confirms the logic query (fig 6) result that Stations I, II, IV and V are highly suitable for fish production which agrees with Abohweyere (1990) that the correlation between conductivity and estimate potential yield was positive and significant. An increase in conductivity results in proportional increase in fish yield.

Considering the Carbon dioxide (CO_2), the logic query (Fig. 7) result, indicates Station IV and V as suitable for fish productivity. this could be as a result of the site location of calm water condition which was brought by gentle terrain nature. However, Stations I, II and III were classified unsuitable. for Station I, it could have been due to lower temperature which is said to increase the solubility of carbon dioxide. Stirling and Philip (1990) indicate that depth effect reduces dissolved oxygen, which Rouse (1979) and Hadrian (1985) said increase carbon dioxide in water, while for Station III it could have been due to the shallow and submerged woody vegetation of the site. Therefore, the organic matter decay process used up dissolved oxygen and released carbondioxide resulting to high carbondioxide and less dissolved oxygen. For Station II, it could have been due to heavier waters over loaded with allochthonous material from the catchment area.

Fig. 9 is an index of the logic query result which indicates NO_3-N, PO_4-P, TDS, BOD and transparency as unsuitable and could be attributable to their sources from run off, from road and farmland at Station IV and V, submerged woody vegetation of Site III and effluent discharge from site II, soil erosion and animal manual from the Stations IV and V.

Conclusion And Recommendation

Conclusion

The study provides an index for establishing fisheries database using Geographic Information System and Remote Sensing. The high efficiency of G.I.S to analyse complex spatial data was also demonstrated by the study. The stations suitability map derived for aquaculture and fisheries potential of the Shiroro lake was partly verified by field surveys analyses of satellite images and published data. The predicted stations of the lake suitable for aquaculture and fisheries potential would provide room for diversification for aquaculture activities in the study area.

Recommendation

Since Shiroro lake has high potentials for fisheries production, proper planning and management should not be neglected to ensure sustainable development. The secondary use of the lake should be initiated in conjunction with the primary use to promote and improve the capacity of the lake. Aquacultural practices such as cage culture could be introduce as this will not have negative impact on the power generation activities of the lake as once practice in the Kainji.

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