

Hydrogeomorphologic and Limnologic Characteristics of Goro Dong (Lake) in Numan area, Adamawa State, Northeastern Nigeria

ABSTRACT

This paper examines some hydrogeomorphic and limnologic characteristics of *Goro Dong* - A fluvatile lake, as a contributory objective towards conservation and sustainable use of fluvatile lakes and ponds resources in Numan Area of Adamawa State, Nigeria. Hydrogeomorphic Characteristics of the lake have been examined by an integrated approach involving the applications of Hydrographic Survey, Geographic Information System (GIS) and Mathematical Computations. Site survey and laboratory analyses have also examined some Limnologic properties of the lake. Results revealed that *Goro Dong* is a typical shallow and wide fluvatile lake with suitable morphometric properties for recreation and socio-cultural festivities, as well as good limnologic characteristics for fisheries. Controlled human impacts on the lake have been recommended for conservation and sustainability.

Keywords: Hydrogeomorphic Properties, Limnologic Potentials, Morphoedaphic Index, fish production, *Goro Dong* (Lake).

1.0 Introduction

Two important sciences that contribute greatly to the understanding of the nature, development, changes and relevance of lotic and lentic freshwater bodies are hydrogeomorphology and Limnology. While, Limnology is a long time existing science that is concerned with the biological, chemical, physical, geological, and other attributes of all lotic and lentic inland aquatic ecosystems [1, 2, 3] as well as the understanding of structural and functional **inter-relationships** of aquatic organisms and the their immediate physical, chemical and biological environments [4], **Hydrogeomorphology** is an emerging interdisciplinary science that focuses on the interaction and linkage of hydrologic processes with associated landforms and the interaction of geomorphic processes with surface and subsurface waters in temporal and spatial dimensions [5]. According to [6], most ecologists have found the concept of hydrogeomorphology useful in describing the links between water and geomorphic conditions that define habitats in wetlands, rivers and other environments. Also linking hydrogeomorphology to ecological studies, [7] observed that hydrogeomorphological processes play key roles in creating, modifying and destroying aquatic habitats and as well act as ecological disturbances that shape the ecosystem characteristics and dynamics. This is achieved through Hydrogeomorphic (HGM) Analysis-a three-step process used in evaluating riparian and wetland ecosystems and their surrounding landscapes with the ultimate aim of restoration, conservation and preservation [8]. This is based on the notion that the combined influences of hydrologic, geomorphic and vegetation regimes dominate the variability of freshwater aquatic systems. Therefore, the resourcefulness of lakes and ponds as components of such aquatic systems strongly depend on their hydrogeomorphologic and limnologic characteristics which include morphometric, **physico-chemical** and biological properties.

As vital components of the aquatic ecosystem, lakes and ponds are so endowed with vast and dynamic life supporting potentials and capabilities that make them worth studying on spatio-temporal basis. The Lake and pond resources of the Upper Benue Valley area of Adamawa State, Northeastern Nigeria contribute immensely to the livelihoods of the numerous riverine human communities situated in the area. Such livelihoods which include sociocultural fishing, recreation, irrigation agriculture, livestock production and domestic water supply among others have been acknowledged [9, 10, 11, 12, 13]. *Goro Dong* is a major fluvatile lake in the Numan section of Upper Benue Valley area of Adamawa State, with great historical, **socio-cultural** and economic relevance in the Bachama land, yet little or no information is available on its hydrogeomorphic and limnologic status for the purpose of conservation and sustainable use. Therefore, this study aims at ascertaining

the current morphometric, physicochemical biological characteristics of the lake for the aforementioned purposes.

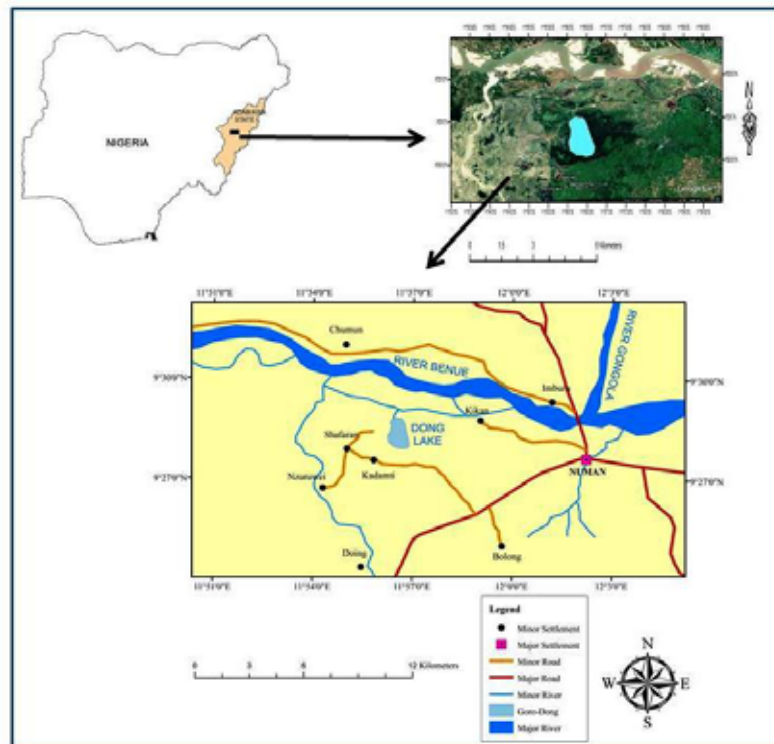
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2.0 Materials and Methods

Goro Dong is located at Latitude 9°24'02"N of the Equator and longitude 11°56'33"E of the Greenwich Meridian (Fig. 1). It is situated on the left bank of River Benue beside Kodomti and Shaforon Villages of Numan Local Government Area of Adamawa State. It is a lateral fluvial lake by origin, having its basin formed on Holocene alluvial deposits by temporal fluvial processes of alternating flood, erosion and deposition events.

The lake area is situated in the Yola arm of the Benue Rift - a section of the West African Rift system formed in the early cretaceous period [14]. It is characterized by substantial zone recent alluvial deposits partially underlain by shales and sandstones with eminences of limestones on the fringes around Kodomti and Shaforon settlements. Influenced by the tropical wet and dry (Aw) type of climate, the area is characterized by high mean annual temperature fluctuations (27.3°C to 30.7°C) with total annual precipitations ranging between 642 mm to 1407 mm [15, 13]. These geologic and climatic characteristics of the area pose tremendous influences on the hydrologic and limnologic states of the lake.

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Figure 1: The Study Area

Three major categories of methodologies (Hydrographic survey, Geographic information System (GIS) Analyses and Physicochemical analyses of the lake) were employed in this study in order to obtain results on the lake hydrogeomorphologic and limnologic states.

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2.1 Hydrographic survey of the lake

A hydrographic survey of the lake was conducted for four days in March 2016. The activity involved the measurement of water depths at 376 sampling points within the lake using the staff sounding

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method [16, 17]. The corresponding longitudinal and latitudinal coordinates of each sampling point were also obtained using the Global Positioning System (GPS-Garmin eTrex).

The survey of **fluid-mud** deposit in the lake was conducted at 52 randomly selected points by Depth Probe Method as described by [18]. This involved the use of hand corer inserted into the lake basin floor to ascertain the **fluid-mud** depth at each sampling point.



Plate 1a: Water Depth Survey



Plate 1b: Fluid mud depth survey

2.2 GIS Analyses and Mathematical Computations

Data generated from the hydrographic survey were then used in preparing the Bathymetric map of the lake using GIS tools and procedures. This involved the use of the Spatial Analyst tools of the ArcMap environment of ArcGIS 10.0 software (Fig. 2). Direct measurements of the **lake** morphometric properties as Surface Area (A), Shoreline Length (SL), Maximum Length/Fetch (L) and Maximum Width (W) were conducted on the prepared Bathymetric map in the ArcMap environment.

Other parameters such as the **Lake Volume** (V), Mean Depth (Z_{mean}), Length-Width Ratio (LW_r), Relative Depth (Z_r), Shoreline Development Index (SDI) and Index of Basin Permanence (IBP) were computed using dimensions provided by the Bathymetric map and appropriate mathematical formulae.

2.3 Water Sampling and **Physico-chemical** Tests

Water samples were collected in the March (Dry Season) and September (Wet Season) 2016. The lake was cross-divided into four sampling sections. In each section, Five (5) water samples were randomly collected and made into one composite sample giving rise to four composite samples for the entire lake. The samples were then homogenized and stored in iced cooled container and transported to laboratory for analysis. Mean value of each parameter was derived from the composite values obtained from the analysis. All onsite and laboratory tests were carried out based on standard procedures. The elemental analyses were conducted using Air Acetylene Flame Integrated Mode (Buck 210 Model) of Atomic Absorption Spectrophotometer [13]. The **physico-chemical** parameters were analyzed using SCL-04 Model of Lamotte Water Analyzer, while pH and Electrical Conductivity

were tested **on-site** using Model 3540 of Jenway pH/Electrical Conductivity Meter. Water **temperatures** were obtained **on-site** at various depths using Field Thermometer, while the colour was detected from the collected water sample by observation. The Lake Morphoedaphic Index (MEI) – a measure of fish yield potential was determined using Total Dissolved Solids (TDS), Electrical Conductivity (EC), and Mean Depth (Zm) values as asserted by [19], [20] and [21].

$$MEI = \frac{TDS}{Z_m} \text{ or } \frac{EC}{Z_m}$$

3.0 Results and Discussion

3.1 Hydrogeomorphic characteristics of the lake

The Bathymetric Map of the lake **prepared in** March 2016 and its basin morphometric characteristics are presented in Figure 2 and Table 1, respectively.

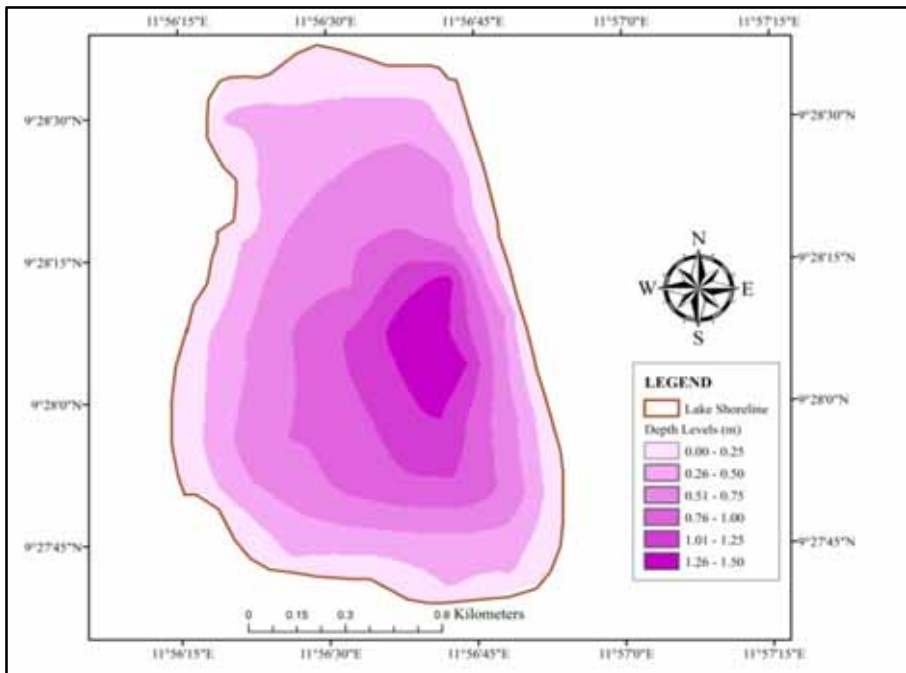


Figure 2: Bathymetric Map of the Lake (Goro-Dong)

Table 1: Morphometric Characteristics of the Lake.

S/No	Morphometric Parameter	Symbol/Formulae	Goro-Dong
1	Shoreline Elevation	h	140m.a.s.l
2	Shoreline Length	SL	5.5 km
3	Surface Area	A	1.65 km ²
4	Maximum Length	L_{Max}	1.7 km
5	Maximum Width	W_{Max}	1.0 km
6	Length –Width Ratio	$LW_r = \frac{L_{Max}}{W_{Max}}$	1.70
7	Maximum Depth	Z_{Max}	1.48 m
8	Mean Depth	$Z_{Mean} = \frac{V}{A}$	1.20 m
9	Relative Depth	$z_r = \frac{50(z_m)\sqrt{\pi}}{\sqrt{A_0}}$	0.15%

10	Shoreline Development Index	$SDI = \frac{SL}{2\sqrt{\pi A_0}}$	1.21
11	Volume	$V_{z_0-z_1} = \frac{1}{3}(A_{z_0} + A_{z_1} + \sqrt{A_{z_0} \times A_{z_1}})(z_0 - z_1)$	1.98 mcm
12	Index of Basin Permanence	$IBP = V/SL$	0.36

The bathymetric map of the lake portrays a conic shape lake basin of steep eastern side and a gentle western side, with the deepest part of the lake tilted to the east. The gentle western slope of the lake basin indicates the activity of sedimentation and *sediment focusing* (the entrainment of sediment from the lake littoral zone to the limnetic zone by water waves). Noticeable pointers to the sedimentation of the lake include such human activities as excessive clearance of surrounding and littoral vegetation for purposes of fishing and crop cultivation as well as creation of water drinking points for livestock and canoe/fishing inlets (Plates 2a, 2b, 2c, and 2d).



Plate 2a - 2d: Activities influencing siltation and sediment focusing in the lake

Morphometric computations and analysis revealed a general shallow characteristic for the lake with 1.48m maximum depth and a mean depth of 1.20m. However, the lake was found to be deeper than Goro Mbemun – another major and prominent lake in the area as ascertained by [13]. With a Maximum Length of 1.7km, a Maximum Width of 1.0 km and a Length-Width Ratio of 1.7, the lake is open to impacts of wind and waves which in turn enhance mixing and sediment focusing. The lake Index of Basin Permanence (0.36) and water content (1.98mcm) indicate that it is characterized by good water holding routine; capable of supporting significant biological productivity and some human uses such as domestic water needs, irrigation, recreation as well as livestock drinking needs (Plate 3). Besides, the lake Shoreline Development Index of 1.21 indicates its crenulated nature and propensity of developing good littoral plant community of great biological relevance.



Plate 3: Water expanse of Goro Dong.

Thickness of the lake **fluid-mud** layer was found to range from 0.15m to 0.33m with a mean thickness of 0.31m. This signifies that the lake basin is less muddy and sticky, having its bed load material ranging from fine sand to silt with very low clay content, as compared to the high muddy and deep **fluid-mud** layer status of Lake **Mbemun**; as observed by [13]. Though this bed load characteristic of the lake (Goro Dong) may pose some negative impact on fish productivity, most especially the species with high affinity for muddy environments, the lake is considered highly suitable for vast sociocultural activities as fishing festivals and water games (recreation).

3.2 Limnological characteristics of the lake

It was also gathered from field studies that lake is less **infested with** littoral plant species of adverse impacts. The most common littoral species noted (though not in large populations) were *Eichhornia crassipes* (Water Hyacinth), *Ipomea aquatica* (Floating Morning Glory) and *Nymphaea* (Water Lilly) [Plates .



Plates 3a and 3b: Eminences of *Eichhornia crassipes*, *Ipomea aquatica* and *Nymphaea* in Goro Dong

The **physico-chemical** properties of the lake in Dry and Wet Seasons (2016) and corresponding Acceptable Standards for Fish productivity as provided by [22] are provided on Table 2.

Table 2: The **physico-chemical** properties of Goro Dong in Dry and Wet Seasons (2016) and corresponding **Acceptable** Standards for Fish productivity.

S/No	Parameter	Lake Status in Dry Season (2016)	Lake Status in Wet Season (2016)	Acceptable Fish Standard (Bhatnagar and Devi, 2013)
1	Temperature (°C)	24 - 28	23 - 26	15 - 35
2	Colour	Pale Green	Light Brown	Pale Green to Light Green
3	pH	6.80	7.20	7.0 – 9.5
4	Electrical Conductivity (S/m)	187.40	203.12	-
5	Turbidity (TNU)	11.10	28.30	30 - 80
6	Total Alkalinity (mg/L)	80.00	78.30	50- 200
7	Total Hardness (mg/L)	102.00	98.70	> 20.00
8	Total Suspended Solids (mg/L)	5.50	36.20	-
9	Total Dissolved Solids (mg/L)	271.00	352.00	-
10	Na (mg/L)	133.05	137.00	-
11	Mg (mg/L)	2.30	4.11	-
12	Calcium (mg/L)	2.56	5.23	25-100
13	Chloride (mg/L)	120.00	124.11	-
14	Sulfate (mg/L)	8.25	9.50	-
15	Phosphorus (mg/L)	2.67	2.92	0.03 – 2.00
16	Nitrate (mg/L)	7.21	10.13	0.00 – 100
17	Dissolved Oxygen (mg/L)	5.11	5.24	3.00 – 5.00
18	BOD (mg/L)	4.06	3.62	3.00 - 6.00

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167 Temperature plays a significant role in determining the limnologic processes of the lake. Therefore,
168 almost all the chemical and biological properties of the lake are dependent on its temperature at all
169 times. For both Dry and Wet Seasons, the lakes diurnal temperature was found to range from 23°C to
170 28°C. This temperature range was found suitable for biological productivity, most especially fish
171 production as opined by [22].

172 Another important determinant of biological productivity of lakes is Water Colour. [23] and [22] noted
173 the suitability of Pale Green, Light Green and Light Brown waters for fish culture. As such, the Pale
174 Green to Light Brown colour status of Goro Dong (Lake) in Dry and Wet Seasons fall within the
175 acceptable limits for fish culture in the lake. In addition, the lake transparency as measured by its low
176 turbidity values 11.10 (in dry season) and 28.30 (in wet season) indicate high levels of transparency
177 and light energy transmission, suitable for biological productivity.

178 The pH values for both dry and wet seasons ranged from slightly acidic to neutral, while its moderate
179 Total Alkalinity values (80.00mg/L in dry season to 78.30mg/L) indicated its measure of total bases as
180 well as its ability to resist changes in pH. Both the pH and the Total Alkalinity values fell within
181 permissible requirements for fish production in the lake.

182 Electrical Conductivity is a measure of the total ionic content of a water body, which indicates
183 freshness or the water body or otherwise [24]. It is also an important Morphoedaphic variable for
184 determining fish yield potentials of a lake. Conductivity values for Goro Dong ranged from 187.40S/m
185 to 203.12S/m for the two seasons. These gave rise Morphoedaphic Indices (MEI) ranging from
186 156.17 to 169.27, indicating good fish yield potentials.

187 Phosphorus is an essential plant nutrient. A significant concentration of phosphorus or phosphates in
188 a lake is capable of influencing or enhancing the growth of aquatic plants (Algae and Macrophytes) in
189 it. As a matter of fact, 0.03mg/L content of total phosphorus can cause algal bloom in a lake or
190 reservoir [25]. Therefore, the concentration of phosphates (2.67 mg/L) in Goro Dong is substantial
191 enough to cause Algal bloom and the productivity of other aquatic plants in the lake.

192 A major determinant and influential factor for survival, growth and development of most aquatic flora
193 and fauna is Dissolved Oxygen (DO). The DO values for the lake as provided on Table 2 were found

adequate for the survival of the plants and animals in it. However, the Biochemical Oxygen Demand Values also indicated substantial levels of pollution by microorganisms which used up some quantity of the lake DO.

Values of other observed physicochemical properties such as Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and all the ionic concentrations presented on Table 2 were found within the acceptable limits for fish production in the lake.

As confirmation to the fish productivity potentials of the lake, it was gathered from field survey and oral interview that over 30 fish species inhabit the lake. The most prominent species observed included *Bagrus bayad*, *Bagrus docmac*, *Gymnarchus niloticus*, *Chrysichthys nigrodigitatus*, *Lates niloticus*, *Heterobranchus bidosalis*, *Clarias anguilaris*, *Citharinus citharus*, *Clarotes laticeps*, *Malapterurus electricus*, *Hydrocynus forskalii*, *Mormyrops deliciousus*, *Mormyrus rome*, *Hepsetus odoe*, *Lutjanus sp.*, *Physailia pellucida*, *Heterotis niloticus*, *Hemisynodontis membranaceus*, *Labeo coubie*, *Hyperopsis bebes*, *Barbus occidentalis*, *Oreochromis niloticus*, and *Mugil cephalus*.

4.0 Conclusion

In light of the results and discussion above, Goro Dong is a fluvatile lake with defined hydrogeomorphic characteristics (water content, surface area and depth), adequate for supporting vast domestic and sociocultural activities in Numan area. Besides, the lake was found to be of good limnologic status with high capabilities of supporting both human and aquatic lives in the area. Therefore, it is recommended that excesses of human activities within and around the lake be controlled in order to check siltation and water pollution. While periodic recreation and sociocultural activities such as water games fishing festival can tolerated in the lake, a well-designed fish farming project is also recommended.

6.0 References

1. Găstescu, P. Limnology, Lake Basins, Lake Waters. Lakes, Reservoirs and Ponds, 2009. 3(1): 7-12.
2. Bertoni, R. Limnology of Rivers and Lakes. *UNESCO Encyclopedia of Life Support Systems*. 2011. [www.ise.cnr.it/crypta/ebooks/Limnology\(Bertoni2011\)UNESCO-EOLSS.pdf](http://www.ise.cnr.it/crypta/ebooks/Limnology(Bertoni2011)UNESCO-EOLSS.pdf)
3. Gravel Lake Association. Gravel Lake Limnological Assessment, 2016. 74590001. Progressive AE. Pp 2.
4. Wetzel, R.G. Limnology: Lake and River Ecosystems. 2001. 3rd Edition. California, USA; Academic Press; An imprint of Elsevier.
5. Gregorie, S. The Concept of Hydrogeomorphology reflected in scientific literature. *Geopolitics, History and International Relations*. 2014. 1, 359-366.
6. Jefferson, A. What do you mean by "Hydrogeomorphological Process" (some thought following my GSA session on the topic). 2010. Retrieved May 16, 2012 from www.all-geo.org/highlyallochthonous.html
7. Montgomery, D. R. and Bolton, S. M. Hydrogeomorphic Variability and River Restoration. *American Fisheries Society*. 2003. Retrieved June 12, 2013 from www.gis.ess.washington.edu/grg/publications/pdfs/Mont_Bolton.pdf
8. Natural Resource Program Center Hydrogeomorphic (HGM) Analysis - Fact Sheet 2012. https://www.fws.gov/refuges/NaturalResourcePC/pdfs/FY2012_NRPC_HGM_Fact_Sheet.pdf
9. Yonnana, E., Tukur, A. L., and Mubi, A. M. Physicochemical Parameters and Water Quality for Livestock Consumption from Selected Lakes in the Upper Benue Valley Area of Adamawa State, Northeastern Nigeria, *International Journal of Health and Medical Information*, 2014. 3(1); 42-47.
10. Yonnana, E. Assessment of Hydrogeomorphic characteristics of lakes in the Upper Benue Valley of Adamawa State, Nigeria. 2015. Unpublished PhD Thesis, Department of Geography, Modibbo Adama University of Technology Yola, Adamawa State.

- 244 11. Yonnana E. and Jerry. H. S. Land use Impacts on Hydrogeomorphology of Lakes in the Upper
245 Benue Valley Area of Adamawa State, Nigeria. International Journal of Research in Geography
246 (IJRG), 2016. 2(1);26-33. www.arcjournals.org
- 247 12. Yonnana E., Tukur, A. L., and Mubi, A. M. Water balance of selected fluvial lakes in the
248 upper Benue valley, Adamawa State, Nigeria. African Journal of Geography and Regional
249 Planning, 2017a. 4 (1), pp. 312-317. www.internationalscholarsjournals.org.
- 250 13. Yonnana E. and Raji, A. Assessment of Hydrogeomorphic Suitability of Lake Mbemun for Socio-
251 cultural Fishing Festival in the Bachama Chiefdom, Adamawa State, Northeastern Nigeria.
252 International Journal of Geography, Environment and Earth Science 2017. 10(3): 1-9.
253 DOI:10.9734/JGEESI/2017/33534
- 254 14. Ofoegbu, C. O. & Okereke, C. S. Rifting in West and Central Africa. In C.O. Ofoegbu, (ed). The
255 Benue Trough: Structure and Evolution. 1990. Braunschweig, Friedr. Vieweg and Son.
- 256 15. Yonnana E., Shinggu, D. Y., Kaigama I., and Bedeson, A. N. Assessment of Water Quality for
257 Goro Dong (Lake) and Its Suitability for Consumption and Domestic Use by the Immediate Lake
258 Communities in Numan, Adamawa State Nigeria. Journal of Geography, Environment and Earth
259 Science International, 2017b. 12(4): 1-8. DOI:
260 10.9734/JGEESI/2017/37517.
- 261 16. Basak, N. N. Survey and Leveling. New Delhi, McGraw Hill Ltd. 1994. Pp 475-476
- 262 17. Arora, K. R. Irrigation, Water Power and Water Resources Engineering. 2002. Delhi, Lomus Offset
263 Press.
- 264 18. Schaap, B. D. and Sando, S. K. Sediment accumulation and distribution in Lake Kampeska,
265 Watertown, South Dakota. 2002. WRI; 2002-4171.
- 266 19. Ryder, R. A. A Method for Estimating the Potential Fish Production of North-temperate Lakes.
267 Transactions of the American Fisheries Society, 1965. 94(3); 214-218. Doi.org/10.1577/1548-
268 8659(1965)94[214:amfep]2.0.co;2
- 269 20. Henderson, H. F., and Welcomme, R. L. The Relationship of Yield to Morpho-Edaphic Index and
270 Numbers of Fishermen in African Inland Fisheries; Food and Agriculture Organization of The
271 United Nations. CIFA Occasional Paper 1974. No. 1.
272 <http://www.fao.org/docrep/008/e6645b/E6645B00.htm#TOC>
- 273 21. Jenkins, R. M. and Oglesby, R. T. The Morphoedaphic Index—Concepts and Practices: The
274 Morphoedaphic Index and Reservoir Fish Production. Transactions of the American Fisheries
275 Society, 1982. 111(2); 133-140. Doi: 10.1577/1548-8659(1982)111<133:tmiapt>2.0.CO;2
- 276 22. Bhatnagar, A. and Devi, P. Water Quality Guidelines for the Management of Pond Fish Culture.
277 International Journal of Environmental Science, 2013. 3(6); 1980-2009.
278 Doi:10.6088/ijes.2013030600019
- 279 23. National Agricultural Extension and Research, Water Quality Management in Fish Culture,
280 Extension Bulletin No. 98 Fisheries Series 1996. No 3 Published by Liaison Services Ahmadu
281 Bello University, Zaria.
- 282 24. Ogbeibu, A. E. and Victor, R., Hydrological studies of water bodies in the okomu forest
283 reserves (sanctuary) in Southern Nigeria, Physico-chemical Hydrology, Tropical Freshwater
284 Biology, 1995. 4, pp 83-100.
- 285 25. Jones, B. Interpreting Lake Data: Indiana Clean Lakes Program. Factsheet. n.d. 08-01.