

Hydrogeomorphologic and Limnologic Characteristics of *Goro Dong*: An implication for Conservation and Sustainability of Lakes and Ponds Resources in Numan area, Adamawa State, Northeastern Nigeria

ABSTRACT

Some hydrogeomorphic and limnologic characteristics of *Goro Dong* - A fluvial lake, have been examined as a contributory objective towards conservation and sustainable use of fluvial lakes and ponds resources in Numan Area of Adamawa State Nigeria. Hydrogeomorphic Characteristics of the lake were examined by a combined approach of Hydrographic Survey, Geographic Information System (GIS) Analyses and Mathematical Computations. Some Limnologic properties of the lake were also examined by site survey and laboratory analyses. Results revealed the *Goro Dong* as a typical fluvial lake with shallow depth and wide morphometric properties good enough for recreation and sociocultural 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 interrelationships 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, physicochemical 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 fluvial lake in the Numan section of Upper Benue Valley area of Adamawa State, with great historical, sociocultural 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.

2.0 Materials and Methods

Goro Dong is located on Latitude $9^{\circ}24'02''\text{N}$ of the Equator and longitude $11^{\circ}56'33''\text{E}$ 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.

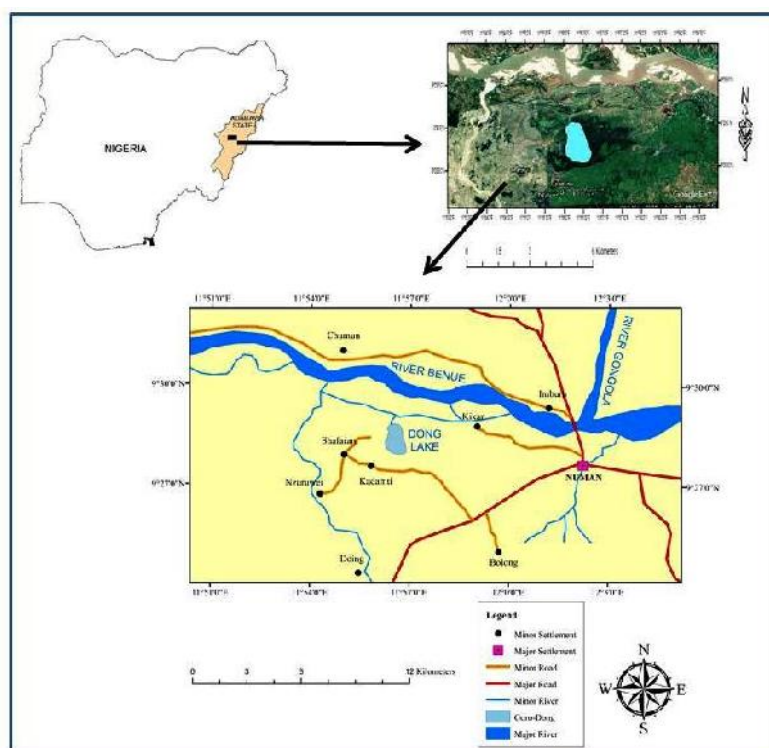


Figure 1: The Study Area

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's hydrogeomorphologic and limnologic states.

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 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 so as 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's 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's 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 Physicochemical 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 (Yonnana and Raji, 2017). The physicochemical parameters were analyzed using SCL-04 Model of Lamotte Water Analyzer, while pH and Electrical Conductivity were tested onsite 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's 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 for March 2016 and its basin morphometric characteristics are presented in Figure 2 and Table 1, respectively.

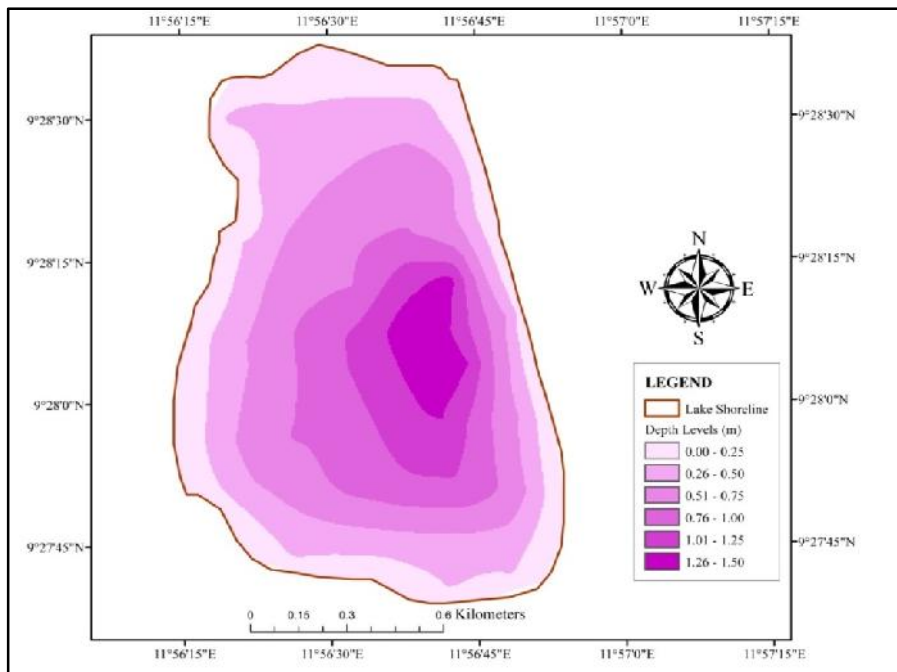


Figure 2: Bathymetric Map of the Lake (Goro-Dong)

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's 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's 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's Shoreline Development Index of 1.21 indicates its crenulated nature and propensity of developing good littoral plant community of great biological relevance.



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150 **Plate 3:** Water expanse of Goro Dong.

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

158 **3.2 Limnological characteristics of the lake**

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



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

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

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Table 2: The physicochemical properties of Goro Dong in Dry and Wet Seasons (2016) and corresponding Acceptable Standards for Fish productivity are provided on.

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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174 Temperature plays a significant role in determining the limnologic processes of the lake. Therefore,
 175 almost all the chemical and biological properties of the lake are dependent on its temperature at all
 176 times. For both Dry and Wet Seasons, the lakes diurnal temperature was found to range from 23°C to
 177 28°C. This temperature range was found suitable for biological productivity, most especially fish
 178 production as opined by [22].

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

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

189 Electrical Conductivity is a measure of the total ionic content of a water body, which indicates
 190 freshness or the water body or otherwise [24]. It is also an important Morphoedaphic variable for
 191 determining fish yield potentials of a lake. Conductivity values for Goro Dong ranged from 187.40S/m
 192 to 203.12S/m for the two seasons. These gave rise Morphoedaphic Indices (MEI) ranging from
 193 156.17 to 169.27, indicating good fish yield potentials.

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

A major determinant and influential factor for survival, growth and development of most aquatic flora 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's DO.

Values of other observed physicochemical properties 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.*, *Physallia 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, adequate enough in water quantity, surface area depth, capable of 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.

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