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Morphometric Analysis of Lake Ruma, Song, Adamawa State in Northeastern Nigeria

Yonnana Ezekiel[1*], Apollos Thandime[2], James Thomas[1]

[1] Adamawa State University Mubi, Department of Geography, Nigeria.
[2] Adamawa State University Mubi, Department of Fisheries and Aquaculture, Nigeria.

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Abstract

The morphometric analysis of lakes is vital for vast limnologic, ecologic and sustainable use of the lake resources. In this study, a morphometric analysis assessment of Lake Ruma was conducted using an integrated approach of hydrographic survey, mathematical computations and field observations. Results revealed that the lake is characterized by a Surface Area (A_0) of 0.56km^2; a Volume (V) of 0.80mcm and a Mean Depth (Z_{Mean}) of 1.43m. Its Relative Depth (Z_r) of 0.88% and 0.18 Index of Basin Permanence (IBP) are clear indications of the lake's shallow status, susceptibility to mixing and the littoral effect on the basin volume. The lake's Development of Volume index (1.19) portrays the conical depression nature of its basin as also presented by its bathymetric map, while its Shoreline Development Factor (D_L) of 1.64 indicates its crenulated nature and potential for development of littoral community. Major identified uses of the lake are the small scale (local) fishing and water supply for livestock consumption and domestic uses. The lake is recommended for proper conservation and management to support a longer term and a larger scale of fish farming, irrigation for agriculture and water supply for livestock and domestic uses.

Keywords: Lake Ruma, Morphometry, Hydrographic, Bathymetry, Mathematical computation.

1. Introduction

With the increased focus on integration and holistic approaches to water management across the world, the need for lake resources management is not left out. At the World Summit on Sustainable Development in Johannesburg in 2002, Integrated Water Resources Management (IWRM) and Water Efficiency Plans were proposed in order to overcome the world's essential water resources issues including those of the lake ecosystems (UNEP Collaborating Centre on Water and Environment, 2007). Therefore, Lake Resources Management is regarded as an integral component of IWRM with lake morphometric assessment as a vital activity that provides relevant information on lake basin morphology and water content.

Lakes are primarily water storage bodies with a considerabe variation in size, shape and depth (UNEP Collaborating Centre on Water and Environment, 2007) having a great significance to humans and many other organisms. They are found throughout the world, most especially in North America, Africa, and Asia where about 70 % of the world's total lake water exist (Lake, 2010). Among the world's largest lakes are Lake Baikal (Central Asia), the Caspian Sea (Central Asia), Lake Tanganyika (Eastern Africa), Lake Superior and the Great Lakes (North America), Crater Lake (Oregon, USA), and Aral Sea (Western Asia). Others include Lake Eyre (Australia), Lake Vanern Northern Europe, Lake Titicaca (Western South America) and Great Slave Lake (Canada). Containing over 90 % of the world's liquid surface freshwater, natural and artificial lakes provide many uses for sustainable human livelihood and economic developments (International Lake Environment Committee-ILEC, 2007) as well as uses for socio-cultural developments, while serving as habitats for a great variety of flora and fauna.

In the recent decades, the human impact on lake ecosystems has increased due to the intensification of agriculture, irrigation, water consumption, and electrical purposes, in a way that noticeable environmental changes have been observed in the shallowest lakes (Ławniczak et al., 2011). Furthermore, it has been noted that the majority of such changes within lakes are associated with changes in the water level, progressing degradation, or plant succession leading to lake disappearance taking place within the littoral zone. The United Nations World Water Assessment Programme, (2010) has earlier commented on the alarming deteriorating state of most lakes in the world, which calls for a timely and periodic monitoring and conservation measures that include bathymetric mapping and morphometric analysis. In this line of thought, studies conducted on the fluviatile lakes of the Upper Benue Valley area of Adamawa State, in Northeastern Nigeria showed that the lakes are subjected to gradual changes in their basin morphology and loss in their hydrological potentials over time as they gradually shrink and dry up or accumulate mineral and organic materials, filling up their basins through the combined influences of natural and anthropogenic processes of climate change as well as catchment erosion and deposition rates associated with changing land uses (Yonnana, 2015; Yonnana and Hyellamada, 2016).

Lake Morphometry is simply the measurement and description of lake morphology (shapes and size of lakes)

* Corresponding author e-mail: ezekiel97@adsu.edu.ng

(Wetzel and Likens, 1991; Kalff, 2002). It is a very vital concept used in detailed analyses of the limnologic properties of freshwater lakes (Wetzel, 2001; Kalff, 2002). The Morphometric characteristics of lakes are paramount in the assessments of numerous limnologic properties of the lake ecosystem, ranging from status and changes in the lake basin morphology to the quantity and quality of its waters in relation to the biological productivity and human uses. Stefanidis and Papastergiadou (2012) added that the morphology of lakes is one of the most important factors controlling the trophic status, physicochemistry, productivity, and distribution of aquatic organisms, and that lake morphometric properties such as surface area, volume, maximum and average depths are strongly related to nutrient cycling and the lake water chemistry. Expressing the usefulness of Lake Morphometry in Limnology, Hakanson (2005) noted that the size and form of lakes regulate many general transport processes, such as sedimentation, re-suspension, diffusion, mixing, burial and outflow, which in turn regulate many abiotic and chemical variables. More so, by influencing water clarity, Lake Morphometry regulates both the primary and secondary biological productions of the lake, for example the production of zooplankton and fish. Management techniques, such as the loading capacity for effluents and the selective removal of undesirable components of the biota, are also heavily dependent on a detailed knowledge of the morphometry and water retention times in freshwater ecosystems (Wetzel and Likens, 1991). Morphometric studies conducted on natural lakes in Brasil revealed that Lake Palmas was the deepest (Barroso et al., 2014). Similarly, studies carried out on lakes Mbemun and Goro Dong in Lamurde and Numan areas of Adamawa State in Nigeria (Yonnana and Raji, 2017; Yonnana et al., 2018), respectively, showed that variations in their morphometric properties are responsible for variations in their suitability for socio-cultural fishing festival in the Bachama Chiefdom, even though they both possess good potentials for fish production. While Lake Mbemun was found to be shallower in its water level and more muddy and sticky, Lake Goro Dong was discovered to be deeper in the water level, and less muddy and not sticky.

Considering the importance of lake morphometry as well as the craving for surface freshwater resources by humans on one hand and the fast depletion tendencies of lakes on the other hand, there is a serious and urgent need for inventory and conservation methods of the existing freshwater lakes, most especially in the sub Saharan African countries (including Nigeria) where the rages of climate change and anthropogenic degradation prevail (Serdeczny, et al., 2015; Yunana et al., 2017). Though a very important and the only existing lentic surface water body in Song Local Government Area of Adamawa State, Lake Ruma lacks detailed and documented morphometry information for proper planning and management. It is against this background that the current study was conducted on the lake with the sole aim of ascertaining its morphometric properties. The objectives of the study are to prepare a bathymetric map that portrays the lake basin morphology, examines its morphometric properties and identifies its major potentials. The study constitutes part of an ongoing research and information gathering exercise by the researchers on lakes' and ponds' potentials in Adamawa State for the purpose of conservation and sustainable use of the state's water resources.

2. Materials and Methods

2.1. Study Area

Lake Ruma and its immediate environs are located between latitudes 09°31'30"N and 09°43'30"N and longitudes 12°40'00"E and 12°44'30"E. The lake is situated in Song Local Government Area of Adamawa State, Northeastern Nigeria; about 15km Southeast of Song Town, on the right bank floodplain of River Kilange, southwards of Wuro Daudu settlement (Fig. 1).

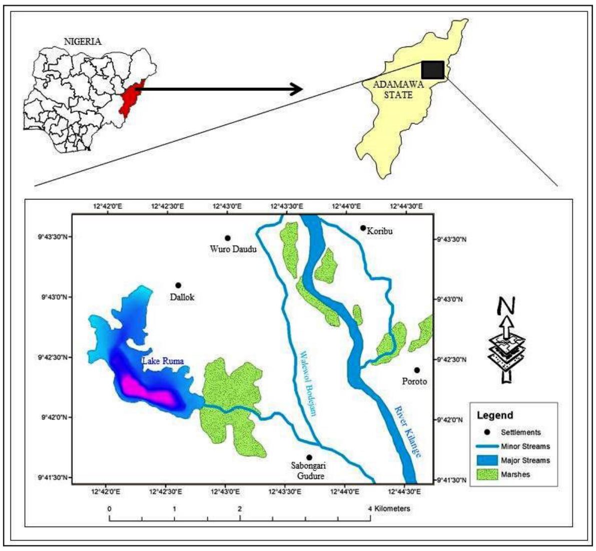

Figure 1. Study Area Map showing the location of Lake Ruma

The major sources of its water are direct rainfall, stream inflows from the Kilange River, most especially at periods of peak discharges and runoffs from the immediate surroundings during periods of high and intensive rainfalls. The lake area is surrounded by riverine alluvium soils with its littoral zones dominated by vast species of submerged, floating and emerged aquatic plants; prominent among which are Ipomea aquatica (Floating Morning Glory), Nymphaea nouchali (Water Lilly) and Typhalatifolia (Typha grass) and Pistia stratiotes (Water lettuce). The lake environs are characterized by a large expanse of a grazing land with few farmlands and few isolated human settlements.

2.2. Data Collection

Both process and historical methods of lake system studies in geomorphology as suggested by Kashiwaya (2017) were employed in this study. Therefore, an integrated approach involving the applications of hydrographic survey, GIS analyses, mathematical computations using relevant mathematical formulae, field observation and oral interviews were employed for the sake of assessing the morphometric characteristics and functionality of the lake.

The hydrographic survey of the lake basin involved a combined sounding routine over the lake in which HONDEX PS-7 Portable Handheld Depth Sounder and the Sounding Rod Method as described by Davis et al., (1981) and Basak (1994) were used. The Handheld Depth Sounder was used for most of the depth measurements owing to its accuracy propensity at the depth range of 0.6m to 80m, while the Sounding Rod procedure was employed as an alternative measure at the lake portions of less than a 0.6m depth. The soundings were randomly conducted at 478 sampling points over the lake covering the portion of open water and parts with less littoral vegetation. The sounding sample size (462 points) was tied to the small size state of the lake. At each sounding point, depth was recorded as Z coordinate alongside its corresponding X, Y coordinates (Northing and Easting) obtained in Universal Traverse Mercator (UTM) format using the Global Positioning System (GPS-Garmin etrex 20) owing to the small nature of the study lake. With a 2.0m to 3.0m range of accuracy, the GPS used had a very minimal effect on the results of spatial variations.

The hydrographic survey data were compiled in a Microsoft Excel sheet and then converted into a point-shape file in ArcGIS 10.0 for preparation of the lake bathymetry. Through geo-processing procedures involving the use of the Nearest Neighbor Interpolation method, the Lake's Bathymetric map was generated from the imported hydrographic survey data. From the generated bathymetric map, the lake's morphometric parameters such as Shoreline Length (SL), Surface Area (A), Maximum Length (L_{Max}) and Maximum Width (W_{Max}) were directly measured on the generated bathymetric map in ArcGIS 10.0 using the measure tool of the Arc Map.

While the lake's shoreline elevation and maximum depth values were obtained directly from the hydrographic survey data, other parameters such as the Relative Depth (Z_r), Mean Depth (Z_{Mean}), Development of Volume (D_v), Lake Volume (V), Shoreline Development Index (D_L) and Index of Basin Permanence (IBP) were obtained by mathematical computations using the appropriate formulae as shown in Table 1.

Table 1. Lake Morphometric parameters and corresponding mathematical formulae

Morphometric Parameter	Symbol/Formulae	Source
Shoreline Elevation	H	Wetzel, 2001;
Shoreline Length	SL	Wetzel, 2001; Kalff, 2002; SWCSMH, 2015
Surface Area	A_0	Wetzel, 2001; Kalff, 2002; SWCSMH, 2015
Maximum Length	L_{Max}	Wetzel, 2001; Kalff, 2002; SWCSMH, 2015
Maximum Width	W_{Max}	Wetzel, 2001; SWCSMH, 2015
Maximum Depth	Z_{Max}	
Mean Depth	$Z_{Mean}=V/\ A_0$ V= Lake Volume	Wetzel, 2001; Kalff, 2002 SWCSMH, 2015
Depth Ratio	$R_z= Z_{Mean}/Z_{Max}$	Kalff, 2002
Relative Depth	$zr = \frac{50(z_{\max})\sqrt{\pi}}{\sqrt{A_0}}$	Wetzel, 2001; SWCSMH, 2015
Shoreline Development Factor	$D_{SL} = \frac{SL}{2\sqrt{\pi A_0}}$	Wetzel, 2001; SWCSMH, 2015
Development of Volume	$D_v = 3Z_{Mean}/Z_{Max}$	Wetzel, 2001; Kalff, 2002; SWCSMH, 2015
Volume (V)	$V_{z0-z1} = \frac{1}{3}\left(A_{z0} + A_{z1} + \sqrt{A_{z0} \times A_{z1}}\right)\left(z_0 - z_1\right)$ z_0 = Zero depth (Shoreline) z_1 = Next successive area at depth z_0	Wetzel, 2001; Kalff, 2002; SWCSMH, 2015
Index of Basin Permanence	IBP = V/SL	Wetzel, 2001; Kalff, 2002; SWCSMH, 2015

Information on the functional relevance of the lake was obtained by observation and historic inquiries through a focus group discussion with fishermen and settlers in the lake environs.

3. Results and Discussion

Results of the lake's morphometric parameters as obtained are provided in Table 2. The results revealed that the lake is characterized by a surface area (A_0) of 560,000.00m^2 (0.56km^2), a maximum length (L_{max}) or fetch of 1.22km, and a maximum width (W_{max}) of 0.34km, resulting in a length-width ratio (Extension) of 3.59. The maximum length value indicates a good lake surface state, adequate for the development of water waves by wind action as well as the enhancement of adequate water mixing which promotes a good circulation of oxygen within the lake.

While the Shoreline Length (SL) is the farthest distance of the lake's entire marginal line that marks the water and land boundary, the Shoreline Development Index (D_L) is the ratio of the shoreline length to the length of the circumference of a circle of area equal to that of the lake, which is a measure of the lake's shape and a morphometric parameter that reflects the lake's potential for development of littoral communities, which are usually of high biological productivity (Soil and Water Conservation Society of Metro Halifax - SWCSMH, 2015). Analysis and mathematical computations yielded a Shoreline Length of 4.34km and a Shoreline Development Factor of 1.64, which is an indication of its crenulated state and potential for littoral community development. This property is a relevant pointer to the lake's viable potential for fishery development.

Table 2. Morphometric Parameters of Lake Ruma estimated in January, 2019

Morphometric Parameter	Symbol/Formulae	Dimension
Shoreline Elevation	H	215 m a.s.l
Shoreline Length	SL	4.34 km
Surface Area	A_0	0.56km^2
Maximum Length	L_{Max}	1.22 km
Maximum Width	W_{Max}	0.34 km
Maximum Depth	Z_{Max}	3.60 m
Mean Depth	$Z_{Mean}=V/\ A_0$	1.43 m
Depth Ratio	$R_z= Z_{Mean}/Z_{Max}$	0.40
Relative Depth	$zr = \frac{50(z_{\max})\sqrt{\pi}}{\sqrt{A_0}}$	0.43
Development of Volume	$D_v = 3Z_{Mean}/Z_{Max}$	1.19
Shoreline Development Factor	$D_{SL} = \frac{SL}{2\sqrt{\pi A_0}}$	1.64
Volume	$V_{z0-z1} = \frac{1}{3}\left(A_{z0} + A_{z1} + \sqrt{A_{z0} \times A_{z1}}\right)\left(z_0 - z_1\right)$	0.80mcm^3
Index of Basin Permanence	IBP = V/SL	0.18

The mean depth of a lake serves a common parameter used for depth comparison among lakes, while the relative depth (a ratio of the lake maximum depth to its mean diameter) portrays general shallow or deep characteristics of the lake (SWCSMH, 2015; Kalff, 2002). A Maximum Depth (Z_{max}) of 3.60m was obtained from the hydrological survey data, while mathematical computations revealed a Mean Depth (Z_{mean}) of 1.43m and a Relative Depth of 0.43%, all indicating the lake's shallow status. Comparing the lake's mean depth with those of other fluvial lakes in the Benue valley area of Adamawa State, the lake was found to be substantially deeper than Lakes Geriyo-Yola North (0.70m), Gwakra-Girei (0.75m), Pariya-Fufore (0.79m) and Mbemun-Lamurde (0.82m) and in the ranges of Lakes Pariya Ribadu-Fufore (1.41m) and Goro Dong-Numan (1.20m) (Yonnana et al., 2015; Yonnana and Raji, 2017; Yonnana et al., 2018). The relative depth value (0.43%) obtained for the lake indicates its relatively very shallow status (<15ft or 4.60m) as asserted by Bischoff (2014) and Wenk News (2017) and thus its susceptibility to mixing and exposure to sunlight and nutrients which could enhance aquatic plant productivity by photosynthesis.

Lake volume (V) is a measure of the water content of the lake in cubic meters (m^3) or million cubic meters (mcm). It is normally computed from the lake bathymetry map information using the formula provided on table 1. A volume of 0.80mcm was computed for the studied lake. In comparison to the volumes of Lakes Mbemun (2.99mcm), Goro Dong (1.98mcm), Geriyo (1.12mcm) and Pariya Ribadu (1.08mcm) (Yonnana et al., 2015; Yonnana and Raji, 2017; Yonnana et al., 2018), Lake Ruma was found to be smaller, yet confirmed as another substantial lentic water body of great aquatic potentials in Adamawa State, though smaller in volume compared to other lakes.

Two important morphometric parameters that provide good estimates of the Lake Basin form are

the Depth Ratio (R_z) and Development of Volume (D_v). Depth Ratio (R_z) relates the lake basin depression to that of a perfect cone with the same height and basal area as that of the lake's maximum depth and surface area, respectively (Neumann, 1959 in Kalff, 2002). R_z values from 0.33 to 0.35 indicate elliptical cone-shaped basins, while values from 0.66 to 0.67 indicate ellipsoid-shaped basins (Kalff, 2002). As such, the Depth Ratio value (0.40) obtained for Lake Ruma indicates the departure of its basin form and elliptical cone-shape towards an ellipsoid form as also portrayed by the Bathymetric map (Fig. 2) and the lake's Hypsographic Curve (Fig. 3).

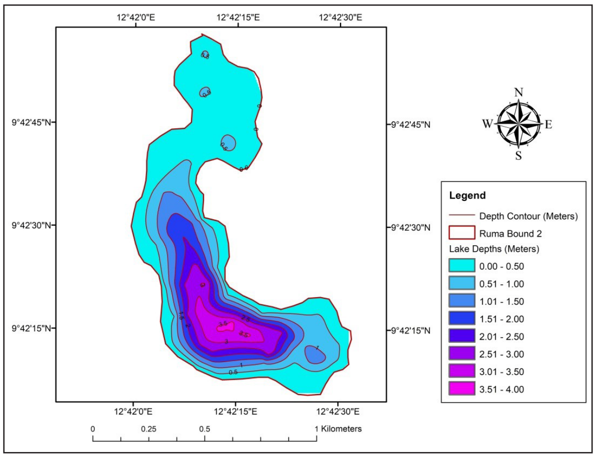

Figure 2. Bathymetric Map of Lake Ruma for January, 2019

Development of Volume is a measure of departure of the shape of a lake basin from that of a cone, in that the value is greater than 1.0 for the majority of lakes and greatest in shallow lakes with flat bottoms (SWCSMH, 2015). Lake Ruma yielded a D_v value of 1.19 depicting the slight conical shape of its basin.

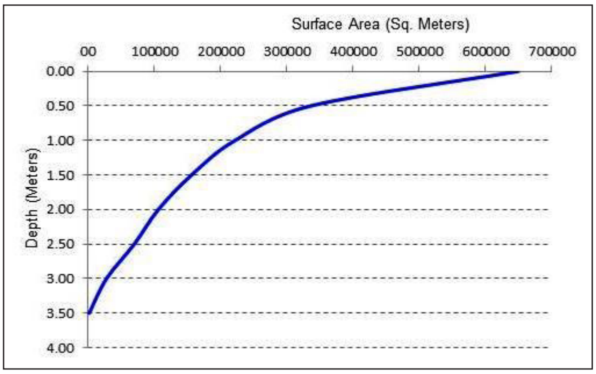

Figure 3. Hypsographic Curve of the lake

A parameter that reflects the littoral effect on lake volume is the Index of Basin Permanence (IBP). It is the ratio of the lake volume to its shoreline length in kilometers. It also indicates a state of shallowness so that lakes with IBPs in the vicinity of 0.1 and below are commonly dominated by rooted aquatic macrophytes, while values of 0.2 and above indicate a level of more water permanence (SWCSMH, 2015). The 0.18 IBP value obtained for Lake Ruma therefore indicates its shallow and non-permanence status as well as the dominance of its littoral zone by rooted aquatic plants; prominent among which are Typha latifolia, Nymphaea nouchali Oryza Spp and Pistia stratiotes as found from field studies.

Field studies revealed that besides its ecological function as a habitat for vast aquatic flora and fauna, Lake Ruma serves as an important fishing site that supports over fifty occupational fishermen on an annual basis. It also serves as a major source of drinking water for livestock and domestic uses for humans living in its vicinity, most especially in the dry seasons. Even though irrigation agricultural practices were observed to be very minimal in the area, animal rearing and rain-fed agriculture were found to be the most prominent land uses in the lake environs. It was also observed that sheet wash and surface runoff in form of rills from the surrounding farmlands drain water and some quantity of sediments into the lake at several points. Thus, the encroachment of farming activities closer to the lake shore is capable of intensifying sediment loading and focusing in the lake basin, which in time can eventually lead to gradual siltation of the lake.

4. Conclusions

The morphometric properties of Lake Ruma were found to be similar to those of the fluvial lakes in the Benue River valley area of Yola. It is a shallow and elongated fluvial lake of a concise surface area, volume and maximum length, adequate for supporting aquatic productivity with viable potentials for fisheries and aquaculture as well as substantial water quantity for livestock production in the area. However, the encroachment of farming practices closer to the lake shores poses the dangers of siltation in the near future. Therefore, proper management of the lake against sediment generating land uses in the area is recommended. Besides, the data and information generated from this study will be very useful for the monitoring and management of the lake, most particularly, with regards to the aspects of water budget and siltation abatement.

References

Barroso, G.F., Gonçalves, M.A., Garcia, F.C. (2014). The Morphometry of Lake Palmas; A deep Natural Lake in Brazil. PLoS One, 9(11). doi:10.1371/journal.pone.0111469

Basak, N.N. (1994). Survey and leveling. New Delhi, MacGraw Hill Ltd. 1994;475-476

Bischoff, J. (2014). Shallow Lake Ecology. Retrieved July 14, 2018 from https://minnehahacreek.org/sites/minnehahacreek.org/files/Shallow%20Lake%20Forum%204-12-14%20Bischoff.pdf

Davis, R.E., Foote, F.S., Anderson, J.M., Mikbail, E. M. (1981). Surveying Theory and Practice (6th ed). New York, McGraw-Hill, p 878.

Hakanson, L. (2005). The Importance of Lake Morphometry for the Structure and Function of Lakes. International Review of Hydrobiology, 90(4): 433-461. doi. 10.1002/iroh.200410775

International Lake Environment Committee (ILEC) Foundation (2007). How can we stop

Degradation of the World's Lake Environments? Retrieved July 12, 2018 from http://www.ilec.or.jp

Kalff, J. (2002). Limnology: Inland Water Ecosystems. New Jersey, Prentice Hall; pp85-91

Kashiwaya, K. (2017). Geomorphology of Lake-Catchment Systems: A New Perspective from Limnogeomorphology. Singapore, Springer Nature Ltd.

Lake (2010). In the Encyclopaedia Britannica Student and Home Edition. Chicago: Retrieved July 14, 2018] from https://www.britannica.com/science/lake

Ławniczak, A.E., Choiński, A., Kurzyca, I. (2011). Dynamics of Lake Morphometry and Bathymetry in Various Hydrological Conditions. Polish J. of Environ. Stud. 20(4): 931-940. http://www.pjoes.com/pdf-88636-22495.

Serdeczny, O., Adams, S., Baarsch, F., Coumou, D., Robinson, A., Hare, W., Schaeffer, M., Perrette, M. (2015). Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions. Regional Environmental Change, 15(8). DOI 10.1007/s10113-015-0910-2

Soil and Water Conservation Society of Metro Halifax - SWCSMH (2015). Lake Morphology. Retrieved July 12, 2018 from www.3dflags.com.

Stefanidis, K., and Papastergiadou, E. (2012). Relationships between Lake Morphometry, Water Quality, and Aquatic Macrophytes, in Greek Lakes. Fresenius Environmental Bulletin PSP, 21(10a): 3018 - 3026

UNEP Collaborating Centre on Water and Environment (UCC Water). (2007). Sustainable Management of Lake Basins in the Context of IWRM Concepts and Issues. Paper No.2. https://www.gwp.org/.../sustainable-management-of-lake-basins-in-the-context-of-irwm.../pdf

United Nations World Water Assessment Programme (2010). Lakes: Freshwater Storehouses and Mirrors of Human Activities. Retrieved, July 2, 2018 from www.unesdoc.unesco.org/images/0018/001863/186316e.pdf.

Wenk News (2017). Carp and Shallow Lake Ecology. Retrieved July 19, 2018 from https://www.wenck.com/news/off-the-hook-carp-and-shallow-lake-ecology/

Wetzel, G. R. (2001). Limnology; Lake and River Ecosystems, 3rd ed. Academic Press, California.

Wetzel, R.G. and Likens, G.E. (1991) Limnological Analysis. 2nd Edition, New York, Springer Verlag,

Yonnana, E. (2015). Assessment of Hydrogeomorphic characteristics of lakes in the Upper Benue Valley of Adamawa State, Nigeria. Unpublished PhD Thesis, Department of Geography, Modibbo Adama University of Technology Yola, Adamawa State.

Yonnana, E., Tukur, A.L., Mubi, A.M. (2015). Morphometric Characteristics of Selected Fluviatile Lakes in the Upper Benue Valley Area of Adamawa State, Northeastern Nigeria Journal of Geography and Regional Planning, 8(3): 56-64. DOI: 10.5897/JGRP2014.0470.

Yonnana, E., and Hyellamada J.S. (2016). Land Use Impacts on Hydrogeomorphology of Lakes in the Upper Benue Valley Area of Adamawa State, Nigeria. International Journal of Research in Geography. 2(1): 26-33. www.arcjournals.org.

Yonnana, E., and Raji, A. (2017). Assessment of Hydrogeomorphic Suitability of Lake Mbemun for Socio-cultural Fishing Festival in the Bachama Chiefdom, Adamawa State, Northeastern Nigeria. Journal of Geography, Environment and Earth Science International, 10(3): 1-9. http://www.sciencedomain.org/review-history/19206. doi: 10.9734/JGEESI/2017/33534

Yonnana, E., Raji, A., Alikidon, A.V. (2018) Hydrogeomorphologic and Limnologic Characteristics of Goro Dong (Lake) in Numan Area, Adamawa State, Northeastern Nigeria. Asian Journal of Environment and Ecology, 6(3): 1-9. http://www.sciencedomain.org/review-history/24368, doi: 10.9734/AJEE/2018/4117

Yunana, D. A., Shittu A. A., Ayuba, S., Bassah, E.J., Joshua, W.K. (2017). Climate change and lake water resources in sub-Saharan Africa: Case Study of Lake Chad and Lake Victoria. Nigerian Journal of Technology (NIJOTECH), 36(2): 648 – 654. www.nijotech.com; http://dx.doi.org/10.4314/njt.v36i2.42.