



Morphometric analysis and functionality of Lake Ruma, Song Adamawa State, Northeastern Nigeria

Analyse morphométrique et fonctionnalité du lac Ruma, État Song Adamaoua, Nord-est du Nigeria

Yonnana EZEKIEL, Apollos G. T. & James THOMAS

© 2019 CJTG-RCGT All rights reserved / Tous droits réservés

Abstract:

The morphometric analysis of lakes is vital for limnologic, ecologic and sustainable use of the lake resources. In this study, a morphometric analysis and functionality assessment of Lake Ruma has been conducted using an integrated approach of hydrographic survey, Geographic Information System analysis, Mathematical Computations, and field observation. The results reveal that the lake's properties of depth is similar to those of most fluvial lakes in the Benue valley area; though with a surface area of 1.4 km² and a volume of 1.010 000 m³ this lake is slightly smaller in size. Relative depth of 0.32% and 0.11 Index of basin permanence are clear indications of the lake's shallow status even though a maximum depth of 4.32 m was recorded during the hydrographic survey. Observable major functions of the lakes were small scale (local) fishing and water supply for livestock, and human consumption as well as for domestic uses. The lake is recommended for proper conservation and management to support long term large scale fish farming, irrigation agriculture and water supply for livestock and domestic uses.

Résumé:

L'analyse morphométrique des lacs est essentielle pour une meilleure utilisation écologique et des ressources lacustres. Dans cette étude, une analyse morphométrique et une évaluation de la fonctionnalité du lac Ruma ont été menées en intégrant les données du levé hydrographique, les Systèmes d'information géographique, les calculs mathématiques et les observations de terrain. Les résultats ont révélé que les propriétés de la profondeur du lac étaient similaires à celles de la plupart des lacs fluviaux de la vallée de la Bénoué ; bien qu'avec une superficie de 1,4 km² et un volume de 1,010 000 m³, le lac Ruma est légèrement plus petit que tous les autres. La profondeur relative de 0,32% et l'indice de pérennité du bassin lacustre de 0,11 sont des indications claires de sa faible profondeur en dépit du fait qu'une profondeur maximale de 4,32 m a été enregistrée pendant le levé hydrographique. Les principales fonctions observables du lac sont la pêche à l'échelle locale, l'approvisionnement en eau pour le bétail, les usages domestiques et la consommation humaine. Afin de pérenniser la pisciculture, l'agriculture irriguée, l'approvisionnement en eau pour le bétail et les usages domestiques, une gestion plus rigoureuse du lac est recommandée.

Keywords / Mots clés

*Lake Ruma, lake morphometry, hydrographic survey, bathymetric map, mathematical computation
Lac Ruma, morphométrie lacustre, levé hydrologique, carte bathymétrique, mathématique*

Article history/Histoire de l'article

Received/Reçu: September 28, 2018

Accepted/Accepté: July 26, 2019

Published online/Publié en ligne: December 25, 2019

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 vital activity that provided relevant information on lake basin morphology and water content.

Lakes are primarily water storage bodies with variations in size, shape and depth (UNEP Collaborating Centre on Water and Environment 2007) with great significance to humans and many other organisms. They are found throughout the world, most especially in the North America, Africa, and Asia where approximately 70 percent of the world's total lake water occur (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 Environmental 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, human impact on lake ecosystems has increased due to an increase in agriculture, irrigation, water consumption, and electrical purposes; strong changes have been observed in shallow lakes, which are more sensitive to environmental changes and characterized by unfavorable morphometric parameters (Ławniczak et al., 2011). It was also noted that majority of such changes within a lake are associated with changes in water level, progressing degradation, or plant succession leading to lake disappearance take place within the littoral zone. Studies conducted in the fluvial lakes of the Upper Benue Valley area of Adamawa State, Northeastern Nigeria showed that the lakes are subjected to gradual changes in their basin morphology and loss in 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 climate change as well as catchment erosion and deposition rates associated with changing land uses (Yonnana, 2015; Yonnana and Hyellamada, 2016). It is in this line of thought that United Nations World Water Assessment Program, (2010) commented on the alarming degradation state of most lakes in the world, therefore insisting on a timely and periodic monitoring and conservation measures that include bathymetric mapping and morphometric analysis.

The measurement and description of lake morphology (shapes and size of lakes) is referred to as lake morphometry (Wetzel and Likens, 1991; Kalf, 2002). It is a very vital concept used in detailed analysis of the limnologic properties of freshwater lakes (Wetzel et al., 2001; Kalf, 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 water in relation biological productivity and human uses. Stefanidis and Papastergiadou (2012), stressed 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 with nutrient cycling and 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, resuspension, diffusion, mixing, burial and outflow, which in turn regulate many abiotic state variables, such as concentrations of phosphorus, suspended particulate matter, many water chemical variables and water clarity, which in turn regulate primary production, which regulate secondary production, for example 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). Studies carried out on two opposite floodplain lakes (Mbemun and Goro Dong) in Lamurde and Numan areas of Adamawa State Nigeria (Yonnana and Raji 2016; Yonnana et al., 2017), respectively, showed that variations in their morphometric properties is responsible for the

differences in their suitability for socio-cultural fishing festival in the Bachama Chiefdom, even though they both possess good potentials for fish production. On the basis of morphometric description and comparison, Lake Palmas was found to be the deepest natural lake in Brazil (Barroso et al., 2014).

Having in mind 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 of existing freshwater lakes, most especially in sub Saharan countries (including Nigeria) where the ranges of climate change, and anthropogenic degradation prevail. It is on this background that the morphometry of Lake Ruma was analyzed and its functionality examined. The study forms part of the ongoing information gathering exercise on lakes and ponds potentials of Adamawa state for the purpose of conservation and sustainable use of the state's water resources.

MATERIALS AND METHODS

STUDY AREA

Lake Ruma and its immediate environs are located between latitudes 09°31'30"N and 09°43'30"N of the equator and between longitudes 12°40'00"E and 12°44'30"E of the prime meridian. The lake is situated in Song Local Government Area of Adamawa state northeastern Nigeria; about 15 km southeast of Song Town, on the right bank floodplain of river Kilange, a little south of the Wuro Daudu settlement (Fig. 1).

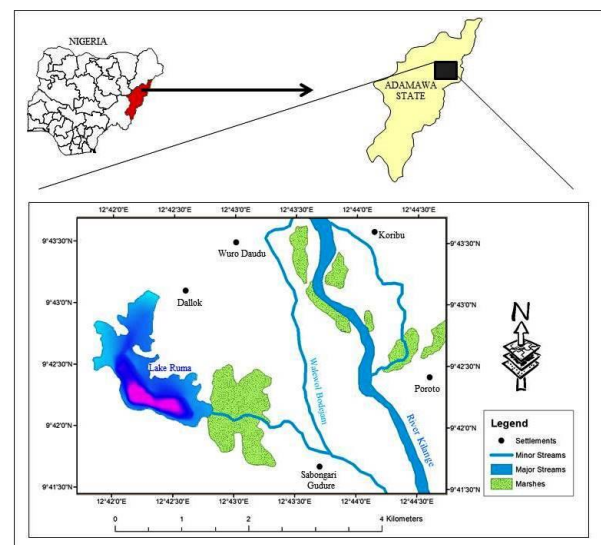


Figure 1: Study Area

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 shoreline areas 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 *Typha latifolia* (Typha grass). Its surrounding areas are characterized by a large expanse of grazing land with few farmlands and few isolated human settlements.

DATA COLLECTION AND ANALYSIS

Both principle and process geomorphology methods of lake systems as suggested by Kashiwaya (2017) were used in this study. Therefore, an integrated approach involving the applications of hydrographic survey, Geographic Information System Analysis, mathematical computations using relevant mathematical formulae and field observation in relation to historical past was employed in 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 Depth Sounder PS-7 and the Staff Sounding Method as described by Basak (1994) were used (Plate 1a and 1b). The soundings were conducted at 478 points over the lake and the depths were recorded as Z coordinates alongside the corresponding X, Y coordinates (Northing and Easting) obtained in Universal Traverse Mercator (UTM) Format using the Global Positioning System (GPS-Garmin etrex).



Plate 1a and 1b: Sounding Methods used

The hydrographic survey data were compiled in a Text Tab Delimited Database Format in Microsoft Excel environment and then exported to the ArcMap environment of ArcGIS 10.0 for preparation of the lake's bathymetric map. Through geoprocessing procedures involving the use of spatial analyst tools of the Arc Toolbox, the lake's bathymetric map was prepared from the imported hydrographic survey data. From the prepared bathymetric map, the lake's morphometric parameters such as shoreline length (SL), surface area (A), maximum length (LMax) and maximum width (WMax) were directly obtained by GIS analysis.

While the lake's shoreline elevation and maximum depth were obtained directly from the hydrographic survey data, other parameters as relative depth (Zr), mean depth (ZMean), depth indicator (Zi), lake volume (V), extension (λ), shoreline development index (DL) and index of basin permanence (IBP) were obtained by mathematical computations using the appropriate formulae.

Through field studies of the lake's shoreline shape, position and orientation in relation to the area's relief and the immediate fluvial system, complemented by historic inquiries of the area's hydrogeomorphic behavior, possible morphogenetic processes of the lake were deduced. Furthermore, the functional relevance of the lake was also examined by observation and historic inquiries through a focus group discussion with fishermen and settlers in the surrounding areas.

RESULTS AND DISCUSSION

Results of the lake's morphometric parameters as obtained are provided on Table 1. The results revealed that the lake is characterized by a surface area (A0) of 1.43 km², a maximum length (Lmax) of 2.17 km and a maximum width (Wmax) of 0.75 km, resulting to a length-width ratio (extension) of 2.89. These

properties indicate a good fetch characteristic, adequate enough for the development of water waves by wind action as well as enhancement of adequate water mixing which promotes good circulation of oxygen within the lake.

S/No	Morphometric Parameter	Symbol/Formulae	Dimension
1	Shoreline elevation	H	215 m.a.s.l
2	Shoreline length	SL	9.43 km
3	Surface area	A ₀	1.43 km ²
4	Maximum length	L _{Max}	2.17 km
5	Maximum width	W _{Max}	0.75 km
6	Extension	$\lambda = L_{Max}/W_{Max}$	2.89
7	Maximum depth	Z _{Max}	4.32 m
8	Mean depth	$Z_{Mean} = V / A_0$	0.70 m
9	Depth ratio	$R_z = Z_{Mean} / Z_{Max}$	0.16
10	Relative depth	$z_r = \frac{50(z_{max})\sqrt{\pi}}{\sqrt{A_0}}$	0.32%
11	Shoreline development Factor	$D_L = \frac{SL}{2\sqrt{\pi A_0}}$	2.22
12	Volume	$V_{z_0-z_1} = \frac{1}{3}(A_{z_0} + A_{z_1} + \sqrt{A_{z_0} \times A_{z_1}})(z_0 - z_1)$	1.01mcm
13	Index of basin permanence	IBP = V/SL	0.11

Table 1: Morphometric parameters of lake Ruma for August 2018

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 (DL) is the ratio of the shoreline length to the length of the circumference of a circle of area equal to that of the lake; a measure of the lake's shape and a morphometric parameter that reflects the lake's potential for development of shoreline communities, which are usually of high biological productivity (Soil & Water Conservation Society of Metro Halifax - SWCSMH, 2015). Analysis and mathematical computation yielded a shoreline length of 9.43 km and a shoreline development factor of 2.22 for lake Ruma, which is an indication its deviation from a circular shape and its endowment with a developed shoreline area that is capable of supporting substantial biological productivity. This property is a relevant to the lake's a viable potential for fisheries development.

Two important parameters that portray general depth characteristic of a lake are mean depth (Zmean) and relative depth (Zr). The mean depth serves a most common parameter used for depth comparison among lakes, while the relative depth (a ratio of the lake maximum depth to its mean diameter expressed in percentage) portrays general shallow or deep characteristic of the lake (SWCSMH, 2015; Kalf, 2002). Even though a maximum depth (Zmax) of 4.32 m for the lake was obtained from the hydrological survey data, a mean depth (Zmean) of 0.70m and a relative depth of 0.32% were obtained from mathematical computations as measures of the lake's shallow status. Comparing the lake with other fluvial lakes in the Benue valley area of Adamawa state, it was found to be almost of same mean depth with lakes Geriyo (Yola North), Gwakra (Girei), Pariya (Fufore) and Mbemun (Lamurde) and Shallower than lakes Pariya Ribadu (Fufore) and Goro Dong (Numan) (Yonnana et al., 2015; Yonnana and Raji, 2017; Yonnana et al., 2018). The relative depth value (0.32%) obtained for the lake indicates its very shallow status and susceptibility to improper mixing.

Another important morphometric parameter that relates the lake basin depression to that of a perfect cone with the same height and basal area as that of the lake maximum depth and surface area, respectively, is the depth ratio (Rz) (Neumann, 1959 in Kalf, 2002). For a perfect conical lake basin, Rz is > 0.33 (Kalf, 2002). However, a value of 0.16 computed for lake Ruma was an indication that the lake basin depression does not possess a

conical shape property. This could be clearly seen on the bathymetric map (Fig.2) where the deepest portion of the lake is situated at the extreme southern part, leaving a large expanse of shallow portion to the north.

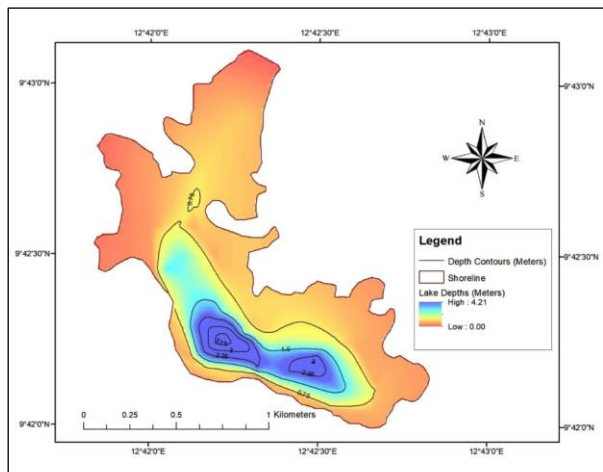


Figure 2: Bathymetric map of lake Ruma for August 2018

Lake volume (V) is a measure of water content of the lake in million cubic meters (000 000 m³). It normally computed from the lake bathymetric map information using the formula provided on Table 1. A volume of 1.010 000 m³ was computed for the studied lake. This confirms the lake as another substantial lentic water body of great aquatic potentials in Adamawa state. Though the lake was lesser than lakes Mbemun (2.990 000 m³) and Goro Dong (1.980 000 m³), it was found to be almost in the equals of lakes Geriyo (1.120 000 m³) and Pariya Ribadu (1.080 000 m³) but almost 10 times greater than the volume of lake Pariya (0.120 000 m³) (Yonnana et al., 2015; Yonnana and Raji, 2017; Yonnana et al., 2018).

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 such 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 0.11 IBP value obtained for lake Ruma therefore indicates the lake's shallow and non-permanence status as well as the dominance of its shoreline area by rooted aquatic plants; prominent among which are *Typha latifolia*, *Nymphaea nouchali* and *Oryza Spp* (Plate 2).

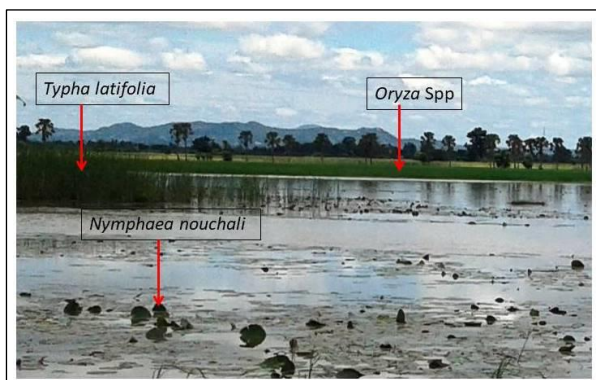


Plate 2 Aquatic plants

Besides its ecological functions as a habitat for vast aquatic flora and fauna, lake Ruma also serves as an important fishing site that supports over 50 occupational fishermen on an annual basis. It also serves as a major source of drinking water for livestock and humans living in its vicinity, especially in the dry seasons. The most prominent land uses in the area were animal rearing and rain-fed agriculture. As such, the functionality of the lake for irrigation agriculture was confirmed as very minimal.

CONCLUSION

It is concluded that lake Ruma is a shallow fluvial lake with promising characteristics for fisheries and aquaculture as well as water supply for livestock farming in the area. Improvement in the lake basin morphology through temporal dredging can enhance its potential for a long term large scale fish farming, irrigation agriculture and water supply for both livestock and domestic uses in the area.

REFERENCES

- Barroso, G. F., Gonçalves, M. A. and 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
- 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 April12, 2011 from <http://www.ilec.or.jp>
- Kalff, (2002). *Limnology: Inland Water Ecosystems*. New Jersey, Prentice Hall; pp 85-91
- Kashiyawa, K. (2017). *Geomorphology of Lake-Catchment Systems: A New Perspective from Limnogeomorphology*. Singapore, Springer Nature Pte Ltd.
- Lake (2010). In the *Encyclopaedia Britannica Student and Home Edition*. Chicago: Encyclopaedia Britannica.
- Ławniczak, A. E., Choiński, A., and 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>.
- Soil & Water Conservation Society of Metro Halifax - SWCSMH. (2015). *Lake Morphology*. 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
- United Nations World Water Assessment Program (2010). *Lakes: Freshwater Storehouses and Mirrors of Human Activities*. Retrieved, July 2, 2018 from www.unesdoc.unesco.org/images/0018/001863/186316e.pdf.
- Wetzel, G. R. (2001). *Limnology; Lake and River Ecosystems*, 3rd ed. Academic Press, California.

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 Fluvial 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 Ezekiel and Aminu Raji (2017). Assessment of Hydrogeomorphic Suitability of Lake Mbemun for Socio-cultural Fishing Festival in the Bachama Chieftdom, 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 Ezekiel, Aminu Raji and Alikidon Ambrose Voh (jr). (2018). Hydrogeomorphologic and Limnologic Characteristics of Goro Dong (Lake) in Numan Area, Adamawa State, Northeastern Nigeria. Asian Journal of Environment & Ecology 6(3): 1-9. <http://www.sciencedomain.org/review-history/24368> doi: 10.9734/AJEE/2018/41171

To cite this article

Electronic reference

Yonnana Ezekiel, Apollos G. T. & James Thomas, (2019). «Morphometric analysis and functionality of Lake Ruma, Song Adamawa State, Northeastern Nigeria». Canadian journal of tropical geography/Revue canadienne de géographie tropicale [Online], Vol. (6) 2. Online in December 25, 2019, pp. 1-8. URL: <http://laurentian.ca/cjtg>

Authors

Yonnana Ezekiel
Department of Geography
Adamawa State University Mubi, Nigeria
E-mail: ezekiel97@adsu.edu.ng

Apollos G. T.
Department of Fisheries and Aquaculture
Adamawa State University Mubi, Nigeria

James Thomas
Department of Geography
Adamawa State University Mubi, Nigeria