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*Full Length Research Paper*

# Morphometric characteristics of selected fluviatile lakes in the Upper Benue Valley Area of Adamawa State, Northeastern Nigeria

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**Bathymetric survey and mapping are important procedures for monitoring temporal changes in hydrogeomorphic characteristics of lakes. This study is the first ever carried out on the lakes, and as such provides relevant baseline information for current use and future studies. The studied lakes (Gwakra, Geriyo, Pariya-Ribadu and Pariya) were purposively selected for the study on the basis of size and relevance. The bathymetric survey was conducted by sounding rod method. Preparation of the Bathymetric Maps involved the application of GIS procedures. Morphometric parameters of the lakes were determined from prepared maps by direct measurements and mathematical computations using appropriate formulae. Information derived from the prepared maps revealed that the lakes are characterized by gentle Basin Slope and almost uniform bottom morphologies with slight ruggedness. Maximum Lengths of the lakes ranged from 0.89 (Pariya) to 3.14 m (Geriyo), while Maximum Widths ranged from 0.34 (Pariya) to 1.52 m (Gwakra). The lakes were also found to be generally shallow with mean dry season depths ranging from 0.40 to 1.33 m and volumes ranging from 0.17 to 1.12 mcm. The lakes were characterized by low Indices of Basin Permanence (0.04 to 0.27), indicating senescence and dominance by littoral plants. Relative depths were also very low (0.07 to 0.42), indicating high propensity of water mixing and circulation of dissolved Oxygen adequate enough to support biological productivity. Thus, the lakes are recommended for substantial fish farming and livestock production in the area. Proper management involving temporal morphological assessment of the lakes based on this study is also recommended for sustainable use.**

**Key words:** Fluviatile lakes, hydrographic survey, bathymetric mapping, lake morphometric characteristics.

## INTRODUCTION

Lake bathymetric data collection and mapping are very important hydrographic activities, most especially in parts of the world where lakes are regarded with high level of importance for various uses. As a matter of fact, having a bathymetric map of a water body is an invaluable piece of information that can provide much needed and helpful data for years to come (Aquatic Environment Consultants Inc., 2012). Lake bathymetric maps are similar to

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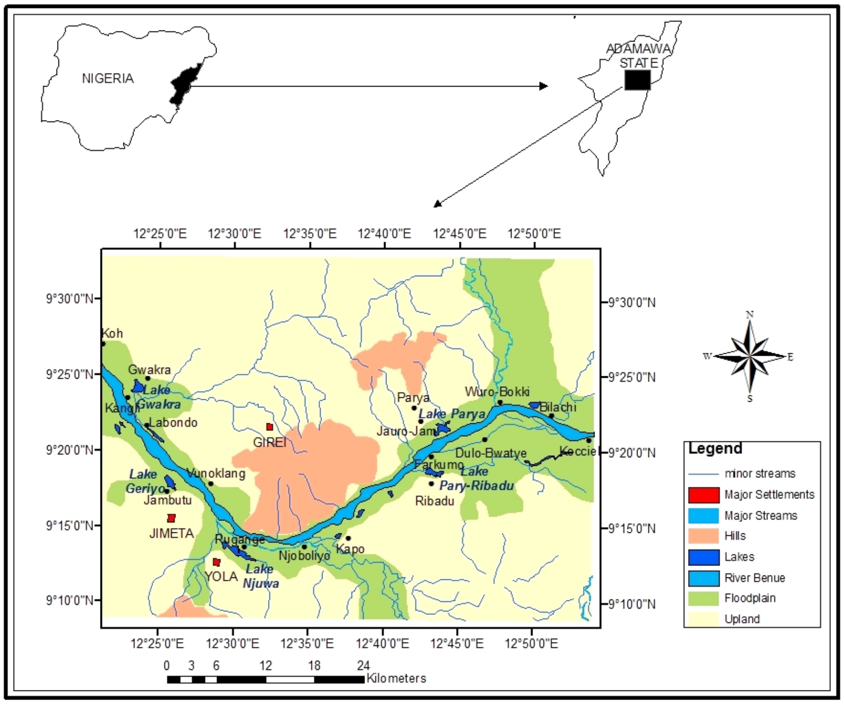


**Figure 1.** Study area and the lakes.

topographic maps as they provide detailed morphometric information about Lake Basin terrains and their water contents (Cole, 1979; Aqualink, 2012; Florida, 2001). Such maps are useful in the determination of lakes' Surface Areas ($A_0$) and Volumes (V) which are vital for water management; Relative Depths ($Z_r$) and Indices of Basin Permanence (IBPs) which help in predicting biological productivity; fetches from all directions and lake bottom morphologies for navigation and fishing and assessment of sedimentation rates (Limgis, 2001; Ayenew, 2009; CT-ECO, 2009). Notably, a special bathymetric survey project of Lake Tahoe was conducted in August 1998 to study the terrain of the lake floor. This activity was aimed at helping scientists identify the materials that make up the lake basin and throwing more light on the basin history hidden by waters of the Lake (US Geological Survey, 2003). In addition, a considerable number of Bathymetric Maps of East African Lakes have been prepared for morphometric and hydrological studies of the lakes (Baxter et al., 1965; Bekele, 2006; Ayenew and Demlie, 2004; Demlie et al., 2007). Since the bathymetric map of a lake can only represent the lake's dimensions at the time of measurement (Ayenew, 2009), changes in the lake's morphological characteristics can be evaluated from subsequent bathymetric exercises. From such changes, sedimentation rates can be deduced.

On the Benue Valley Floodplains of Adamawa State is an assortment of fluviatile lakes that support a wide range of activities which include fishing, animal production, irrigation agriculture, recreation, socio-cultural festivities and domestic uses. Characterized by varied shapes and sizes, the lakes undergo gradual deformations owing to seasonal flooding and sediment deposition on the floodplains. The 2012 extreme flood episode in the Benue Valley resulted in merging of the fluviatile lakes into a continuous sheet of lotic water similar to the cases of Middle Parana Floodplain Lakes at periods of high water stages as stated by Drago (1989). At the recede of the flood, some changes in the morphology of the Benue floodplains; which affected the lakes were observed. However, since neither bathymetric information (maps) nor morphometric records of the lakes exist, the magnitude of the flood effects on basin morphologies of the lakes could not be ascertained.

This informs the need of this baseline study. Its findings shall serve as important baseline information for future and related studies that may require Basin Morphology information on the lakes.

The Upper Benue Valley Area of Adamawa State, within which the selected lakes for this study are situated, is located between latitudes 09˚ 09' 00"N and 09˚ 33' 00"N of the equator and between longitudes 12˚ 21' 00"E and 12˚ 54' 00"E of the prime (Greenwich) meridian. The area stretches from Kocciel in Fufore to Koh in Girei Local Governments Areas of Adamawa State, covering a total length of about 76.250 km (Federal Surveys, Nigeria, 1971). The selected lakes include Gwakra (09°24'26"N, 12°23'38"E), Geriyo (09°18'15"N, 12°25'34"E), Njuwa (09°13'15"N, 12°30'12"E), Pariya-Ribadu (09°18'36"N, 12°43'12"E) and Pariya (09°21'17"N, 12°43'27"E), as shown in Figure 1.

## MATERIALS AND METHODS

This research focuses mainly on hydrographic survey, bathymetric mapping and interpretation morphometric characteristics of selected Fluviatile Lakes in the Upper Benue Valley Area of Adamawa State. The lakes were purposively selected based on their apparent sizes and relevance in terms of multiple uses.

### Hydrographic survey and bathymetric mapping

Hydrographic survey of the lakes was conducted in dry season (March, 2013) using Sounding Rod Method based on presumed shallow nature of the lakes (<10.00m) as described by Basak (1994) and Arora (2002). This involved the use of a boat and a leveling staff for depths sounding as well as Germin 76 GPS for determining X and Y coordinates of sounding point. Series of depths (Z coordinates) and their corresponding X and Y coordinates in Universal Transverse Mercator (UTM) projection system were obtained along defined transects in each of the four lakes surveyed. Same X and Y coordinates were obtained round the lakes along their shorelines where depth is zero in order to obtain outlines of the lakes current shorelines.

Bathymetric data processing and map preparation involved the application appropriate Geographic Information System (GIS) procedures. The bathymetric data for each of the lakes were tabulated in Microsoft Excel and saved in Text Tab Delimited Format (TTDF). It was then opened in ArcView GIS 3.2a environment and converted into a Database Format (DBF) and finally exported to ArcMap environment of ArcGIS 9.3 for map preparation. The sounding point events and bathymetric map of each of the lakes were then prepared using spatial analyst tools of ArcGIS 9.3, while 3D versions of the lakes' Basin Morphologies were prepared in the Map Environment of Surfer 10 Software.

### Morphometric measurements and computations

Lake maximum Depth ($z_m$) values were obtained directly by rod sounding, while Surface Area ($A_0$), Fetch or Maximum Length ($l_{max}$), Maximum Width ($b_{max}$) and Shoreline Length ($L$) values were obtained from the bathymetric maps using the measure tool of ArcGIS 9.3 ArcMap tools bar. Values of derivative morphometric parameters were obtained by computations using the following formulae:

*Mean Width* $b_{mean} = A_0/l_{max}$ ……………. Equation 1 (Wetzel, 2001)

*Lake Volume:* $V_{z0-z1} = \frac{1}{3}\left(A_{z0} + A_{z1} + \sqrt{A_{z0} \times A_{z1}}\right)(z_0 - z_1)$ ….Equation 2 (Cole, 1976; Wetzel, 2001)

Where, $V_{zo-z1}$ is volume of truncated part of the lake between the shoreline on depth ($z_0$) and successive depth $z_1$, $A_{z1}$ is Surface area of lake at depth $z_1$.

*Mean Depth* $z_{mean} = V/A_0$………….. …………Equation 3 (Wetzel, 2001)

*Relative Depth($z_r$) in % =* $z_r = \frac{50(z_m)\sqrt{\pi}}{\sqrt{A_0}}$ ……….. Equation 4a (Wetzel, 2001)

or simply as

$$z_r = \frac{88.6 \times z_m}{\sqrt{A_0}}$$ ……………………Equation 4b

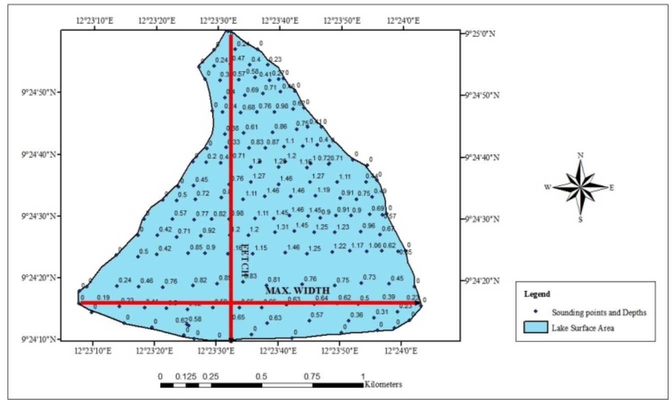


**Figure 2.** Sounding points for Lake Gwakra.

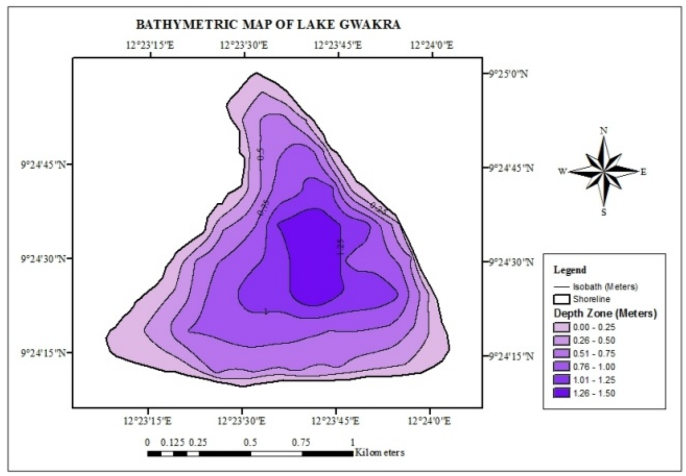


**Figure 3.** Bathymetric map of Lake Gwakra.

*Index of Basin Permanence (IBP) = V/L* ….….Equation 5 (Soil and Water Conservation Society of Metro Halifax 2006).

## RESULTS AND DISCUSSION

Figures 2, 5, 8 and 11 present information on sounding points events of the lakes obtained during the Bathymetric Surveys, while Figures 3, 4, 6, 7, 9, 10, 12 and 13 provided information on Basin Morphologies of the studied lakes. The varied shape and size characteristics of the lakes as portrayed by the bathymetric maps are tied to the lakes' origin and hydrogeomorphic dynamics of the Benue Valley. The bathymetric maps revealed that the lakes are characterized by regular bottom topographies of almost steady gentle slopes. However, the northeastern part of Lake Gwakra is marked by a sharp steep shore about 1m high giving the lake a steep shore on one side and a gentle shore on the other (Figures 3 and 4). The slight rugged bottom terrain observed in Lake Geriyo could be attributed to urban

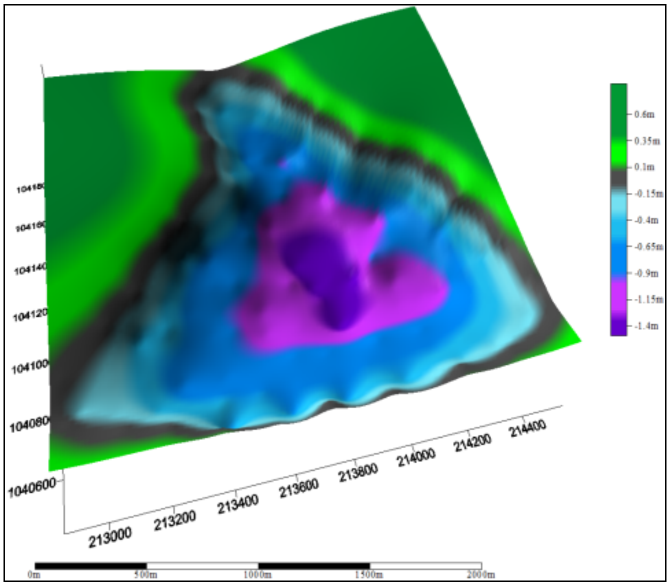


**Figure 4.** Basin morphology of Lake Gwakra.

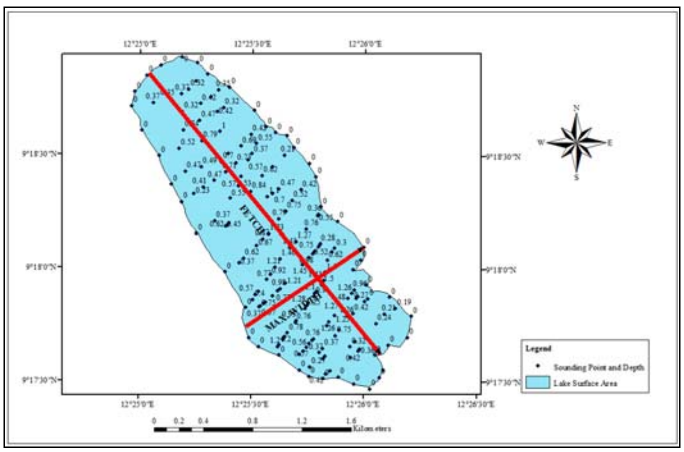


**Figure 5.** Sounding points for Lake Geriyo.

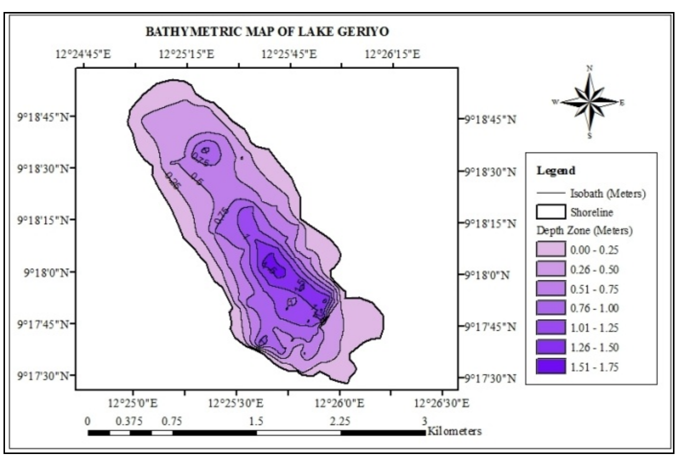


**Figure 6.** Bathymetric map of Lake Geriyo.

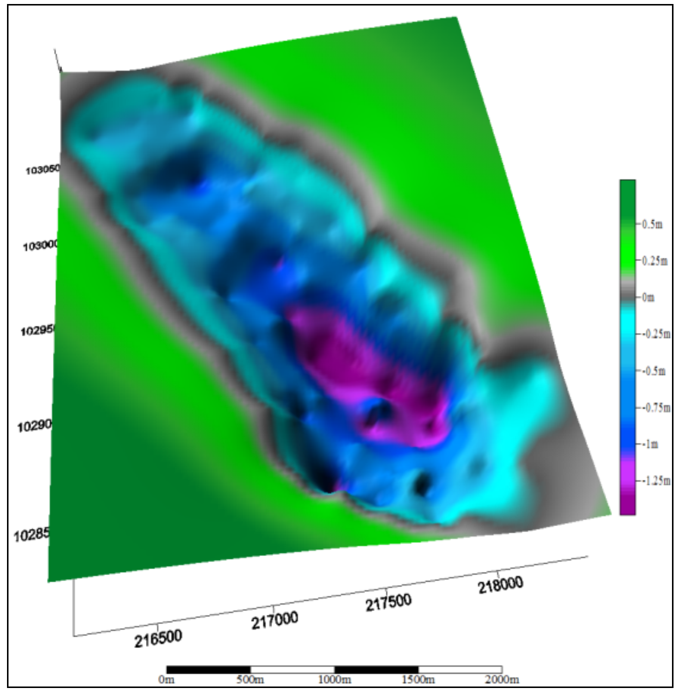


**Figure 7.** Basin morphology of Lake Geriyo.

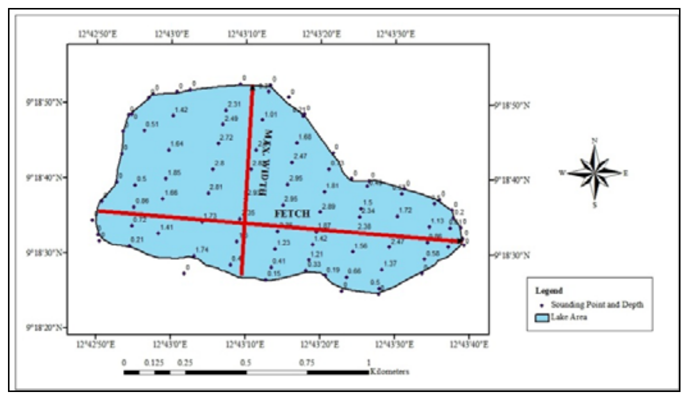


**Figure 8.** Sounding points for Lake Pariya Ribadu.

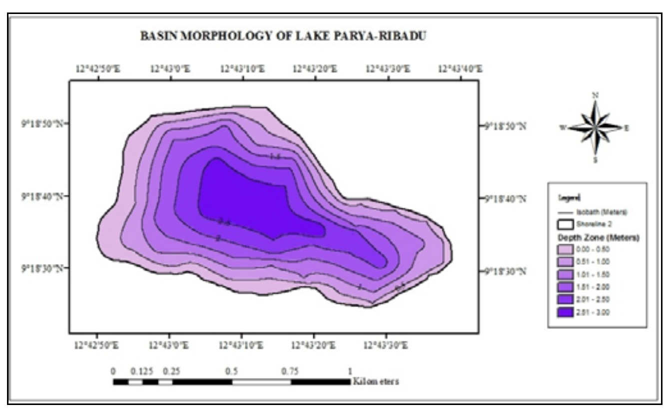


**Figure 9.** Bathymetric map of Lake Pariya Ribadu.

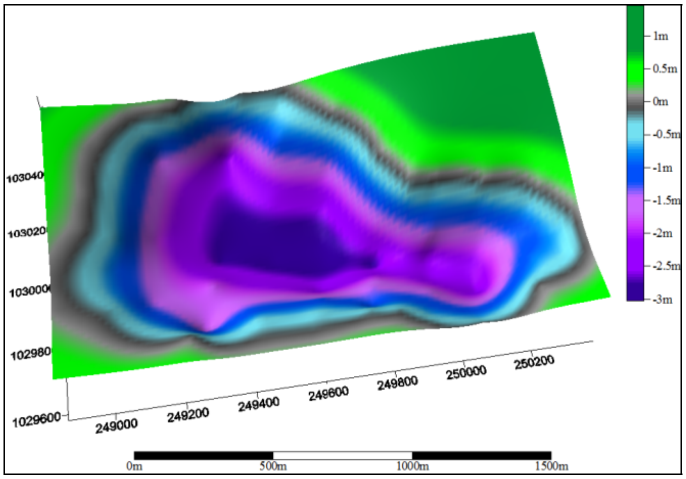


**Figure 10.** Basin morphology of Lake Pariya Ribadu.

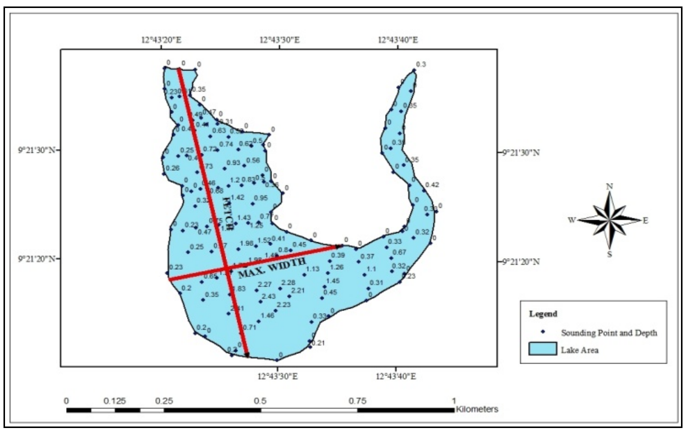


**Figure 11.** Sounding points for Lake Pariya.

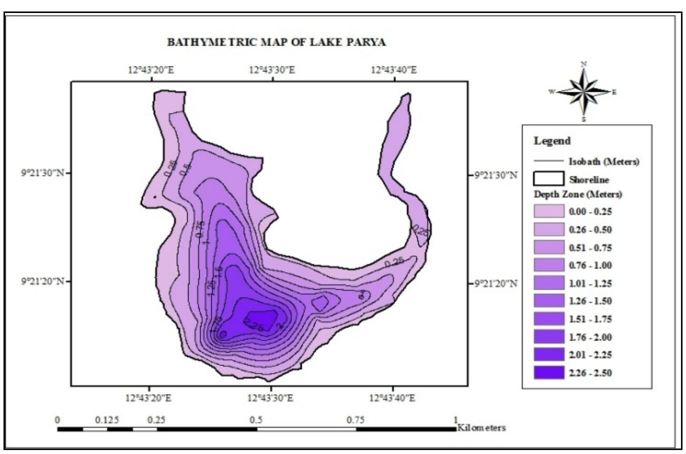


**Figure 12.** Bathymetric map of Lake Pariya.

runoff contributions and intense human activities within and around the lake ranging from excessive pumping for

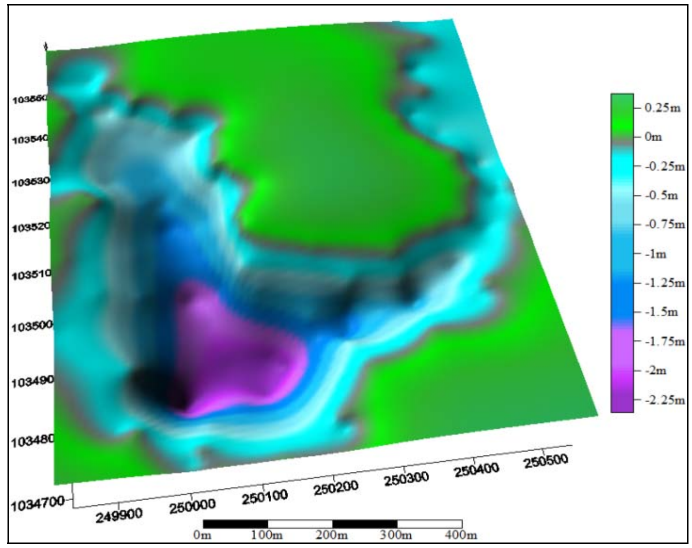


**Figure 13.** Basin morphology of Lake Pariya

irrigation to continual land tillage and waste disposal at different points (Figures 6 and 7). Lake Pariya Ribadu Portrayed a more regular basin morphology in terms of ruggedness owing to less fluvial and human interferences (Figures 9 and 10). Lake Pariya tends to be gentle on its northern part and steeper on the southern part. This indicates that more lake sediments are generated from farm lands north of the lake than from the Benue channel at the south (Figs. 12 and 13).

The morphometric data on Table 1 showed that, Pariya-Ribadu was the deepest of the lakes, having a maximum depth of 2.95 m and a mean depth of 1.41 m; while Lake Pariya had a maximum depth of 2.43 m and a mean depth of 0.79 m. Lakes Geriyo and Gwakra exhibited almost the same maximum and mean depth characteristics (Table 1). However, Lake Geriyo was found to be the shallowest (0.70 m) of the lakes in terms of mean depth characteristics.

Based on field studies, the major factors responsible for variation in depth characteristics of the lakes include downstream slope characteristics of the Benue Valley System, impacts of lakes inlets and differential land activities within and around the lakes. Lakes Pariya-Ribadu and Pariya, situated on the upstream of the studied valley section, exhibited higher maximum and mean depth values than lakes Gwakra and Geriyo situated on the downstream. To a greater extent, this is attributed to more sedimentation on the downstream section of the valley during flooding. Continual sediment load into the lakes basins through their inlets (streams) also contributed immensely to the shallow depths of the lake basins. In addition, large quantities of sediment generated from agricultural (Cultivated and grazing lands) and residential land uses contribute to the shallow depth characteristics of the lake basins.

**Table 1.** Morphometric properties of study lakes.

| Morphometric characteristic | L. Gwakra | L. Geriyo | L. Pariya-Ribadu | L. Pariya |
|---|---|---|---|---|
| Mean Elevation (m) | 151.00 | 153.00 | 160.00 | 162.00 |
| Maximum Length (km) | 1.66 | 3.14 | 1.53 | 0.89 |
| Maximum Width (km) | 1.52 | 1.07 | 0.80 | 0.34 |
| Shoreline Length (km) | 5.22 | 8.10 | 3.94 | 3.84 |
| Maximum Depth (m) | 1.46 | 1.48 | 2.95 | 2.43 |
| Mean Depth (m) | 0.75 | 0.70 | 1.41 | 0.79 |
| Relative Depth (%) | 0.11 | 0.07 | 0.29 | 0.42 |
| IBP | 0.16 | 0.14 | 0.27 | 0.04 |
| Surface Area (Ha) | 140.66 | 282.32 | 81.36 | 26.43 |
| Volume (mcm) | 0.85 | 1.12 | 1.08 | 0.17 |

**Figure 14.** Lake Pariya depicting senescence and dominance of rooted aquatic plants (*Nymphaea spp.*)

Relative Depths of the studied lakes were found to be generally low, owing to their shallow characteristics in relation to their Shoreline lengths. Lake Geriyo exhibited the lowest relative depth (0.07%), while Lake Pariya-Ribadu had the highest (0.42%). These low relative depth characteristics were observed to be similar to those of most Brazilian lakes as presented by Von (n.d.). Since Relative Depth is a percentage measure of resistance to mixing of lake water (Soil and Water Conservation Society of Metro Halifaxm, 2006), the low percentages observed indicated that the lakes are exposed high vertical circulation and mixing, adequate enough to aid the transfer of dissolved oxygen and surface temperature conditions to their bottom zones. In addition, Indices of Basin Permanence (IBPs) for the lakes were also very low (Table 1). This indicates how senescent the lakes are in terms of easy penetration of sunlight to their basin floors, which in turn aids high dominance by rooted aquatic plants such as Nymphaea spp. The effect of this parameter is more eminent in Lake Pariya with an IBP percentage of 0.04 (Table 1 and Figure 14). The combined effects of low Relative Depths and IBPs of the lakes are responsible for the occurrence and functioning of vast biological activities ranging from growth of varied aquatic flora to the existence of vast aquatic fauna species.

Relationships between depths and surface areas of the lakes are presented by the hypsographic curves plotted (Figures 15 to 18). It was deduced from the curves that at depth of 1.0 m from the surface (0m mark), changes in surface area of Lake Gwakra are bound to remain within a range of 13.37Ha to 140.66Ha or even more; 22.78 to 283.23 Ha for Lake Geriyo; 48.89 to 81.36 Ha for Lake Pariya-Ribadu; and 7.29 to 26.43 Ha for Lake Pariya. Analysis from the hypsometric cures also revealed that greater portions of the lakes' surface areas occurred at depths of 1.0 m and below. Lakes Gwakra and Geriyo being shallower had 90.1 and 91.9% of their surface

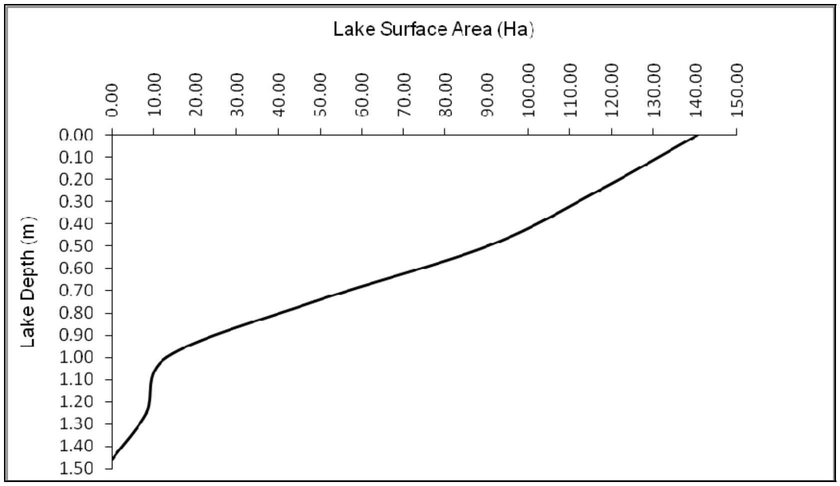


**Figure 15.** Hypsographic curve of Lake Gwakra.

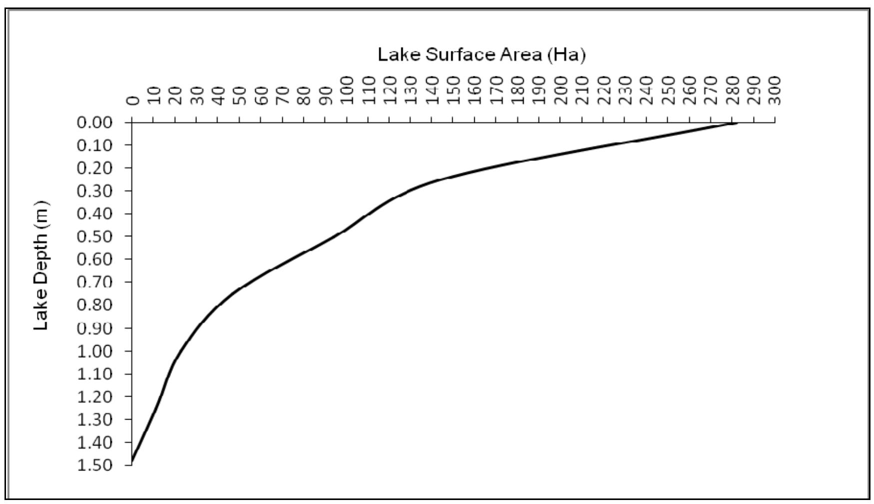


**Figure 16.** Hypsographic curve of Lake Geriyo.

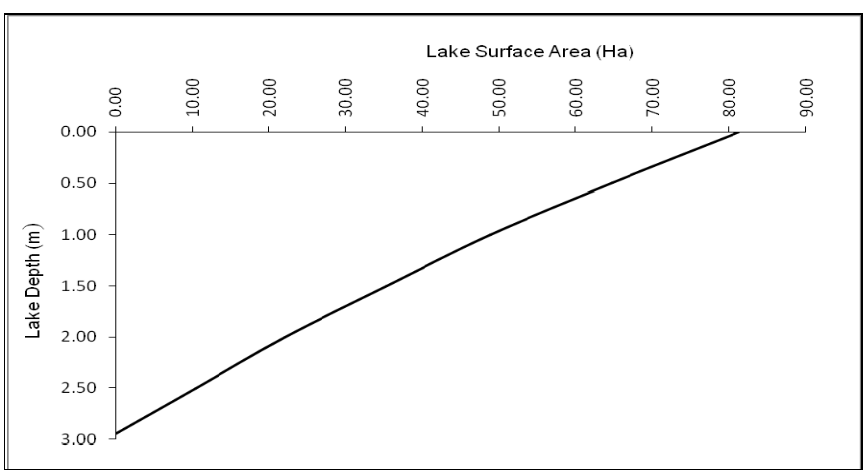


**Figure 17.** Hypsographic curve of Lake Pariya Ribadu.

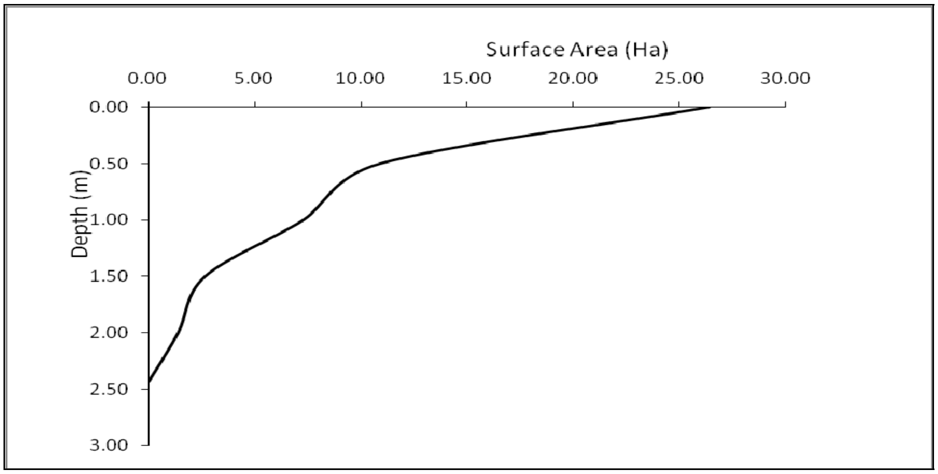


**Figure 18.** Hypsographic curve of Lake Pariya.

areas occurring at depths of 1.0 m and below, while Lakes Pariya-Ribadu and Pariya being a little deeper had 60.1 and 72.4% respectively. Besides, the hypsographic curves of the lakes presented easy means of estimating their surface areas any depth. For instance, estimations from the curves showed that at maximum depths of 1m, Lake Gwakra would have an estimated surface area of about 13 Ha; Geriyo would have 23 Ha; Pariya-Ribadu, 49 Ha; and Pariya, 7ha.

## Conclusion

The bathymetric maps prepared present good baseline morphological information of the lakes basins and serve as relevant tools for morphometric assessment of the lakes, while the hypsographic curves serve as vital tools for estimating their surface areas using available depth data.

Even though the lakes were found to be generally shallow and smaller in size compared to world major lakes, they are considered viable enough to support substantial biological productivity in terms of their volume, surface area, Relative Depth and Index of Basin Permanence. Therefore, viable economic agricultural programs such as commercial fish farming, irrigation agriculture and livestock production alongside well designed water management plans for sustainable utility of the lakes are recommended. Periodic hydrographic surveys and bathymetric mapping of the lakes will also be of great relevance in monitoring temporal hydrogeomorphic changes in basin morphologies of the lakes.

## Conflict of Interests

The authors have not declared any conflict of interests.

## ACKNOWLEDGEMENT

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## REFERENCES

Arora KR (2002). Irrigattion, Water Power and Water Resources Engineering. Delhi, Lomus Offset Press.

Aqualink Inc. (2012). Pond and Lake Mapping. Retrieved June 18, 2012 from http://www.aqualink.com/pond-and-lake-mapping.aspx.

Aquatic Environment Consultants Inc. (2012). Bahthymetric Mapping. Retrieved March 29, 2013 from http://www.aeclakes.com.

Ayenew T (2009). Natural Lakes of Ethiopia. Addis Ababa, Addis Ababa University Press p.84.

Ayenew T, Demlie M (2004). Bathymetric Survey and Estimation of Water balance of Lake Ardibo, Northern Ethiopia. SINET: Ethiopian J Sci. 27(1): 61-68.

Basak NN (1994). Survey and Leveling. New Delhi, McGraw Hill Ltd. pp.475-476.

Bekele S (2006). Investigation of Physical and Bathymetric Characteristics of Lakes Abaya and Chamo, Ethiopia, and their Management implications. Lakes and Reservoirs: Research and Management 11(3):133.

Baxter RM, Prosser MV, Talling JF, Wood RB (1965). Stratification in Tropical African Lakes at moderate altitudes (510-520). Limno. Oceano. 10: 511-520.

Cole GA (1979). Text Book of Limnology. 2nd Edition. Toronto; C.V. Mosby Company.

CT-ECO (2009). Lake Bathymetry. Retrieved may 16, 2013 from www.cteco.uconn.edu/lake_bathymethry.htm.

Drago EC (1989). Morphological and Hydrological characteristics of the floodplain ponds of the Middle Parana River (Argentina). Rev. Hydrobiol. Trop. 22(3):183-190.

Demlie M, Ayenew T, Wohnlich S (2007). Comprehensive hydrological and Hydrogeological study of topographically closed lakes in highland Ethiopa: the case of Hayd and Ardibo. J. Hydrol. (339):145-158.

Federal Surveys, Nigeria (1971). Yola Sheet 48. Edition 1.

Florida Lakewatch (2001). A Beginner's Guide to Water Management-Lake Morphometry. Information Circular 104. 2nd Edition. University of florida. Retrieved June 14, 2012 from http://Florida Lakewatch.ifas.ufl.edu

Limgis (2001). Limnology: Essentials. Retrieved April 12, 2013 from cess.iisc.ernet.in/energy/monograph/Limpage2.html.
Soil and Water Conservation Society of Metro Halifax (2006). Lake Morphology. Retrieved December 12, 2011 from http://www.lakes.chebucto.org/index.html.
US Geological Survey. (2003). Lake Tahoe Bathymetry: What lies beneath Lake Tahoe? Retrieved May 16, 2013 from http://www.tahoe.usgs.gov/bath.html
Von Sperling E (n.d). The Role of Relative Depth in the prediction of Eutrophication of Lakes and Reservoirs. Retrieved December 12, 2013 from www.bvsde.paho.org/bvsaidis/caliagua/peru/bracca163.pdf
Wetzel RG (2001). Limnology: Lake and River Ecosystems. 3rd Edition. California, USA; Academic Press; An imprint of Elsevier.