ESTIMATING THE CAPACITY OF THE SURFACE AREA OF JABI LAKE, ABUJA-NIGERIA USING NORMALIZED DIFFERENCE WATER INDEX ALGORITHMS DERIVED FROM OPERATIONAL LAND IMAGER, ABUJA-NIGERIA

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Abstract

The Normalized difference water index (NDWI) with Ratio of vegetation index (RVI) is successfully used to extract the information of the lake reservoir capacity in the Month of May during the wet/rainy season and for the month of November during the dry/cold season using Landsat-8 Operational Land Imager (OLI) multispectral images. This study specifically uses spectral band-5/NIR (0.845-0.885), band-6/SWIR (1.560–1.660) and the spatial resolution of 30m for NDWI and RVI assessment. The results provided an opportunity to show the correlations of changes of which OLI NDWI/RVI algorithms achieve an overall level of accuracy/strength of 100% and a kappa coefficient of determination of 1.0000 (100%). The results showed a decreasing trend in the lake water surface area from the month of October/November, 2015 (cold/dry season) period, when the lake lost almost 0.42 km^2 (38.2%) of its surface area of water. It is evident that excessive ground water exploitation such as sinking/drilling of borehole and wells, and seasonal variation of rain water has all reduced the surface area of the Lake reservoir. The results illustrate the effectiveness of the NDWI and RVI approach for water measurement, especially in detecting the changes between two seasons simultaneously. Therefore, appropriate measures need to be taken to prevent further decline of

the lake, so that the function postulates by the lake as the only medium for balancing heat transfer and corridor of recreational will not be defeated.

Keywords: NDWI, RVI, OLI, surface area, water reservoir

1. Introduction

The lake consists of a combination of natural and manmade features spanning to approximately 1.78 km from Jabi resettlement camp toward Kado. The lake serves the area as the only primary drainage receiver, fishing corridor, recreational and to balance heat transfer. It provides a window for extracting moisture or liquid water information changes more directly due to its cloudless appearances to outer-space sensors (Sun, et al. 2012). The water conditions have a complex hydraulic setting that is characterized by highly unsteady flows, the complexity leads to differential unique water information (Badaru, et al. 2014).

1.1. Study Area

Jabi Lake or reservoir is located in the Federal Capital City (FCC), Abuja; it has the geographic coordinates of latitudes 8°30′N and 9°20′N, longitudes 6°20′E and 7°33′E. The lake spans from jabi resettlement camp to kado, which is about 1.78 km long and 0.55 km wide. The climate of the lake basin is characterized by temperate weather, being influenced by the surrounding conditions of the lake.

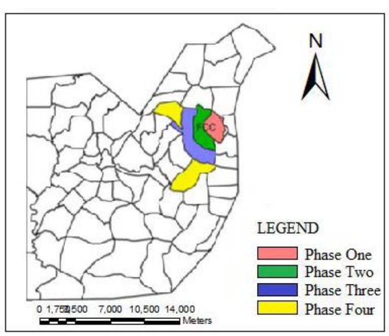

Figure 1: Map of the FCT, showing the location of the city of Abuja (AGIS, 2006)

1.2 Aim and Objectives

The aim of the study is to carry out the spatio-temporal variation analysis of changes in the lake reservoir using OLI classification algorithms in order to produce the best result. The Objectives of the study include:

- Detailed ground truthing of the site for effective examination of the study areas
- To carry out a comparative spatial analysis of the findings.
- To assess the accuracy of the changes.

2. The Normalized Difference Water Index related studies

Gao (1996), developed the Normalized Difference Water Index (NDWI) for determination of VWC based on physical principles. According to Gao (1995), the values of NDVI and NDWI are in the range between –1 and +1 can be computed for each pixel using the following equations (Gao, 1995):

$$NDVI = \frac{\rho(band4) - \rho(band3)}{\rho(band4) + \rho(band3)} \text{ And } NDWI = \frac{\rho(band4) - \rho(band5)}{\rho(band4) + \rho(band5)}$$

Where band 4 is 0.86 and band 5 is 1.24, where p represents the radiance in reflectance units. Hardisky et al. (1983) developed the similar Normalized Difference Infrared Index for the Landsat Thematic Mapper of which this index is related to VWC. For Landsat TM/ETM+, RNIR and RSWIR correspond to bands 4 (0.78 – 0.90 Am) and 5 (1.55 –1.75 Am), respectively. New satellite sensors (Gao, 1996) such as the Moderate Resolution Imaging Sensor (MODIS) on NASA’s Terra and Aqua satellites now make such data routinely available. Gao further recommend the use of a SWIR band centered at 1.24 Am, now available on MODIS, for NDWI because this band has similar atmospheric transmittance as the NIR band.

3. Method to validate the NDWI

The Normalised Difference Water Index (NDWI) of landsat-8 Operational Land Imager (OLI) employs the near-infrared (NIR) band and a band in the short-wave infrared (SWIR). The NIR band 5 (0.845-0.885) and SWIR band 6 (1.560–1.660 micrometer) are used. The NDWI index is expressed with the following equation: NDWI=NIR-SWIR/NIR+SWIR, NDWI=Green-NIR/Green+NIR (Mc-Feeters, 1996). Surface water change detection is usually conducted by extracting water features individually from the multi-date satellite images, before making comparisons to detect their changes (Du, et al. 2012: Xu, H. 2006).

4. Results

4.1 NDWI of the month of May 2015

Figure 2 shows the relevant information extracted in the month of May of the 2015, during the period of wet/rainy season which is classified into their intensity values. The radiance reflectance presented in light-green indicates NDWI values of 0.438 and RVI level of 0.5, that shows the ultimate dimension of the reservoir at 0.76 km^2. In the same vein, The Figure 2 further demonstrate the reflectance in dark-red intensity indicating RVI level of 0.1 meaning that the water bodies in that section of the reservoir indicates the presence of bedrock saturated with shallow liquid-water. However, the light-green NDWI image represents the supersaturated and deepest part of the reservoir, whereas dark-red NDWI image represents the saturated and lowest or shallow part. As a result, it appears that Jabi lake give high NDWI values in the month of May that suggests the period of wet/rainy season are adequately saturated with water.

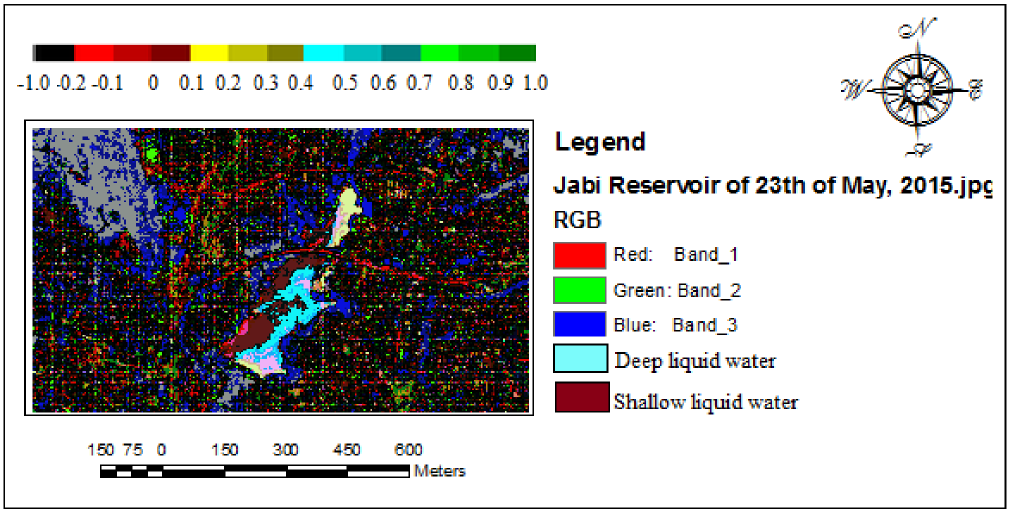

Figure 2: The NDWI for the month of May, 2015 (wet/rainy season)

4.2 NDWI of the month of November 2015

Figure 3 shows the analysis of the month of November of the 2015, during the period of cold/dry season. The reflectance in dark-green indicates NDWI values of 0.438 and RVI level of 1.0, of which the shallow water paradigm spans at the dimension of 0.34 km^2. Consequently, the lake is experiencing a tremendous decrease, since they do not receive any additional water in the cold/dry season.

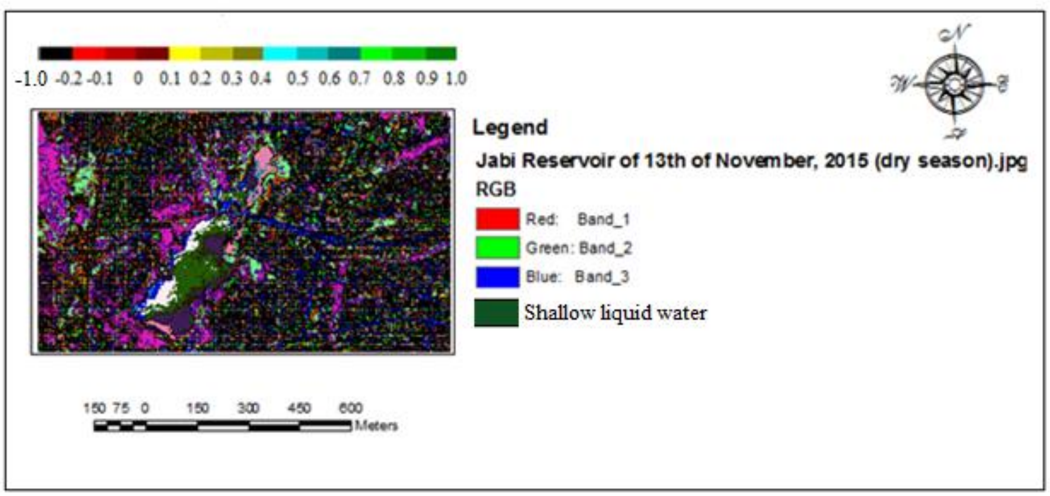

Figure 3: The NDWI for the month of November, 2015 (dry season)

4.3 Change detected

The Figure 4 shows the decreasing trend of the lake, accelerating at a slow movement as indicated in the pixel F1 corresponding to F8, and faster between the pixels D3-6 that corresponds to D9-12 as recorded in the month of May and November. The Figure also indicates that some reasonable reduction of the lake dimension occurred at A5, A6, B4, B6, C3, C6, D3, D7, E2, E5, F1, F3, G1, G2 in the wet/rainy period as against A12, B11, B12, C10, C13, D10, D12, E10, E11, F8, F10, G8 and G9 in the cold/dry period (Figure 4).

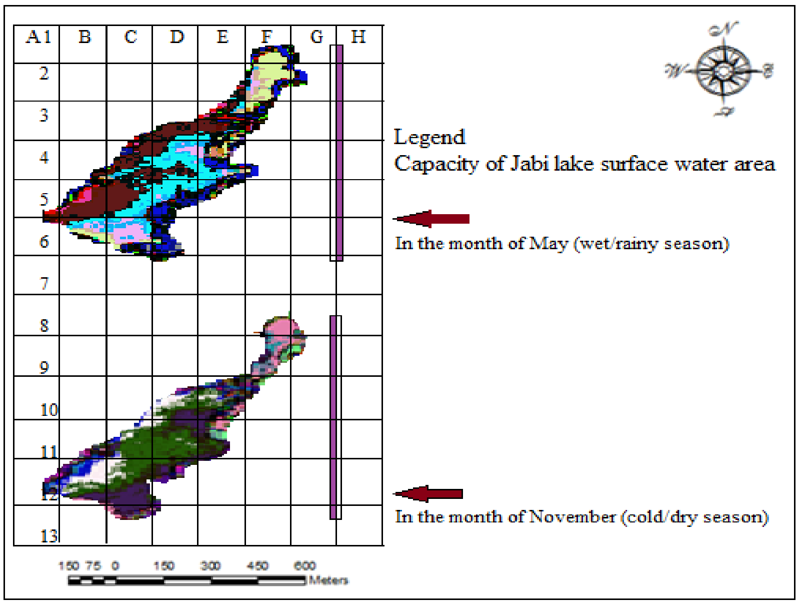

Figure 4: The paradigm of the change detected during the month of May and November, 2015

4.4 Regression Analysis

Figure 5 shows positive relationship to the decreasing trend in the capacity of water in the lake, particularly in the month of November 2015 as against the month of May when the lake water was saturated, of which the kappa coefficients of determination R^2 are 1.0000 (100%). These results show a high level of accuracy and strength in their relationship that are 100%. Therefore, the study concludes that both values are statistically significant.

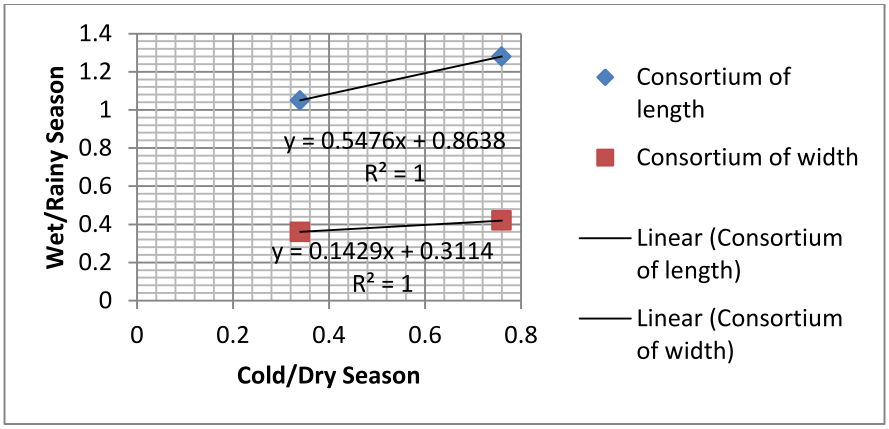

Figure 5: The statistical analysis of wet/rainy and cold/dry seasons for the month of May and November, 2015

4.5 Discussions

The Figures 2-5, indicate the paradigm of shrinkages of the capacity of water as recorded between the month of May (2015) and November (2015) during the wet/rainy season and cold/dry season. Tentatively, the capacity of the water in the lake shows a decrease of 0.42 km^2, and further indicates monthly average of 0.06 km^2 for the month of May, June, July, August, September, October and November have also recorded 14.29% shrinkage in 2015. Jabi Lake lost more than half of its water in the period of the cold/dry season with half of this decline occurring in the months of October and November, 2015. If this trend continues, it is very likely that the lake will lose all of its liquid water in the near future. This is very critical because the lake provides many benefits for the society and the people living in its surroundings. Therefore, appropriate measures need to be taken by policy makers to prevent further decline of the lake and to restore the lake to its original condition. It is evident that excessive ground water exploitation and absence of rain water have all reduced the capacity of the surface area or Lake Reservoir.

5.0 Conclusions

This study aimed to conceptualize the spatial temporal changes of the Lake of the period of wet/rainy and cold/dry seasons, in the month of May and November of 2015 respectively. The results shows intense decrease in the lake water in the mid part of October and November 2015 when the lake lost about 0.42 km^2 (38.2%) of its water. If such a decreasing trend in the Lake continues, it is very likely that the lake will lose its entire water surface in the near future.

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References

Badaru, Y.U., Onuh, S., Musa, Y., Ishiaku, I. & Nassir, Y.M. (2014). Analysis of Sensor Imaging and Field-Validation for Future Flood along River Niger and Benue Confluence Ecology, Lokoja, Nigeria. "*Journal of Environment and Earth Science*" Vol. 4, No.22 (2014), pp. 90-99

Du, Z., Linghu, B., Ling, F., Li, W., Tian, W., Wang, H., Gui, Y., Sun, B. & Zhang, X. (2012). Estimating surface water area changes using time-series Landsat data in the qingjiang river basin, "*China Journal of Application of Remote Sensing*". 6, doi:10.1117/1.JRS.6.063609.

Gao, B.C. (1995), A normalized difference water index for remote sensing of vegetation liquid water from space, in SPIE's 1995 Symposium on OE / Aerospace Sensing and Dual Use Photonics, Vol. 2480, Orlando, FL.

Gao, B. C. & Goetz, A. F. H. (1995). Retrieval of equivalent water thickness and information related to biochemical components of vegetation canopies from AVIRIS data. "*Remote Sensing of Environment"*, 52, 155 – 162.

Gao, B.C. (1996) NDWI - A normalized difference water index for remote sensing of vegetation liquid water from space. "*Remote Sensing of Environment"*, Vol. 58: 257-266

Hardisky, M. A., Klemas, V. & Smart, R. M. (1983). The influences of soil salinity, growth form, and leaf moisture on the spectral reflectance of Spartina alterniflora canopies. "*Photogrammetric Engineering and Remote Sensing"*, 49, 77 – 83.

Mcfeeters, S.K. (1996). The use of normalized difference water index (NDWI) in the delineation of open water features. "*International Journal of Remote Sensing*", 17, pp. 1425–1432.

Sun, F., Sun, W., Chen, J. & Gong, P. (2012). Comparison and improvement of methods for identifying water bodies in remotely sensed imagery. Gery. "*International Journal Remote Sensing*". 2012, 33, 6854–6875.

Xu, H. (2006). Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. "*International Journal Remote Sensing*". 27, 3025–3033.