

WATER LEVEL FLUCTUATION ASSESSMENT OF LAKE CHAD FOR ENVIRONMENTAL SUSTAINABILITY USING REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM TECHNIQUE

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ABSTRACT:

Surface water is a significant constituent of the water cycle, and is paramount for human survival, social and economic development as well as environmental sustainability. Water level shrinkage and global warming are the main phenomena that becoming worldwide environmental problems. Lake Chad has been in a critical situation in recent years due to a continuous decline in surface water and drought, over abstraction of water and climate change caused a significant change of a land cover patterns. The present study aimed to highlight the change pattern of water level in the lake over the past three decades, and the satellite images of the Lake Chad from Landsat-TM, ETM+ and OLI were analyzed to investigate the change of land cover pattern during three periods: the 1985, 2000 and 2015. Supervised classification was performed for land cover change analysis. Then the overall accuracies of the classification of Landsat-TM is 93.80, Landsat-ETM+ is 90.80 and Landsat-OLI is 86.20 respectively. The result shows that there are continuous decline of water bodies, barren land and shrub, with rapid increment of farmland and gallery forest.

1. INTRODUCTION

Lake Chad Basin (LCB) in Central Africa has witnessed a continuous decline in its water level over some past decades due to some factors including over abstraction and climate change, and also part of droughts. The lake which was once the 6th largest in the world has shrunk by more than 90% area for about five decades (Gao *et al.*, 2011). The years of the major droughts fall between 1970s and 1980s and over abstraction of water mostly for irrigation purposes was a major contributor to the decreased water level in the lake and surrounding rivers, which are some of the contributors to the lake's water (Chari-logone, Komadugu-Yobe and Yedsaram/Ngadda). The shrinkage and water overuse caused significant changes to land cover which results in shoreline variation, and these could be attributed to improper water administration practices throughout the recent 50 years (Babamaaji and Lee, 2014). These issues of droughts and the lake's shrinkage have great consequences on the natural resources of the lake, as well as the standard of living of the inhabitants of the area in terms of job opportunities/poverty reduction and food security.

The Basin is described by high temperatures all over the year, little moistness except during rainy season, extreme solar radiation and solid breezes prompting a high evapotranspiration assessed to be somewhere in the range of 2,000 and 3,200 mm/year over the lake relying upon the area (Boronina and Ramillien, 2008; Candela *et al.*, 2014). The yearly precipitation differs between 1,500 mm in the southern part of the area to under 100 mm in the northern part (Okonkwo and Demoz, 2014). One significant element of Lake Chad's bathymetry is a shallow ridge or 'pronounced barrier' roughly 40 km wide that keeps running between the northern and southern pieces of the lake.

Monitoring and assessing the lake can easily be achieved through geospatial technique, a blend of remote sensing and

geographic information system (GIS). Remote sensing provides timely and accurate geospatial data and is an excellent tool for mapping, monitoring and modelling of environmental variables and processes. The widespread availability and reduced cost, remotely sensed imagery and geographic information system allow efficient mapping and detection of superficial changes of the natural resources on a greater scale. Also GIS supplies the geographic aspects of an assortment of information (Qiang and Lam, 2015). Essentially, it allows the examination of a database and provides outcomes as some sort of guide (map). Since numerous sorts of information have vital geographic aspects, a GIS can have numerous utilizations, so to see, comprehend, question, decipher and imagine information from multiple points of view and uncover to use connections, examples and patterns.

Furthermore, GIS is "an organized collection of computer hardware, software, geographic data and personnel designed to efficiently capture, store, update, analyze and display all forms of geographically referenced information" (Esri, 2012). GIS innovation has been broadly utilized as a part of various fields of study (for example; hydrology, climate change, ecology, economics, education etc.). The technological advancements brought by GIS have vital applications to numerous ecological examinations and furthermore is gainful as it can provide viable geospatial data to the policy makers in enhancing their choices for sustainable development (Chandio *et al.*, 2013).

2. MATERIAL AND METHODS

2.1 Study Area

Lake Chad Basin, situated in west-central Africa, is geographically located between latitudes 50 22' 46.42" and 250 43' 11.11" north of the Equator, and longitudes 60 42' 13.89" and 240 45' 34.64" east of the Green Witch Meridian. The

dynamic nature of the lake continually changing as a result of variation in temperatures and precipitation, which is realizable from its size, shape and depth. An assortment of natural zones bordering the lake include wetlands, wood/forest, desert, savannahs and mountains (Ovie *et al.*, 2012). Three key drainage schemes supply its water: the Chari-Logone River (in the Central African Republic), the Komadugu-Yobe River (in Nigeria) and the Yedsaram/Ngadda River (in Cameroon). The lake has been recognized as one of the lakes facing the most serious danger of socio-political pressure. For instance, the lake was massively greater (up to 400,000km²) a few thousand years prior than it was in the 1960s; in those days it

was known as Lake Mega Chad amid the whole twentieth century, the lake was at its peak level within 1960 and 1963. Long ago, there was a perception that the condition of the lake's bowl has exacerbated as it has shrunk by more than 90% (25,000km²) from the 1960s to date (Gao *et al.*, 2011). The natural climate of the Lake Basin is characterized by its solid breezes, high temperatures, high evapotranspiration (evaluated at 2,200mm/annum) and fluctuating precipitation patterns. Yearly precipitation fluctuates spatially from almost 1,400mm along the southern pools to under 150mm close to the northern end (Okpara *et al.*, 2015). Figure 1 shows the location of the study area.



Figure 1. Study area.

2.2 Data Collection

Landsat imagery of three (3) epochs were utilized in this study. These include Thematic Mapper (TM) of 1985, Enhanced Thematic Mapper Plus (ETM+) of 2000 and Operational Land Imager (OLI) of 2015. The selection of the Landsat imagery could be attributed to their free access, diverse spectral bands suitable for different applications, moderate spatial resolution, and global coverage (Cenci *et al.*, 2018; Rokni *et al.*, 2014). All

the Landsat scenes chosen as input to this investigation were imaged between December and January (winter period). The images were sourced from the Global Visualization Viewer and Earth Explore of the United State Geological Survey (USGS). Table 1 show the Landsat images used in this study in order to detect some changes.

Table 1. The 1985, 2000, 2015 Landsat images with their path, rows and acquisition dates

Path/ Raw	1985		2000		2015	
	Sensor	Date	Sensor	Date	Sensor	Date
184/051	Landsat TM	20/10/1985	Landsat EMT+	19/11/2000	Landsat OLI	23/12/2015
185/050	Landsat TM	10/11/1985	Landsat EMT+	10/11/2000	Landsat OLI	30/12/2015
185/051	Landsat TM	07/11/1985	Landsat EMT+	10/11/2000	Landsat OLI	30/12/2015
186/050	Landsat TM	02/10/1985	Landsat EMT+	17/11/2000	Landsat OLI	21/12/2015
186/051	Landsat TM	21/10/1985	Landsat EMT+	03/12/2000	Landsat OLI	21/12/2015

2.3 Methods of Data Analysis

The research spilled into three phases and, this section discussed the methods employed to accomplish the objective of the study. Figure 2 gives an overview of the methodology used.

At this point every single phase were carried out accordingly with a view to attain the research objective.

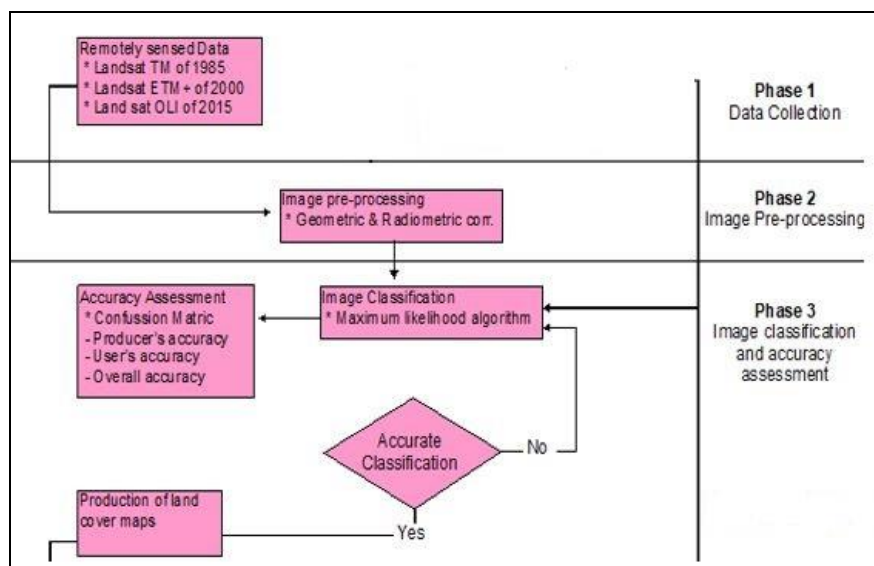


Figure 2. The methodology flowchart

2.4 Image Pre-processing

The raw data procured through satellite-sensor platforms mostly contain noises and distortion as well as other atmospheric errors. To rectify these, the data has to be pre-processed to confirm originality of the data. This differs on account of satellite images, which relies upon the image format, its initial condition and the kind of information required for it, as well the composition of the image scene. In the present study, image pre-processing was adopted to eliminate the noises and distortions obtainable in a raw data (imaging). This preliminary stage of image litigation will permit access to an uninterrupted image for further analysis. Then in addition, the phase will make image workable for it geometric and radiometric characteristics to resemble the radiant energy of the archetype scene. The scenes of Landsat imagery of the study were redressed through subjecting them to radiometric and geometric corrections. Then all Landsat scenes have been geometrically restituted with transformation of local map coordinates. This is to permit the radiometric and geometric characteristics of the image to match the radiant energy of the original scenes (Jensen and Cowen, 1999; Musa *et al.*, 2018).

The collected images were radiometrically improved by utilizing the rescaling parameters accompanied in the metadata associated with the images. The image ratification was performed in two phase system: (a) the highest point of atmospheric reflectance were changed over to surfaces reflectance utilizing dark object subtraction (DOS), (b) the image digital/computerized numbers (DNs) were changed to the best of atmospheric reflectance. The analysis usually eliminate any atmospheric scattering obtained from original image of which pixel value representing background signature were fully erase from individual bands. Therefore, image-to-map rectification process by means of ground control point (GCPs) appearing in either maps or images, was employed to correct scenes of 2015 and it was used as the reference image to rectify the remaining scenes (Sang, 2013). The analysis was observing in two phases involving; 2nd grade polynomial was utilized to transform image toward map geometry and raw/crude Landsat image pixel intensity rate were transposed to transformed geometry by utilizing the nearest neighbour resampling pattern. To avoid loss of fact and misclassification, a broadly used Root Mean Squared Error (RMSE) of ± 0.5 pixel was guaranteed (Imani *et al.*, 2014; Yuan *et al.*, 2005) for accurate investigation.

3. RESULTS AND DISCUSSIONS

This research was conducted to analyze change pattern particularly water level and assess its impact on the study area and examine the usability of satellite imagery, in such a way of assessing water level change in the lake over the last three decades of the basin. A comprehensive analysis has been done, supervised classifications by maximum likelihood algorithm

were performed in this study. Nevertheless, the result of the accuracy assessment indicates that the image classifications have met the criteria for acceptance considering US Geological Survey (USGS) standard of image classification is 85 % for overall accuracy (Anderson *et al.*, 1976). Figures 3, 4 and 5 presented the derived change maps for the year 1985, 2000 and 2015 respectively.

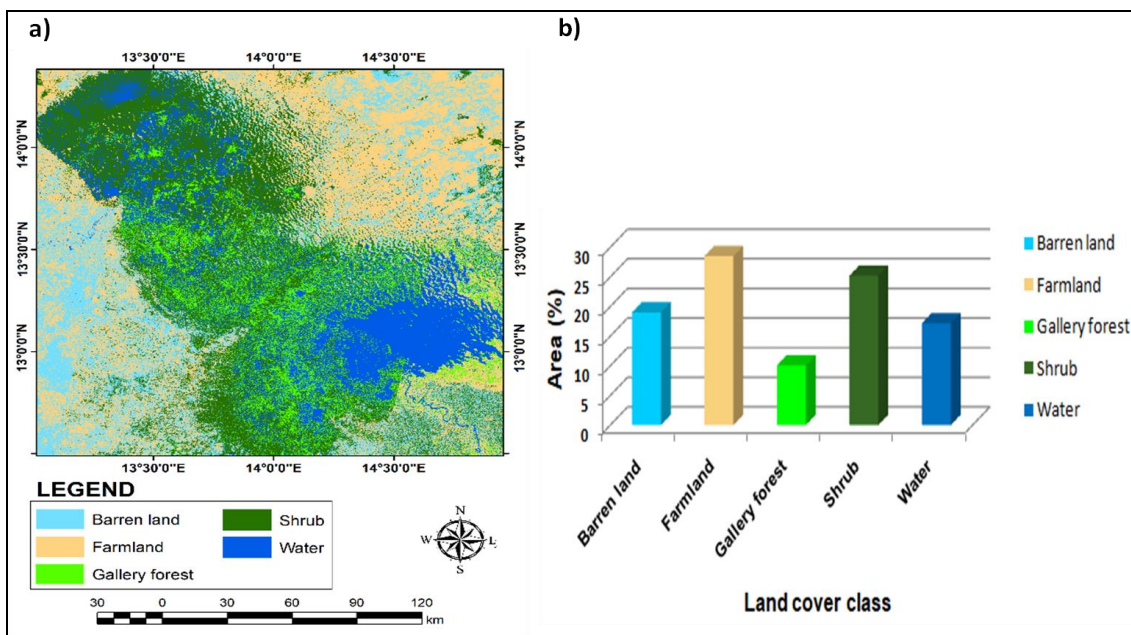


Figure 3. (a) Lake Chad change map in 1985, (b) area coverage percentage for each class

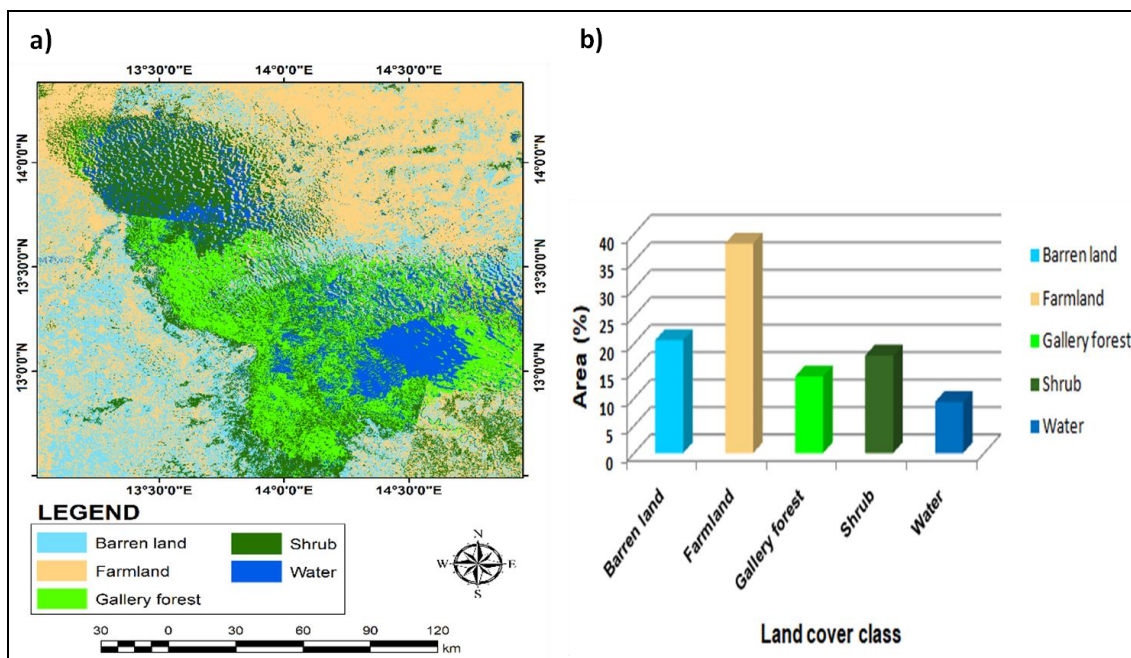


Figure 4. (a) Lake Chad change map in 2000, (b) area coverage percentage for each class

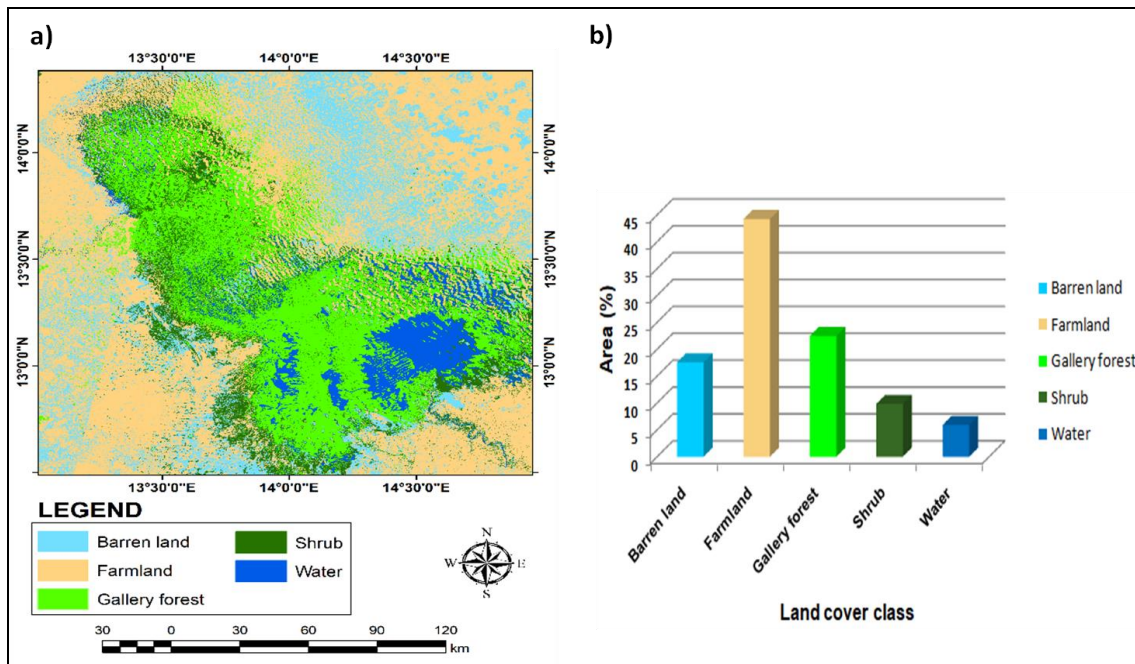


Figure 5. (a) Lake Chad change map in 2015, (b) area coverage percentage for each class

The whole classification assessments comprising the confusion matrices, producer's accuracies, user's, and overall accuracies with Kappa indexes of the classified images are summarized and presented in Table 2. The reasons for achieving the highest accuracy could be attributed to the coarse classification using

five classes only. However, it can be observed that the derived maps have different classification accuracies, which could be attributed to the use of different multispectral bands and temporal variations in the images.

Table 2: Classification accuracies with overall kappa indexes.

Land Cover Category	1985		2000		2015	
	Producer's Accuracy (%)	User's Accuracy (%)	Producer's Accuracy (%)	User's Accuracy (%)	Producer's Accuracy (%)	User's Accuracy (%)
Gallery Forest	100.00	90.00	93.46	90.91	89.19	90.00
Farmland	86.44	97.14	82.86	82.86	73.53	71.43
Barren Land	95.18	87.78	93.55	96.67	95.65	97.78
Water Body	94.79	95.79	98.85	90.53	100.00	85.26
Shrub	94.23	98.00	87.04	94.00	77.19	88.00
Overall Kappa	92.24		88.49		82.72	
Overall Accuracy	93.80		90.80		86.20	

4. CONCLUSION

The present study analyzed the land changes patterns of Lake Chad for the past three decades using Landsat- TM for the 1985, Landsat-ETM+ for 2000, and Landsat - OLI for 2015. Supervised classification methods were used for the land cover analysis of the satellite images, then Landsat has capabilities for detecting numerous land change patterns. This study shows that Landsat is capable of detecting depletion of water bodies. Likewise, the land cover classes contained five categories such as; barren land, farmland, gallery forest, shrub and water body. Barren land has the total percentage of 17, 16 and 15 in 1985, 2000 and 2015. Farmland has 26, 41 and 43 in 1985, 2000 and 2015. Gallery forest has 9, 12 and 21 in 1985, 2000 and 2015. Shrub has 24, 21 and 9 in 1985, 2000 and 2015. Water body

has 16, 9 and 4 in 1985, 2000 and 2015 respectively. The result indicated a remarkable declined of water body, shrub and barren land from 1985 to 2015. On the other hand, a slight increments of gallery forest as well as high increments of farmland.

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