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Change Detection for the Past Three Decades Using Geospatial Approach in Lake Chad, Central Africa

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Abstract. Lakes are extremely touchy and dynamic parts of the earth and have a pivotal part in the farming, environment, industrial and domestic purposes. In Central Africa, Lake Chad Basin (LCB) has observed an uninterrupted decrease in its water level for the past decades as a result of certain variables such as climate change and over-abstraction, and likewise part of dry spells. The aforementioned challenges have serious effects on the standard living of the people in a particular area as well as the lake natural resources. The current study was planned to assess the changes of a lake for the past three epochs, then the Lake Chad satellite imageries include OLI, ETM+, and TM were evaluated with a view to came up with some land cover changes throughout these epochs: 1985, 2000, and 2015. All the scenes were subjected to the pre-processing stage to ensure the originality of the information, and "supervised classification was implemented 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 outcome demonstrates that there is a continuous decline of water bodies, barren land, and shrub, with a rapid increment of farmland and gallery forest".

1. Introduction

During the last five decades, Lake Chad has witnessed drastic changes in its water and land cover pattern (Li *et al.*, 2007). The consecutive drought as of the early 1970s and 1980s brought about the decline of surface water. The aforementioned challenges have serious effects on the standard living of the people in a particular area as well as the lake natural resources concerning food security, poverty reduction, and job opportunities. Anthropogenic activities couple with climatic factors resulted in noteworthy change, particularly the water level of a Basin. Similarly, the combination of the above-mentioned factors has caused the shrinkage of a lake (Nkiaka *et al.*, 2016). Also, the lake which was formerly the sixth biggest on the planets has contracted by over 90% extent for around five decades (Gao *et al.,* 2011).

Encircling waterways, serve as the main supply of the lake water such as (Yedsaram/Ngadda, Chari-logone, and Komadugu-Yobe). The overutilization and decline of water resulted in serious land cover changes, therefore brings about coastline variation, and these are not unconnected to inappropriate water management policy all through the last "50 years (Babamaaji and Lee, 2014). The Basin is considered by having unfavourable temperatures all the year", but with little wetness during the rainy season, Strong breezes with high solar radiation stimulating great evapotranspiration evaluated to be around "2,000, and 3,200 mm/year in the lake depending upon the region (Boronina and Ramillien, 2008; Olivry *et al.*, 1996). Annual rainfall varies spatially around 1,400 mm in the southern pools to less than 150mm near the extreme northern (Okpara et al., 2015)".

The population figures were estimated to be around 22 million people in the year 1991 and it has witnessed rapid increment in the last few decades. Therefore, presently the population estimated to be around 40 million and its supply freshwater within to over 20 million inhabitants living neighbouring areas. Farming activities had mostly been the mainstay economy of the region and keep on supporting around 60% of the population living around the Basin's (Ebenki, 2010; Leblanc *et al.*, 2007). The issues of drought and lake shrinkage have a negative impact, particularly on economic activities such as irrigation, fisheries, fuel wood provision, wetland services as well animal husbandry, which resulted in food insecurity coupled with a shortage of clean water. This has consequences for the wellbeing status of the occupants within the lake. Social effects of freshwater deficiency have been incited by the expanded burden on natural resources because of the relocation of individuals from the dry northern parts of the Basin into areas nearby the Lake as well as a related river basin.

Geospatial approach played a vital role when assessing and monitoring the lake, a mix of "geographic information system (GIS), and remote sensing". GIS delivers a significant geographic detail (Qiang and Lam, 2015). Basically, it permits the assessment of the database and gives results as a type of monitor (map). Meanwhile, various sorts of data have crucial geographic perspectives, also GIS can have various uses, to understand, see, query, translate and envision data from different perspectives and reveal to utilize models, connections, patterns, and examples. Remote sensing offers ideal and precise geospatial information and is an amazing instrument for observing, modelling and mapping of ecological variables and procedure, the extensive accessibility and lessened cost, geospatial approaches permit effective mapping and uncovering of apparent changes in natural resources to large extent (Hussaini *et al.*, 2019).

2. Materials and Methods

2.1. Study Area

The present Lake Chad Basin, eastern and northern limits are demarcated between latitudes 5º 21´46.42″ and 24º42´12.11″ North of the Equator and then 6º41´12.79″ and 24º35´33.64″ East (GMT) Green Witch Meridian. The lake gradually changing because of differences in precipitation and temperature, which is realized from its depth, size, and shape. A combination of normal zones flanking the lake comprises mountains, savannah, desert, forest/wood, and wetlands (Ovie *et al.*, 2012). The main sources of its water include Yobe-Komadugu (in Nigeria), Ngadda/Yedsaram River (in Cameron), and Chari-Logone River (Central Africa Republic). Therefore, lake can be seen as core among the lakes confronting the most genuine risk of socio-political weight. For example, the lake was enormously more noteworthy (around 400,000km^2) a couple of more than hundreds of years earlier than it was during the 1960s; throughout that periods it was recognized as Mega Chad Lake, during the entire twentieth century, between 1960 and 1963 the lake at its highest level. Quite a while in the past, there was a discernment that the state of the lake's basin has worsened as it has declined by over 90% (25,000km^2) since from the 1960s to present (Gao *et al.*, 2011). The normal atmosphere of the Lake Basin is described by its high evapotranspiration, strong breezes, and high temperature (assessed at 2,200mm/annum) and inconsistent rainfall patterns. Annual rainfall varies spatially from nearly 1,400mm through the southern parts and to less than 150mm near the extreme north (Okpara *et al.*, 2015). Figure 1 illustrates the case study area.

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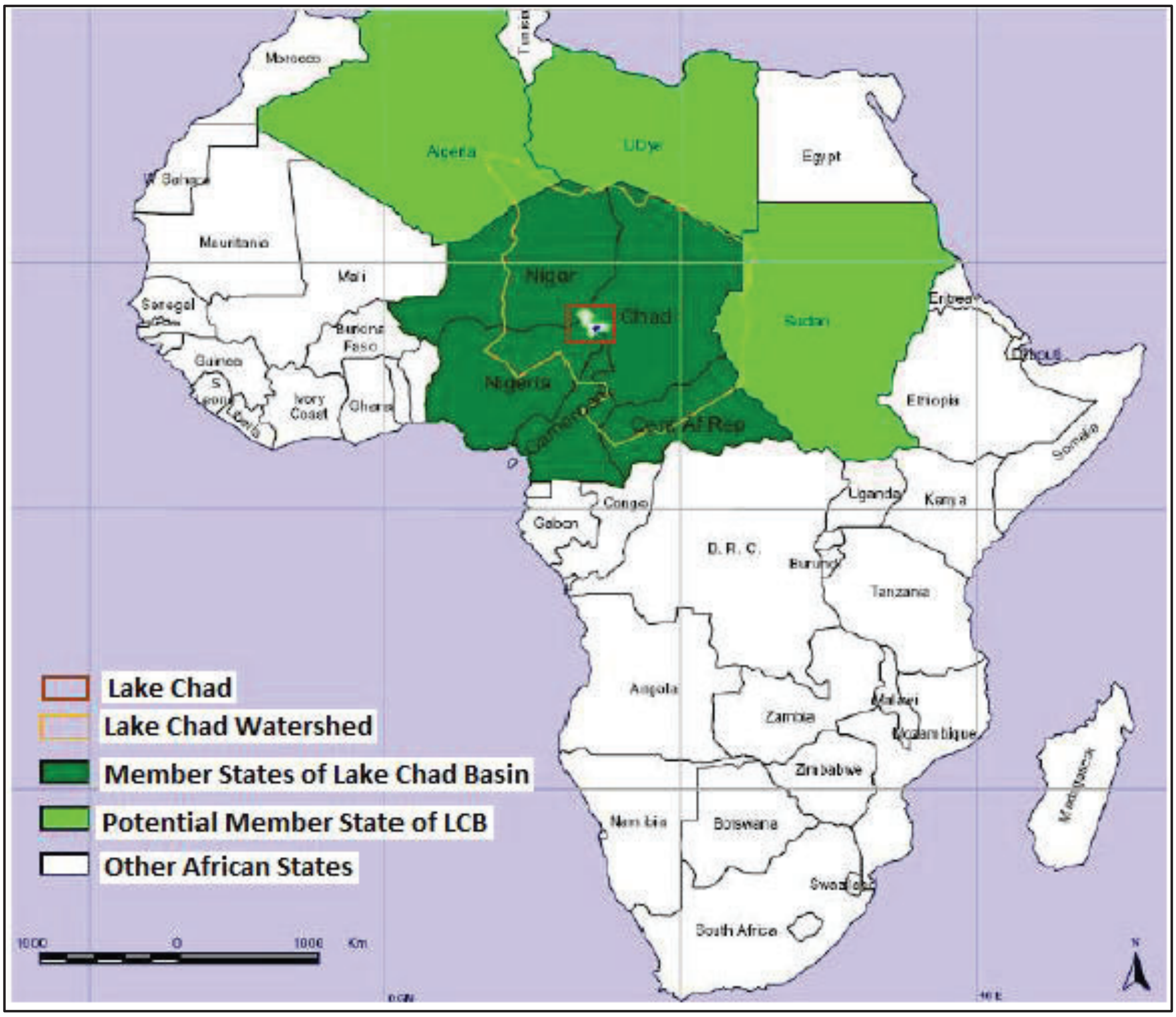


Figure 1. Case Study area

2.2. Geospatial Data Used for the Study

Recently the satellites of higher resolution were started orbiting the earth's surface. Consequently, to effectively analyse the present and past conditions, there is a need to get multi-temporal images that cover the past few decades' events such as Landsat. To achieve that, the satellite imageries were used in this study include Landsat of three decades. These comprised (OLI) Operational Land Imager of 2015, (ETM+) Enhanced Thematic Mapper Plus of 2000, and (TM) Thematic Mapper of 1985. The reasons behind the use of Landsat satellite imageries are due to their appropriate for various applications, worldwide coverage, optimum spatial resolution, and open access (Luca Cenci *et al*. 2018; Komeil Rokni., 2014). Similarly, the Landsat scenes served as an idea to this study were sourced between January to December from (USGS) Earth Explorer, United State Geological Survey, and Global Visualization Viewer. Table 1 illustrates Satellite imagery (Landsat) utilized in this study to perceive changes.

Table 1. The Satellite imageries in 1985, 2000, and 2015

Path/ Raw	1985		2000		2015	
	Sensor	Date	Sensor	Date	Sensor	Date
183/051	Landsat TM	19/12/1985	-	-	-	-
184/051	Landsat TM	20/12/1985	Landsat EMT+	19/12/2000	Landsat OLI	23/12/2015
184/052	Landsat TM	17/12/1985	Landsat EMT+	05/12/2000	Landsat OLI	23/12/2015
185/050	Landsat TM	10/12/1985	Landsat EMT+	10/02/2000	Landsat OLI	30/12/2015
185/051	Landsat TM	07/12/1985	Landsat EMT+	10/12/2000	Landsat OLI	30/12/2015
185/052	Landsat TM	26/12/1985	Landsat EMT+	31/02/2000	Landsat OLI	30/12/2015
186/050	Landsat TM	02/12/1985	Landsat EMT+	17/12/2000	Landsat OLI	21/12/2015
186/051	Landsat TM	21/12/1985	Landsat EMT+	03/12/2000	Landsat OLI	21/12/2015

Similarly, for change assessment, the total number of image scenes used was twenty-two (22), for the study area requires coverage of eight (8) scenes in 1985 and seven (7) scenes in 2000 and 2015 respectively, because their scenes are bigger in size than that of 1985. Then the scenes as shown in Figure 2 below.

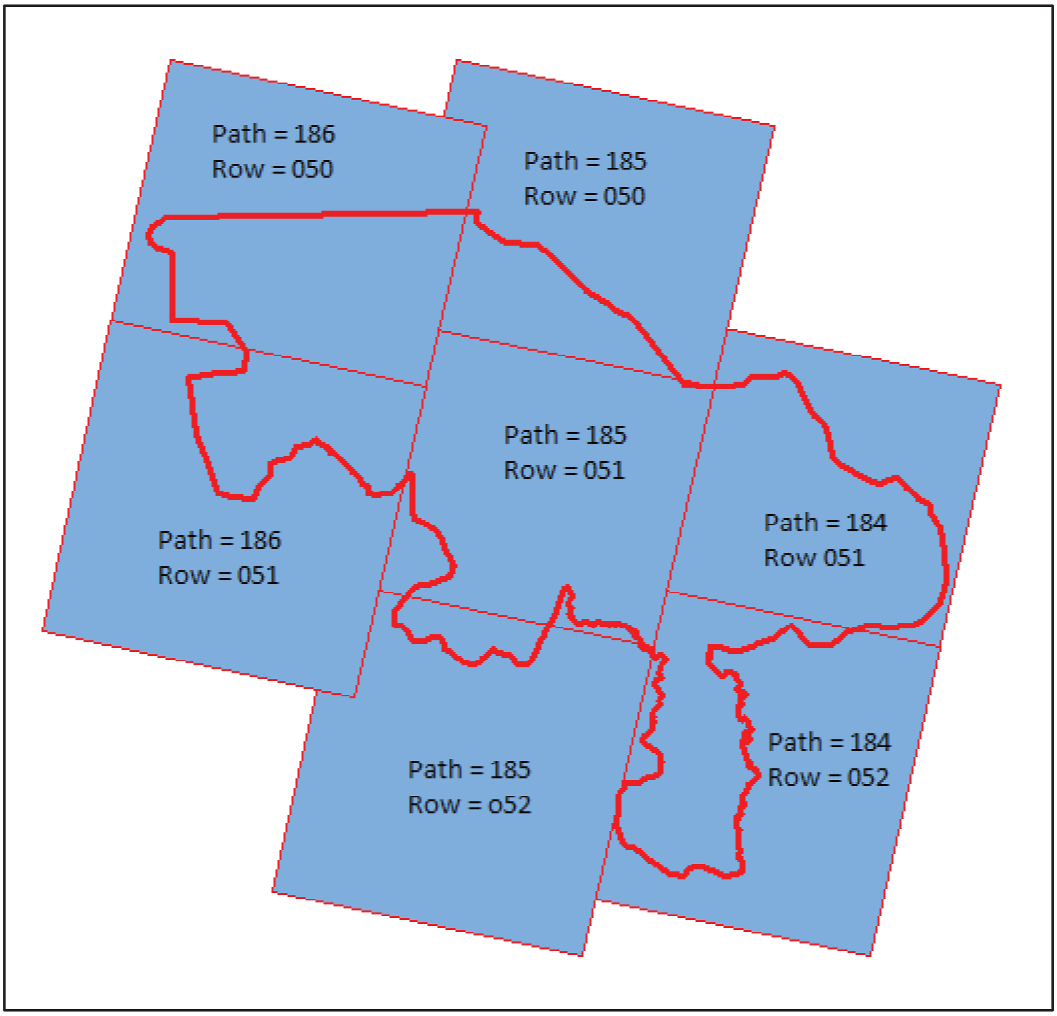


Figure 2. Landsat imagery scenes for Lake Chad and its Environs

2.3. Methods of Data Analysis
This part explained the whole procedure used to attain the objectives of the study. Figure 3 illustrates an outline of the procedure utilized.

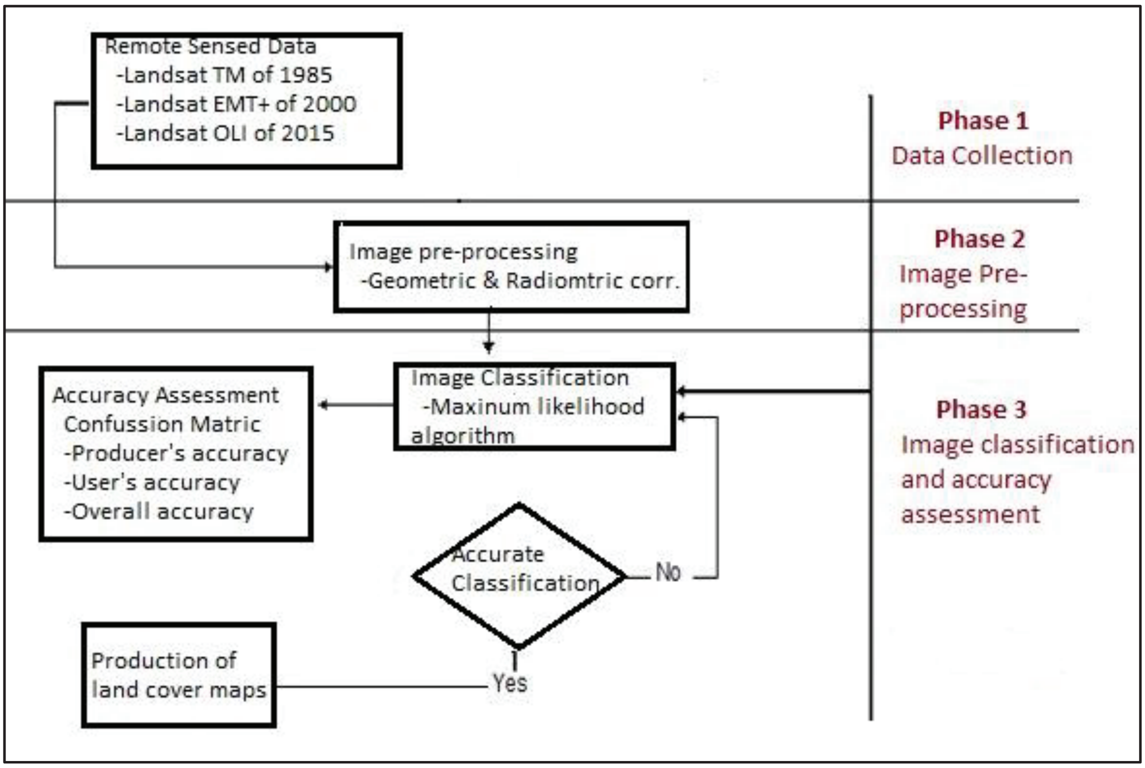


Figure 3. The study flowchart

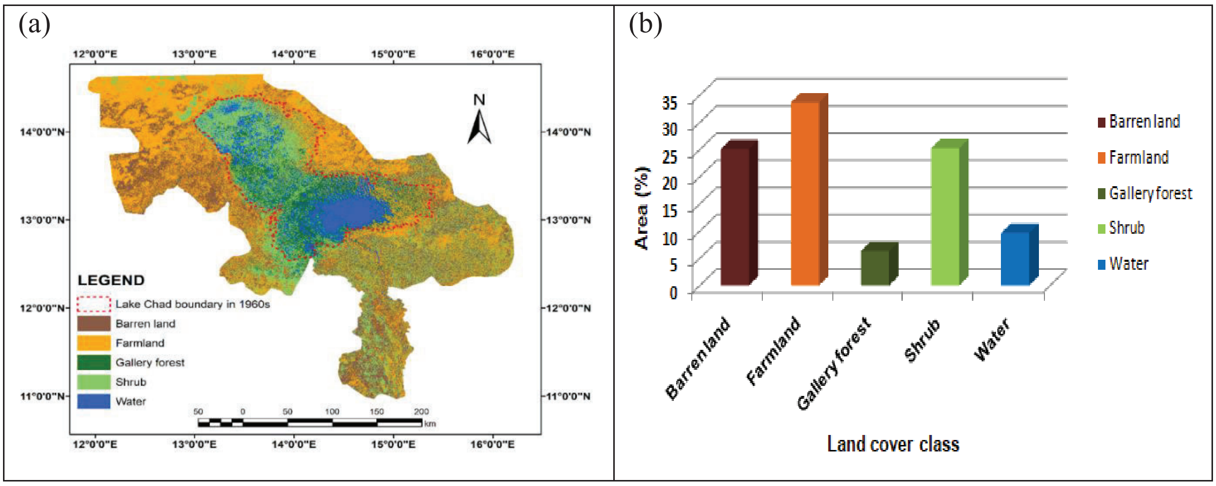
2.4. Imageries Pre-processing
The crude information obtained via satellite platform mostly contaminated with atmospheric error as well as distortion and noises. To redress these issues, the information must be pre-handled, pre-processed to affirm the inventiveness of the information. This contrasts because of satellite imageries, which depend upon the image patterns, its arrangement of the image scene, the types of detail needed from it as well as original condition. At that point all the satellite scenes used in this study must have been atmospherically and geometrically restored with a change of common map coordinates. Therefore this is to allow the geometric and radiometric attributes of the satellite image to harmonize the brilliant energy of the initial scenes (Jensen and Cowen, 1999; Musa et al., 2018). For an image to map geometric rectification, the 2015 scenes were considered as master scenes, then it was utilized to serve as the exact reference scene to address the outstanding scenes (Sang, 2013). “A comprehensively utilized Root Mean Squared Error (RMSE) of ±0.5 pixel was ensured (Imani et al., 2014; Yuan *et al.*, 2005) for precise investigation”.

3. Results
The research was conducted to analyze change patterns and evaluate its influence in the study area as well as observe the effectiveness of satellite imageries, whereby of evaluating land cover change in a lake for the past three epochs of the bowl. A complete investigation has been carried out, the maximum likelihood procedure under the supervised classifications were executed in this study. Nonetheless, “the outcome of the accuracy assessment shows that the classifications have met all the standard procedure considering (USGS) United State Geological Survey standard criteria of classification is 85% of the overall accuracy **(**Anderson et al., 1976)”.

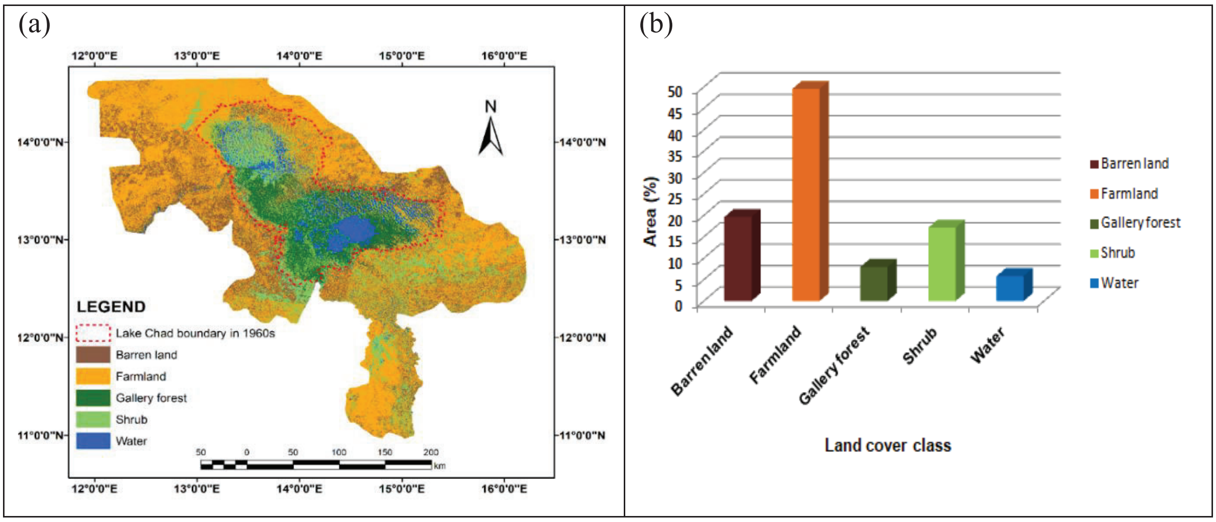
The result showed a remarkable increase in farmlands and gallery forest from 1985 to 2015 on the other hand, decrements of barren land, shrub, and water body were observed. Therefore, the lake declined has the main effect on the lakes' natural resources and, also standard living of the people in the particular areas with respect to food security, poverty and job opportunities. Table 2 and Figure 4, 5 and 6 illustrates the land cover map in the 1985, 2000 and 2015 respectively.

Table 2. Land cover changes of the study area, 1985 to 2015

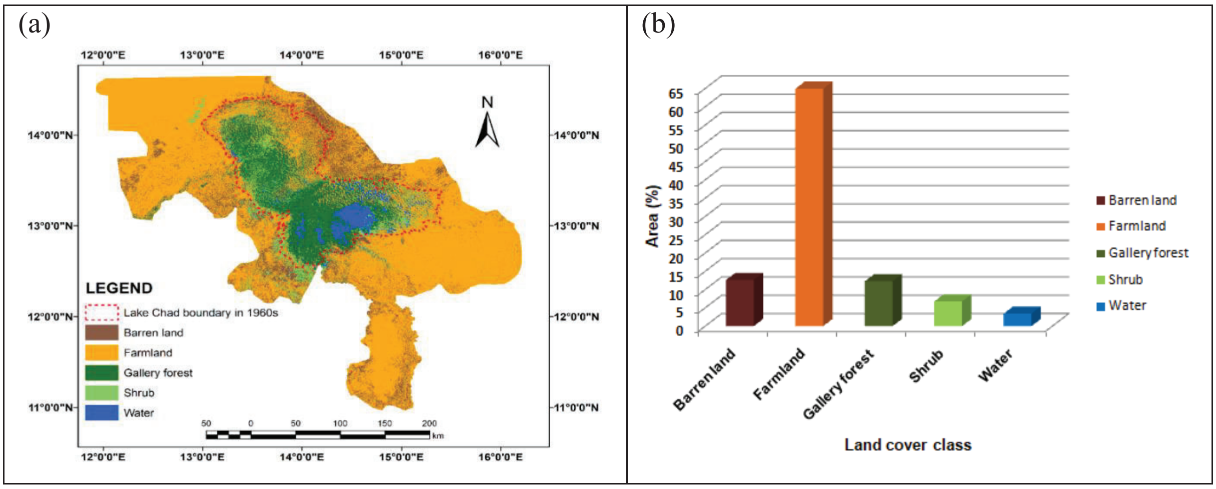
Land cover categories	Area covered in (Sq km)			Changes in (%)		
	1985	2000	2015	1985-2000	2000-2015	1985-2015
Barren land	20678.40	16153.14	10396.04	-21.88	-37.64	-49.73
Farmland	27742.80	40824.79	53513.20	47.16	31.08	92.91
Gallery forest	5237.10	6546.46	10119.31	25.00	54.57	93.22
Shrub	20808.60	14115.51	5566.26	-32.16	-60.56	-73.25
Water	7943.30	4767.65	2812.73	-39.97	-41.00	-64.59



Figures 4. (a) Land cover map of Lake Chad in 1985, (b) "area coverage percentage for each class"



Figures 5. (a) Land cover map of Lake Chad in 2000, (b) "area coverage percentage for each class"



Figures 6. (a) Land cover map of Lake Chad land in 2015, (b) "area coverage percentage for each class"

The motive behind for succeeding the better accuracy due to common classification by utilizing (5) reasonable classes. Nevertheless, it can be witnessed that the change maps have divers classification accuracies, these as a result of numerous temporal differences and multi-spectral bands that were used in the imageries. Table 3 illustrate the summary of accuracies and overall kappa index.

Table 3. Overall kappa indexes classification accuracies.

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

4. Conclusion

The study investigated the land cover change of Lake Chad in Central Africa using satellite imageries of three epoch, which includes OLI for 2015, EMT+ for 2000, and TM 1985. In this case the approaches used for land-use change analysis of satellite imageries was supervised classification, hence the Landsat has the potentialities for monitoring various land cover changes. The study indicates that Landsat is equipped for identifying land cover change. Likewise, the land cover was classified in to five classes includes water body, shrub, gallery forest, farmland, barren land. Water body has the overall proportion of 9, 5, and 2 in “1985, 2000 and 2015”. Shrub has 24, 15, and 5 in “1985, 2000 and 2051”. Gallery forest has 5, 6, and 10 in “1985, 2000 and 2015”. Farmland has 32, 48 and 63 in “1985, 2000, and 2015”. Barren land has 24. 19, and 11 in “1985, 2000, and 2015”. The outcome illustrates an increases of gallery forest as well as farmland from 1985 to 2015. Likewise, a remarkable shrinkage of barren land, shrub and water body also from 1985 to 2015.

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