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MONITORING OF SURFACE WATER RESOURCE DYNAMICS IN A SEMI-ARID ENVIRONMENT OF NIGERIA: A DIGITAL CHANGE DETECTION APPROACH

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ABSTRACT

The aim of this paper is to monitor surface area change of Zobe dam water body in central part of Katsina State. The methods adopted to detect changes include Land use/land cover change assessment in relation to the water body in Zobe dam watershed using satellite image processing, change detection of multi-temporal images and supervised classification using Maximum Likelihood algorithm in ERDAS imagine 2014. This was achieved using multispectral Landsat 7 satellite data of the year 2005 and Landsat 8 OLI of the year 2015 respectively. The study area was classified into five major classes viz: Built up areas, Water bodies, Bare surfaces, Plantation and Farmlands. Post classification Change detection analysis was performed to compare the quantities of land cover class conversions over spatial and temporal scales. Results revealed that surface dimension of the water body of Zobe dam decreased from 270.48km^2 to 259.40km^2 between 2005 and 2015 respectively. This amounted to a decrease of 11.08km^{2}within a ten-year period with an annual rate of decrease of 1.1km^2. Plantation also decreased from 160.19km^2 in 2005 to 92.34km^2 implying a loss of 67.85km^{2}within a period of only ten years. It further revealed increase in bare surface, built-up areas and farmlands from 2005 to 2015. Drivers of the observed changes includes rapid population growth leading to establishment and expansion of existing and new settlements which resulted into widespread conversion of natural vegetated cover to large expanse of cultivated land with serious consequences on the environment. Thus, a detailed and regular study of condition for timely monitoring of surface area of wetlands and other water resources using Remote Sensing and Geographic Information System techniques so as to provide useful spatial information over large geographic areas affecting the structure and function of semi-arid ecosystems were recommended.

Keywords: *Image Classification; Zobe Dam; Water Resources; Change Detection; Semi-arid; Land Cover; Land Use*

INTRODUCTION

Surface water constitutes one of the indispensable resources for human survival as well as socio-economic development (Isah, 2010). It constitutes one of the basic resources for human progress, food crops production, and sustainable ecosystems well-being. Water resources scarcity and deteriorating quality of natural water sources have become critical factors limiting national economic development, expansion of food production and/or provision of basic health and hygiene services to the population (Isah, 2010). Reliable information about the spatial distribution of surface water is critically important in various scientific disciplines, such as the assessment of present and future water resources, agricultural potentialities, river dynamics, wetland inventory and management, watershed analysis, surface water survey and management, flood mapping and areas liable to flood incidence (National Water Resources Institute, 2003).

In Nigeria, rainfall decreases from the southern parts of the country towards the northern parts, while evaporation increases northwards because of longer hours of sunshine and higher mean air temperatures in the northern parts compared to the south. Of the rain that falls over an area, some amounts percolate into the soil to replenish soil moisture and groundwater storage, some amounts run off to join streams and rivers while substantial amount is lost through the evapotranspiration processes. An accurate assessment of the water resources of any area therefore requires knowledge of not only the magnitude of rainfall and its spatial and temporal distribution but also the nature and magnitude of water losses by evaporation, substantial amounts of surface water lost by evapotranspiration which considerably reduces the effectiveness of rainfall particularly in the semi-arid areas of northern parts of the country (Ayoade, 1975). With combination of high and relatively constant temperature regime, annual sunshine of over 2,500 hours, relatively steady northerly or southerly winds and cloudy skies fluctuating with the season’s high evapotranspiration rates predominate in the northern parts and low in the southern parts of the country. The mean potential evapotranspiration (PET) in the northern parts of the country exceeds 2,500mm which is greater than 300% of the mean annual rainfall. In terms of water resources development, PET deserves greater attention particularly in the northern parts where annual water deficiency is greater than the annual surplus by as much as 1,500mm (Adefolalu, 2007).

The pattern of distribution of the annual actual evapotranspiration estimated by the water-budget procedure differs from that of potential evapotranspiration since actual evaporation depends not only on climatic factors but also on soil and plant factors. Since water is not assumed to be always available for evapotranspiration processes, the spatial distribution of actual evaporation is closely linked with that of rainfall. Hence whereas the potential evaporation increases from the southern parts towards the northern parts, the actual evaporation like rainfall decreases northwards (Adefolalu, 2007). hus, while dry season lasts longer (about 7 months) in the study area with its characteristics short wet season (between 3–4 months) and low annual rainfall amounts (about 700mm), the situation in the southern parts of the country is directly opposite, and therefore expose surface water resources (such as dams) in the northern parts to serious threats of rapid drying-up and shrinkages over time (Adefolalu, 2007). The scenario above lends credence to the predictions of changes in climate which demonstrated the variability and uncertainty of future surface water resource availability particularly in the semi-arid areas.

Increased anthropogenic activities (such as rapid urbanization, deforestation, etc.) coupled with natural climate change phenomenon have contributed to imperil rapid regeneration in semi-arid ecosystems. Fundamentally, these ecosystems are complex and fragile and so due to high risks of evapotranspiration and wide scale deforestation and bush burning by local people, there seems to be serious pressure or threats to available surface water bodies in this area. As a result of dusty and cold harmattan wind that characterized the area between the months of November to March, most localized surface water bodies such as ponds, hand-dug and open wells, shrink or completely dry up causing serious impact on biodiversity, ecosystem and livelihoods of the people in the area. Semi-arid environments are especially sensitive to the impacts of the harmattan wind system and high temperature regimes (Adefolalu, 2007).

Currently, due to global warming, several inland lakes and water bodies are at serious risk of both positive and negative changes and at best serve as natural indicators of climate change. This is because their expansion or contraction reflects changes of water balance and heat condition in semi-arid ecosystems. It is posited that the accelerated changes in global temperatures will no doubt affect the size and volume of surface water bodies particularly in the semi-arid ecosystems thereby causing decrease in water level leading to incidence of flooding and inundation on lowland which subsequently brings about siltation of lakes and water reservoirs due to soil erosion (Adefolalu, 2007).

Remote sensing integrated with Geographic Information System (GIS) has developed rapidly to address environmental needs with the ability to capture and record land details instantaneously. Its spatial resolution and aerial coverage provide synoptic view of a land surface over temporal scales. Several research efforts that applied Remote Sensing and GIS in change detection of certain environmental resources proved to be useful. Mattikalli (1995) combined Remote Sensing/GIS to assess changes around River Glen catchments in England using 1931 to 1989 satellite data and revealed the effects of land use/and cover on the river catchment during the study period. Okhimanhe (1993) also combined Spot HRV imagery of 1986 and aerial photographs of 1974 to assess the environmental impact of Bunimburum/Tiga dam in Kano State which revealed vegetation depletion in the study area. Adeniyi and Omojola (1999) combined aerial photographs, Landsat MSS, Spot XS/Panchromatic Image and Topographical maps to study landuse/landcover changes in Sokoto and Guronyo dams, Nigeria, between 1962 and 1986. Ikusemoran (2009) combined 1965 aerial photographs and Landsat images of 1978 and 1995 in a change detection study of Kainji lake basin and revealed expansion of Lake Reservoir due to increased agricultural activities in the area.

The increase in reservoir sedimentation resulting from accelerated erosion from farmland and bare surfaces in the study area around the dam/reservoir have been identified as major causes of high and rapid problem of siltation particularly in the northern Sudan savannah area of Northern Nigeria (Adediji, 2005). This, in conjunction with increasing annual rainfall amounts as well as high evapotranspiration leading to serious threats to the available surface water volume of Zobe dam. However, in spite of many published works on the application of Remote Sensing and GIS to water resources evaluation (Alan and Thomas, 2003; Dimitrios, et. al. 2003; Pao-shan, et. al. 2003; Muhammed, et. al. 2003; Mironga, 2004), there were rather little or no known studies on the application of Remote Sensing and GIS to detect surface water changes in Zobe dam reservoir in Katsina State of Nigeria. Therefore, information on the dynamics of surface water of the dam on spatial and temporal basis will no doubt serve as an important impetus for irrigation water supply planning and management in Katsina State.

MATERIALS AND METHODS

Location and Description of the Study Area

The study area, Zobe Dam, is located between latitude 12°20’34.62” N to 12°23’27.48” N and between longitude 7°27’57.12” E to 7°34’47.68” E, in Dutsin-ma Local Government Area of Katsina State. It covers an approximate area of 968.544km^2. Zobe Dam has two major tributaries which comprised of Rivers Karaduwa and Gada. The Dam was constructed on River Karaduwa and extends to about 2.7 km long and a surface of about 4, 500ha (Table 1). Annual rainfall in the area varies from 600-700mm; mean annual temperature is about 25^{o}C (Adediji, 2005).

Table 1: Characteristic features of Zobe dam

SALIENT FEATURES	FIGURES
Embankment length	2.75km
Embankment height	18.9m
Dam crest width	5.00m
Dam reservoir capacity	177*10 power 6 m cube
Gross irrigation area	8,137 ha (surface and sprinkler)
Reservoir surface area	4,500 ha
Catchment area	2,309km square
Spill way No.1 crest length	110m
Spill way No.2 crest length	78m
Spill way channel	300m
Maximum overflow	1087m 3/5
Intake tower height	23m above river bed
Intake tower diameter	7.4m
Valve chamber	2 pipes of 1,400mm discharges 10.8m3/5 each
Tunnel size	9*5*116m
Instrumentation	55N0. Relief wells for evaluation of seepage
Pilot scheme	100 ha
Bottom outlet	2*1400mm
Time of total emptying	113 days
Free board	2.21m
Upstream slope	1:3.2, Rip-Rap, d=1.00m
Downstream slope	1:2.2, Rip-Rap, d=0.35m
Max. flood storage capacity	263 million cubic meter
Mean inflow	172 million cubic meter /year
Active storage capacity	170 million cubic meter
Dead storage capacity	7.0 million cubic meter
Irrigation requirements	55.53 million cubic meter
Evaporation	40.71 million cubic meter
Seepage	3.60 million cubic meter
Downstream riparian use	14.00 million cubic meter
Sediment accumulation	5.8 million cubic meter
Volume of earth fill	3.1625 million cubic meter
Dam crest level	497.20 mas 1
Maximum flood level	495.11 mas 1
Full storage level	493.00 mas 1
Dead storage level	484.60 mas 1

Source: Sokoto Rima River Basin Development Authority (2015)

The study area is characterized by temperature between 25 - 45^{o}C, constant relative humidity between 19% to 23% and short raining season of about four months usually between late May to late September, while the dry seasons usually lasts longer from November to April (Olofin, 1993). Harmattan breeze arrives mostly in the months November and wanes away in the month of February to March. The seasonal distribution of rainfall provides only enough moisture for grassland with scattered woodlands (Nigerian Metrological Agency, 2015). Main soil types in the study area are the brown and reddish sandy soils strongly influenced by Aeolian deposition active in the recent geological period. The soils are of low- medium fertility, moderately acidic and well drained suited to crops such as millet and groundnut (Katsina Agricultural and Rural Development Agency, 2015). The study area is in Sudan savannah vegetation belt made up of short grasses usually between 1.5m to 2m height.

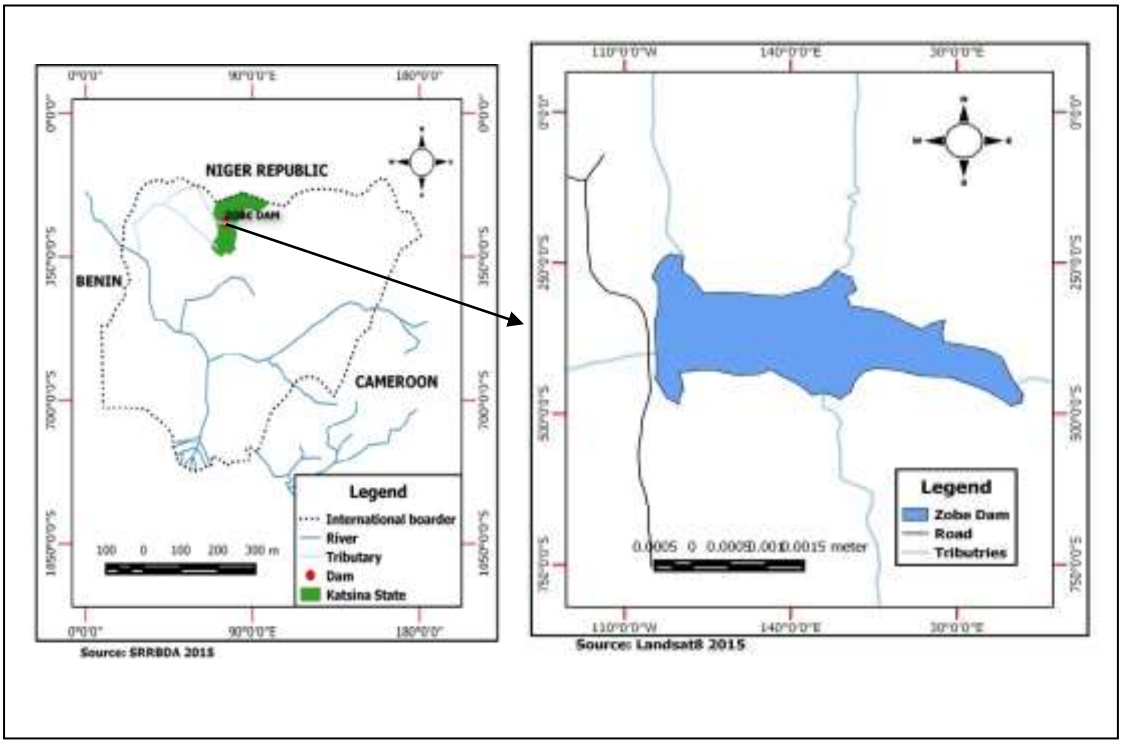


Fig 1: Map of Nigeria showing Zobe dam and Map Zobe dam (study area)

Data types and sources

Table 2 presents data types and characteristic acquired for this investigation. Images used in this study included Landsat7 ETM+ satellite image of 2005 in a Geotiff format and Landsat8 OLI satellite image of 2015. These images were obtained from the USGS GLOVISwebsite and were captured during the dry season with zero cloud cover. Specifically, the two images were for 4th January, 2005, and 21th January, 2015 on WRS 189/051 path and row numbers.

Table 2: Data types and their characteristics

Landsat 7 ETM+	Wavelength	Res. (M)	Landsat 8 (OLI)	Wavelength	Res. (M)		
			Band 1 Coastal aerosol	0.43 - 0.45	30	ETM+	OLI
Band 1	0.45-0.52	30	Band 2 (Blue)	0.45 - 0.51	30	1	2
Band 2	0.52-0.60	30	Band 3 (Green)	0.53 - 0.59	30	2	3
Band 3	0.63-0.69	30	Band 4 (Red)	0.64 - 0.67	30	3	4
Band 4	0.77-0.90	30	Band 5 (NIR)	0.85 - 0.88	30	4	5
Band 5	1.55-1.75	30	Band 6 (SWIR 1)	1.57 - 1.65	30	5	6
Band 6	10.40-12.50	60 * (30)	Band 7 (SWIR 2)	2.11 - 2.29	30	7	7
Band 7	2.09-2.35	30	Band 8 Pan	0.50 - 0.68	15	-	8
Band 8	0.52-0.90	15	Band 9 Cirrus	1.36 - 1.38	30	-	9
		30	Band 10 (TIR1)	10.60 - 11.19	100*(30)	-	10
		30	Band 11 (TIR2)	11.50 - 12.51	100*(30)	-	11

Source: Landsat Handbook (2015)

SATELLITE IMAGE PRE-PROCESSING

The image scenes containing the study area were individually imported into ERDAS Imagine 2014 GIS software and were stacked into multispectral image. In order for the two satellite image datasets to fit perfectly, they were resampled to same projection using nearest neighbor method. The 2005 satellite image was geo-rectified to the baseline image of 2015, using the coordinate of 2015 image.

Radiometric calibration
Satellite images need to be corrected of some atmospheric attenuation such as haze, water vapor etc. The processing of the images was carried out in Erdas Imagine 2014 version. Bands of ETM+ image of 2005 were layer stacked in Erdas window through which a composite of bands 2, 3 and 4 was created. The composite was enhanced through Noise and Haze reduction techniques and subsequent Histogram equalization. Similarly, the procedure was repeated on the Landsat8 data but using bands 3, 4 and 5. The AOI was subset from both ETM+ and OLI datasets.

Geometric correction
Both image scenes were Geo-referenced to a UTM projection, Zone 32 North, World geodetic system (WGS) of 1984 datum (Mina-Nigeria) and (Clarke 1880). The 2015 image was used as the baseline image while the 2005 image was easily Geo-referenced using coordinates of known points of the baseline image using image to image resampling procedure and a resampling option of cubic convolution in Erdas Imagine 2014 GIS software.

Digital Image Classification
Supervised classification procedure was employed in this investigation. This procedure assumes that the user possessed a priori information of the classes of interest (Jensen *et al.*, 1996.Using training samples on the identified land cover classes, the two images were classified separately for 2005 and 2015 on the false color composites. Using supervised approach, calibration pixels were selected and statistics automatically produced for the individual classes of interest. Seed calibration strategy was adopted for this study, because it selects spectrally similar pixels (Chander et al, 2009). One hundred and Seventy (170) points served as GCPs for training sets were cross checked in the field to validate the various land cover classes for classification and accuracy assessment. A classification scheme was adopted based on the National land use/land cover project guidelines (2008) with five predominant classes being utilized for this research (Table 3).

Table 3: Land use/Land cover classification scheme

Code	Classes	Definition
1	Water body	Natural man-made stagnant water body usually created by damming streams or as ponds.
2	Build-up Area	Land covered with buildings in rural and urban centres and towns including both smaller urban centers, large scale nucleated settlements and villages.
3	Farmland	Small scale subsistence farming usually of household or arable crops grown either by irrigation or rain-fed cultivation.
4	Bare Surface	Exposed bare sand surface with little or no vegetation cover.
5	Plantation	Usually large group of plants and especially trees under cultivation.

Source: Adopted from National Land use/Land cover Project (2008)

Maximum likelihood classifier (MLC) appeared to be the most widely used per-pixel algorithm (Zhao et al, 2006). Thus, MLC was applied in the classification of these image subsets. MLC automatically assumes radiance value in each band (Chander et al, 2009) and subsequently allocate pixels in the image to each of the five LU classes. This algorithm classifies data based on the highest probability resulting into accurate classification results (Duadze, 2004) due to field validation. The tables of the classification results for 2005 and 2015 were subsequently crossed/ compared in Post classification comparison (PCC) so as to estimate and compute temporal and spatial changes as well as rate and area extent of changes between 2005 and 2015.

Classification Accuracy Assessment
Classification Accuracy in this research was determined using Error/confusion Matrix or contingency table. This was done by first, computing classification accuracy of individual classes in order to estimate user's accuracy (UA) due to commission of classification error and producer's accuracy (PA) due to omission error as well as overall classification accuracy (OCA) of the entire classification exercise.

Post-classification and Digital Change Detection
Post–classification comparison of classified Lulc statistics was employed using cross tabulation approach (Yang and Lo, 2002) in the surface water change detection analysis in this study. The statistics for each land use/land cover was automatically extracted from the classification of the images for each date (2005 and 2015) separately. These results were exported to SPPS window for computations and determination of areal extent of each class, based on which the extent of change, annual rate and percentage of change in land use between 2005 and 2015 as well as the pattern of changes (positive or negative) in each land cover type was statistically

estimated and compared. These variables were calculated through the following procedures:

Extent of change = Area Estimate for (b) – Area Estimate for (a)

$$Percentage\ Total\ Change = \frac{\text{Extent of change}}{\text{Area Estimate for (a)}} \times 100$$

Where (a) =2005, (b) = 2015

Annual Rate of Change was estimated by the formula adopted from as:

$$K = \frac{Ub - Ua}{Ua} \times \frac{1}{T} \times 100$$

where, K represent the change rate for a single land use/land cover type (in percentage), Ua and Ub represent the areas of the land use/land cover type at the beginning and at the end for a period, respectively. T is time intervals (in years) between Ua and Ub.

RESULTS AND DISCUSSION

Land use/Land Cover Classification around Zobe Dam in 2005

Figure 3.1represents a classified Landsat7 ETM$^+$satellite image of the study area during the year 2005. It shows the spatial distribution of individual thematic classes extracted using Erdas Imagine 2014 version GIS software.

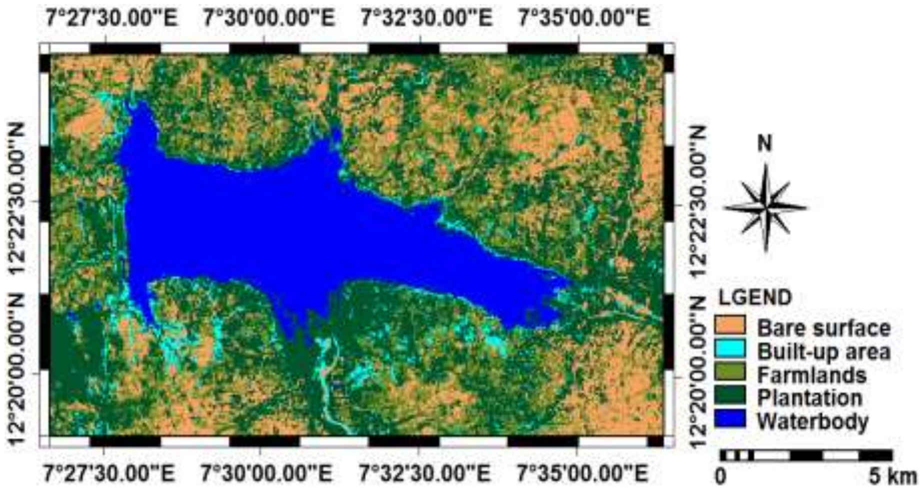
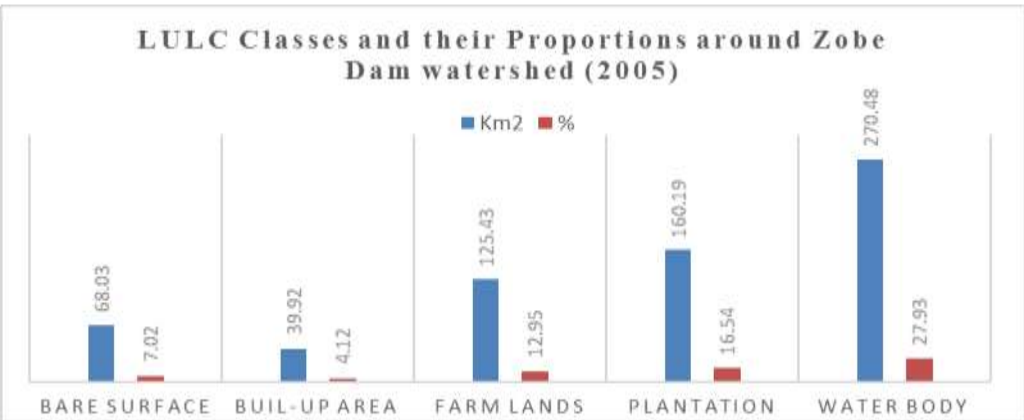


Fig. 2: Land use/Land cover classes around Zobe Dam watershed (2005)

Based on the above classification, Built-up area in 2005 occupied the least land area with 39.92km^2 representing only4.12% of the study area. This accounted for the villages around the dam area which comprised of Dogonruwa, Kunamawa, Shakafito, and Yanlilo villages in downstream area of the dam. Others villages at the upstream area of the dam comprised of Tuge, Makera, Talangwa, and Garfi villages. These villages existed long before the dam was constructed. These villages were all connected by rural feeder roads and foot paths and inhabited predominantly by fishermen and farmers both practicing irrigation and rain-fed crop cultivation. This made the proportion of Farmlands in the classified image as 125.43km^2 representing 12.95%. Due to high water table around the dam, tree plantation occupied the second largest land cover with 160.19km^2 representing 16.54% of the classified area.Water body has the highest land cover with 270.48km^{2}representing 27.93% of the study area.



Source: Classification of 2005 image (2017)

Fig. 3.2: LULC classes and their Proportions around Zobe Dam watershed (2005)

During the construction of the dam, large area of land was cleared for various purposes and remained bare over the years. This resulted in making the proportion of the bare surfaces to be about 68.03km^{2}representing 7.02% of the study area (Figure 3.3).

In this study, 170 polygons for Landsat 8 OLI of 2015 and 67 polygons for Landsat ETM+ of 2005 . were randomly selected to assess classification accuracy. For the Landsat ETM+ of 2005, only 67 polygons were used for testing the accuracy of the classification exercise. Table 3.1 was the error matrix for the individual classes in classification and ground truthing exercises

Table 3.1 Error Matrix table for the 2005 Classified satellite Image

		Classification Data					
	LULC Classes	BS	BU	FL	PL	WB	Total
Ground Truth Data	Bare surface	7	0	5	0	2	14
	Built-up area	1	9	0	1	0	11
	Farmlands	2	0	0	0	8	10
	Plantation	0	3	1	10	0	14
	Water body	4	1	8	4	1	18
	Total	14	13	14	15	11	67

Key: BS: Bare surface; BU: Built-up; FL: Farmland; PT: Plantation;WB: Water body

Source: Field survey and image classification (2005)

Table 3.2 presents Producers (PA) and Users (UA) accuracies of individual classes for the classified Landsat ETM+ of 2005. Overall classification accuracy of Landsat ETM+ of 2005 was estimated at 63.6%.

Table 3.2 Producers and Users Accuracy of classified images (2005)

S/No.	**LULC Classes**	**PA (%)**	**UA (%)**
1	Bare surface	50.0	50.0
2	Built-up area	57.1	57.1
3	Farmlands	38.5	44.1
4	Plantation	89.4	70.0
5	Water body	97.1	97.1
	OVERALL CCURACY		**63.6%**

Source: Field work (2017)

Land use/Land Cover Classification around Zobe Dam in 2015

Figure 3.2 represents the classified Landsat 8 image of the study area into five land use/land cover thematic classes for 2015and the spatial distribution of each class was extracted using Erdas Imagine 2014 software functions. During this period, Bare surface was estimated at 74.75km^2 representing 7.72% of the entire land area around the dam. Built-up area was estimated to be covering about 61.97km^2 representing about 6.40% of the entire study area.

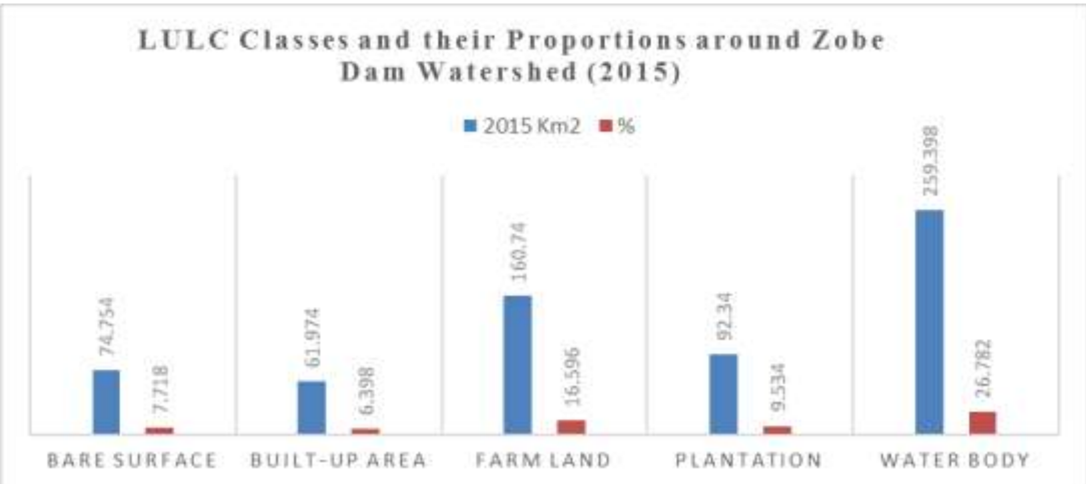


Fig. 3.3: LULC classes and their Proportions around Zobe Dam watershed (2005)

Source: Classification of 2015 image (2017)

Farmland which comprised both irrigation and plots and upland farms were estimated to be covering about 160.74km^2 representing 16.60% of the total land area under this study. This was followed by plantation which came up as a result of riparian vegetation surviving on high water table along the major tributaries that empty into the dam. Plantation was estimated to be covering 92.34km^{2}representing 9.53% of the entire area under study. During 2015, Water body was estimated to be covering 259.40km^{2}representing 26.78% of the area around the dam.

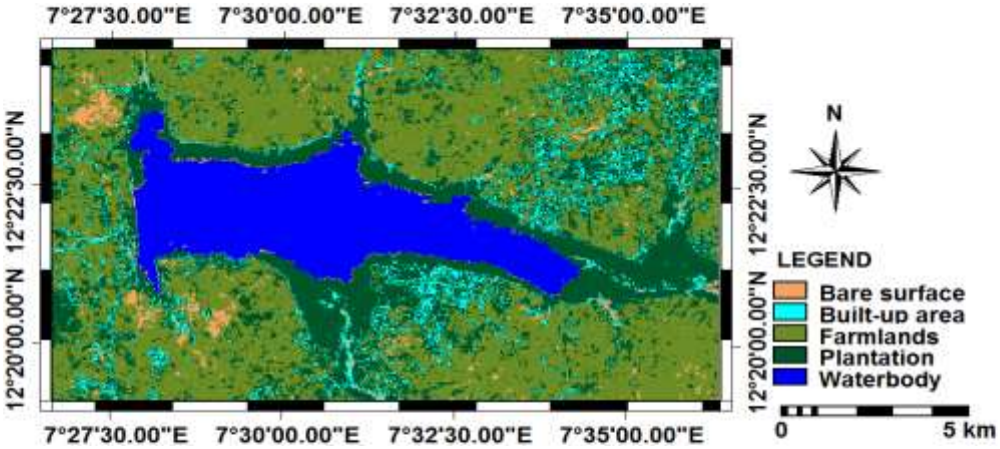


Fig. 3.4: Land use/Land cover classes around Zobe Dam watershed (2015)

For the Landsat 8 OLI of 2015 which was the more recent image, a total of 170 polygons were used for testing the accuracy of the classification exercise. Table 3.5 presents the error matrix for the classification and ground truthing exercises.

Table 3.5 Error Matrix table for the 2015 Classified satellite Image

		Classification Data					
	LULC Classes	BS	BU	FL	PL	WB	**Total**
Ground Truth Data	Bare surface	28	0	5	0	4	37
	Built-up area	3	22	0	3	0	28
	Farmlands	7	2	20	7	0	36
	Plantation	0	5	9	25	0	39
	Water body	3	0	0	0	27	30
	Total	41	29	34	35	31	170

Key: BS: Bare surface; BU: Built-up; FL: Farmland; PT: Plantation;WB: Water body

Source: Field survey and image classification (2015)

Table 3.6 presents Producers and Users accuracies of individual classes for the classified Landsat 8 OLI of 2015 with an estimated overall classification accuracy of 69.4%.

Table 3.6: Users and Producers Accuracy of satellite Image classification (2015)

S/No.	**LULC Classes**	**PA (%)**	**UA (%)**
1	Bare surface	54.2	52.0
2	Built-up area	72.7	66.7
3	Farmlands	44.4	52.6
4	Plantation	90.9	65.2
5	Water body	100	96.3
	Overall Accuracy		**69.4%**

Source: Field work (2017)

Change Detection Analysis of LULC in Zobe Dam between 2005 and 2015

On the basis of Land use/land cover classification in Figures 3.1 and 3.2 above, it could be observed from both figures that significant changes both positive and negative took place over the spatial and temporal scales in the study area. These developments occurred in all the land cover classes around the dam (Tables 3.1 and 3.2). Positive increases in some of the thematic classes at particular period consequently resulted in negative changes in other classes in another period. Among the five land cover classes considered in this study, three were discovered to have manifested positive increases over the study periods.

It could be observed from (Table 3.5) that both Bare surface, Built-up areas and Farmlands have indicated positive increases over spatial and temporal scales. During 2005, Bare surface increased from 68.03km^2 to 74.75km^2 representing an increase of about 6.72km^{2}over the ten-years period. This implied that about 0.7km^2 was being converted to bare surface due primarily to increase in population and other human activities such as expansion of cultivated lands for both irrigation and rain-fed crop cultivation. This was connected to the rapid expansion and growth of rural settlements as a result of large scale cultivation of cash and food crops in the area which subsequently culminated into rapid increase in the built-up areas from 39.92km^2 in 2005 to 61.97km^2 in 2015. It was estimated that over the study period, built-up area increased by about 22.1km^2 representing about 2.2km^2 increases annually for the ten-years period. Expansion of some rural settlements was noticed during ground truth exercise and new settlements came up and some infrastructures such as roads, schools, dispensaries and clinics were improved while others were established during the period in the study area. This explained clearly how farmlands came into being during the study period due to rapid increase in population and expansion of rural settlements in the area. This manifested an estimated annual increase of farmlands of about 3.5km^2 over the ten-year period.

However, it could as well be observed that among the five thematic classes considered in this study, Plantation and Water body manifested some amount of decrease over spatial and temporal scales. It could be observed (Table 3.5) that expansion of both farmland and built-up areas was at the detriment of area under plantation between 2005 and 2015. Most of the Farmlands and built-up areas expanded into plantation areas leading widespread clearance for expansion of crop cultivation. This led to the large decrease in the plantation area of about 67km^{2}with annual decrease of about 6.8km^2 over the study period. This has great environmental implications for the dam in particular and overall biodiversity in the region. This could possibly serve to explain the high rate of decrease in the water body. During 2005, the water body occupied an estimated area of about 270.48km^{2}which reduced to 259.40km^{2}in 2015 with annual decrease of 1.1km^{2}over the ten-year period. This situation could be explained that with rapid clearance of riparian vegetation for cultivation, water body was being exposed to increased sunshine, temperature and rapid harmatan winds that will negatively affect surface water body of the dam over the period of this study.

Fig. 3.5: LULC change analysis between 2005 and 2015
Source: Field Work 2015

These changes have resulted in rapid shrinking leading to the degradation of the environment in form of the rapid loss of vegetative cover and productive agricultural lands as a result of large scale crop cultivation activities.

CONCLUSION

This study examined LULC changes and how these changes affect surface water of Zobe dam in Dutsimma area of Katsina State, northern Nigeria between 2005 and 2015. The study concluded that as a result of changes in LULC around the reservoir, surface water body of the dam has reduced between 2005 and 2015. Both remote sensing and GIS have proven to be veritable tools for monitoring of environmental resources, and therefore should be upheld in ministries of environment, water resources and agriculture among others. This was to facilitate acquisition of rapid spatial information crucial for planning and management of resources. Geospatial technologies should be used in conducting timely assessment of the reservoir and its surrounding in order to keep track of the rapid changes that may have occurred in time and space.

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