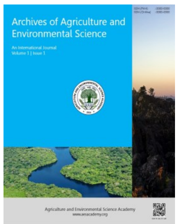
Archives of Agriculture and Environmental Science 1 (1): 1-8 (2016)

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: www.aesacademy.org



ORIGINAL RESEARCH ARTICLE

Remote sensing assessment of Jabi Lake and its environs: A developmental perspective

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ARTICLE HISTORY

Received: 09 Sept. 2016
Revised received: 16 Sept. 2016
Accepted: 25 Sept. 2016

Keywords

Lake
Landuse/Landcover Change
Remote Sensing
Social impact
Sustainable development

ABSTRACT

This paper is aimed at examining the relevance and impact of Jabi Lake in urban development and sustainable environmental change management. It uses a 2km radius buffer of remotely sensed satellite data from Landsat to examine the landuse/land cover dynamics within Jabi Lake and its environs in FCT-Abuja, Nigeria. Using maximum likelihood algorithm in ERDAS Imagine software, the supervised classification result shows that the lake water body decreased from 4.1 % in 1987 to 3.1% in 2006 and later increased to 4.0% in 2014. Built up experienced the highest landuse/land cover change from 3.17% in 1987 to 33.4% in 2006 and 37.5% in 2014. Light and dense vegetation reduced the most, while bare surface also showed an increase due to rapid urban development around the lake in the last 27 years. The focused group discussion (FGD) reveals that the conversion of previous agricultural land use and unplanned land uses to residential land use was due to high demand for residential housing around the lake. The perceived ambience scenery and accessible good road network were ranked as the first and second major positive centripetal forces of attraction to building near the lake while expensive land purchase and high rent were ranked first and second as the most negative centrifugal impacts of the lake on the environment. In conclusion, there is the need to monitor the progression of urban development so as to safeguard the lake for aquatic agriculture and it's immediate environment from further deterioration.

Citation of this article: Susan, E. Ajonye, Innocent, E. Bello, Halilu Shaba, Ibrahim Asmau and Salman Khalid (2016). Remote sensing assessment of Jabi Lake and its environs: A developmental perspective. *Archives of Agriculture and Environmental Science*, 1(1): 1-8.

INTRODUCTION

Conceptually, a lake could be described as an area of variable size filled with water, localized in a basin that is surrounded by land, apart from any river or other outlet that serves to feed or drain it (Bryant and Rainey, 2002; Husain, 2016). Spatially, Lakes lie on land and are not part of the ocean and are also larger and deeper than ponds. Lakes may be contrasted with rivers or streams, which are usually flowing. However most lakes are fed and drained by rivers and streams (Henkel, 2015). A lake can either be artificial or natural. While Natural lakes are generally found in mountainous areas, rift zones, and areas with ongoing glaciation (Gupta, 2011) many lakes are artificial and are usually constructed for industrial or agricultural use, for hydro-electric power generation or domestic water supply, or for aesthetic or recreational purposes. In some parts of the world, there are many lakes because of chaotic drainage patterns left over from the last Ice Age. However, all lakes are temporary over geologic time scales, as they will slowly fill in with sediments or spill out of the basin containing them (John, 2014). Studies reveal that Lakes are generally known to be sources of inspiration, recreation, rejuvenation and discovery and also considered as important elements in the heritage of many cultures (Stewart, 2012).

Like many other water bodies, lakes are used by humans for many purposes such as for fishing, transportation, irrigation, industrial water supplies, and receiving waters for wastewater effluents. Aside from their importance for human use, lakes have intrinsic ecological and environmental values (Limgis, 2001) because they store water, thereby helping to regulate stream flow, recharge ground water aquifers, and moderate droughts. They also provide habitat to aquatic and semi aquatic plants and animals, which in turn provide food for many terrestrial animals, and they add to the diversity of the landscape. Healthy lakes and their shores not only provide us with a number of environmental benefits but they influence quality of life and strengthen the economy (John, 2014).

Coastal zones are most vulnerable for land use changes in this rapid industrialization and urbanization epoch and it is necessary to evaluate land use/land cover (LULC) changes to develop efficient management strategies (Prabaharan, Srinivasa Raju, Lakshumanan and Ramalingam, 2010). For instance, recent research has found that 'blue space' including sea, rivers, lakes and even urban water features can have a positive impact on wellbeing. Studies have also confirmed that people living closer to the coastline are healthier (Smedley, 2013).

Remote sensing is the use of a sensor to measure characteristics of an object without physically touching the object. Satellite multi-sensor data have become important methodology used to investigate the evolution in time and space of Lake as demonstrated by Giardino, Bresciani, Villa and Angiolo (2010) with a case study of Lake Trasimeno in Italy. Similar study was carried out by Zhu (2002) using remote sensing of to monitor coastline changes in Pearl River Estuary. Also, Yu and Ng (2006) integrated evaluation of landscape change using remote sensing and landscape metrics in Panyu, Guangzhou. According to Markogianni, Dimitriou and Karaouzas (2014), the study of degradation of water quality is a major problem worldwide and often leads to serious environmental impacts and concerns about public health. Of particular relevance is the digital change detection in ecosystem monitoring of lakes and its environs (Coppin, Jonckheere, Nackaerts, Muys and Lambin (2004).

For instance, Marwa, Ahmed, Magaly, Rowaida and Iman (2013) used Remote sensing and integrated biological monitoring program for assessing water quality of Lake Timsah, Suez Canal in Egypt. Further research at the European Centre for Environment and Human Health (ECEHH) also showed the benefits of view over sea or water from home or hospital windows on patients with heart rate, blood pressure and mood problems. As a novelty, the study of Jabi Lake draws, in part, from these benefits as no such study has been carried out before.

Jabi Lake emerged from a stream which due to the low lying nature of the terrain was converted to a Lake so as to harvest water for the peripheral urban use. Presently, it has been converted to a resort as shown in Figure 1. Jabi Lake is situated within the Jabi district of Abuja. Abuja is located in the North Central region of Nigeria.

Based on *Aguda* report the centrality, security, accessibility and unifying factors to all Nigerians were among reasons the city was chosen as the new capital territory after Lagos was presumed tool populated and not strategically located (Abumere, 1984). Plans for Abuja were first announced by decree in 1976. Most of the construction for the city began in the 1980's. As of today, the city has become a densely populated land area such that leisure parks/gardens and lakes such as the Jabi lake are now been encroached on despite repeated demolition by successive ministers of the Federal Capital Territory (FCT) (Polgreen, 2006). According to the United Nations, Abuja grew at the rate of 139.7% between 2000 and 2010, making it the fastest growing city in the world. As of 2015, the city is still experiencing an annual growth of at least 35%, still retaining its position as the fastest growing city on the African continent and one of the fastest in the world.

The master plan for Abuja and the FCT was developed by International Planning Associates (IPA) with five consortiums (Eleh, 2001). Being centrally located, the study area is blessed with a mix of agricultural activities and produce such as tubers and root crops of the south (yams, cassava, maize and plantains) and grain (sorghum, guinea corn and rice) of the north. The creation of the new FCT and its capital, Abuja, represents perhaps the most important instrument for enhancing the overall socio-economic development of the entire middle belt of Nigeria (Abumere, 1984).

Abuja has witnessed huge influx of people into the city from different tribes and languages including foreigners from abroad. Temperature in the study area ranges between 28 degree Celsius to as high as 39 degree Celsius in dry season. Rainfall is highest in August (WMO, 2016).

The influence of climate variability on lake water recharge is envisaged especially during wet seasons. The peculiarity of Jabi Lake and its environs as a Savannah Zone vegetation of the West African sub-region makes it unique for change pattern analysis as a result of urbanization and population growth. Since most Nigerian government agencies and international embassies are now headquartered in Abuja, the value for land and rent is perceived to have increased astronomically. While English is the official language in the country in general, other languages often spoken in the territory include Hausa, Edo, Yoruba, Ibo, Idoma, Ijaw, Urhobo, Fulani and other local languages like Gbagyi which is the main local language of the indigenous inhabitant. Population surge has led to the emergence of satellite towns such as Kuje, Kubwa, Bwari and Karu. Since Jabi Lake is a vital resource in Abuja providing a number of social amenities to its inhabitants and the ecosystem at large, the need to carry out detailed landuse/landcover change has become inevitable. To date, requisite data have not been collated and analyzed to document the current changes taking place in the physical characteristics of the lake. Despite this, no research has been carried out on the spatial coverage, benefits as well as the centripetal and centrifugal forces at play on the landuse/landcover dynamics of Jabi Lake and its environs. This and many other factors informed this research. The research is, in part, geared towards providing accurate information to policy makers for proper harnessing of the lake resources and its protection (Abumere, 1984). In view of the above, the present study is aimed at critically examining the spatio-temporal landuse/landcover change in Jabi Lake and its environs (Smedley, 2013). The objectives are to evaluate the changes in the lake in terms of spatial extent and, at the same time, examine the impact of the lake on the immediate environment in terms of socio-economic and ecological challenges and benefits.

MATERIALS AND METHODS

The study utilized both primary and secondary sources of data collection. The primary data used include direct field observation of the prevailing activities within and around the Lake as well as the use of Focused Group Discussions (FGDs) to elicit reactions on how the people perceive the prevailing socio-economic and environmental activities within and around the lake. Remote sensing image classification method and FGDs approach were adopted in this study.

A checklist was used to implement the FGDs and results of perception from 30 participants ranked in order of magnitude with 1 being the highest in terms of impact: whether positive or negative and 10, the least. The secondary data used include three epochs Landsat satellite images of 30m spatial resolution downloaded from the Global Land Cover Facility web link. The images covering the study area were buffered using 2km radius of the lake with the Analyst/Proximity/Buffer Tools in ArcGIS software. The maximum likelihood algorithm was used to analyze the supervised classification of the three images "Area Of Interest" (AOIs) into five landuse/landcover classes as 1: Water body (Lake), 2: Builtup, 3: Light vegetation, 4: Bare Surface, and 5: Dense vegetation respectively using Erdas Imagine software. Due to mixed pixel (MIXEL) errors during classification, the final results were further recoded into appropriate landuse/landcover classes using IDRISI software. Thereafter, the result of classifications were presented in a table using percentage (%) to show the composition of each land cover class for the period studied. Land change modeling statistics were generated using Modeling Simulation/Land Cover Modeler (LCM). Furthermore, the image classification accuracy was examined using the "Confusion or Error Matrix" table to show the user's accuracy (UA), producer's accuracy (PA) and the overall accuracy (OA) for the three epochs studied. To examine the nature of landuse/landcover class dynamics regarding what/how much was lost or gained due to urbanization, a Cross tabulation (Crosstab) image differencing of all the images were generated using GIS Analysis/Database query/Crosstab algorithm sequence. Figure 3 shows a detailed Unified Markup Language (UML) modeling of the image processing methodology adopted. The final results for the analyses were presented using maps, tables and graphs.

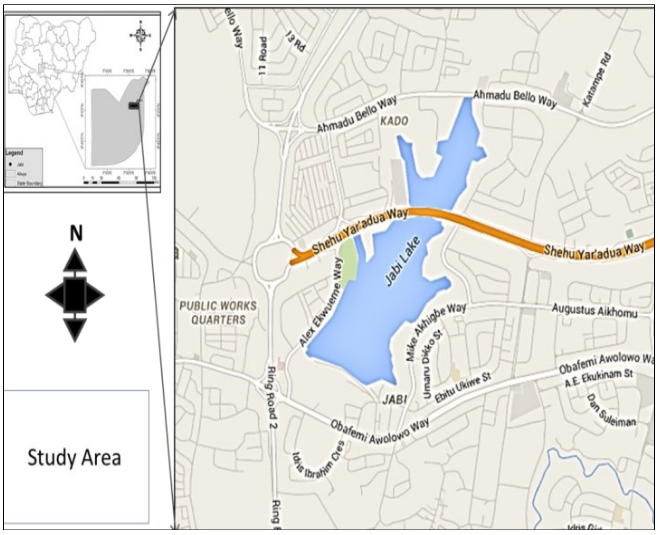

Figure 1. *Study area of Jabi Lake.*

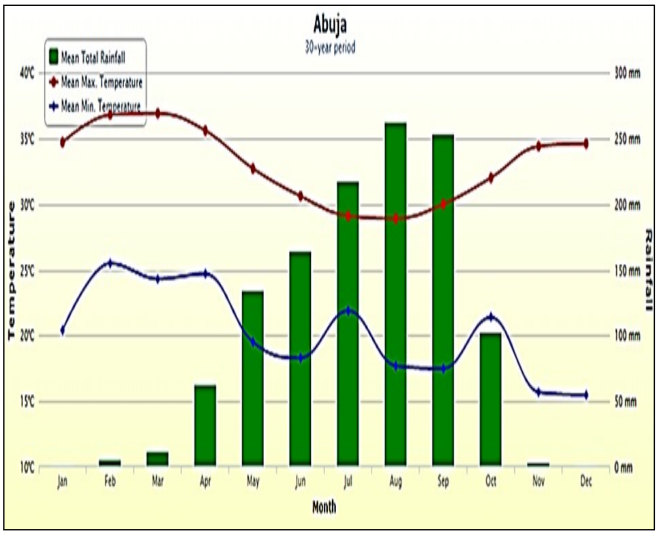

Figure 2. *Thirty years mean temperature and rainfall variability in the study area (Source: World Meteorological Organization, 2016).*

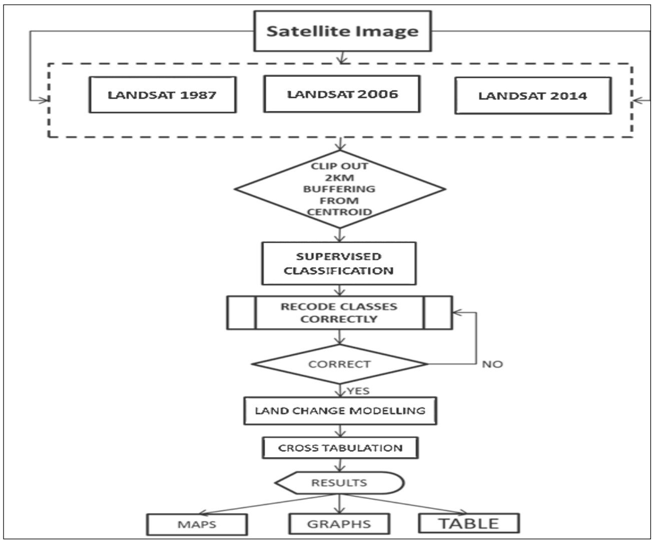

Figure 3. *UML Diagram showing satellite image analysis.*

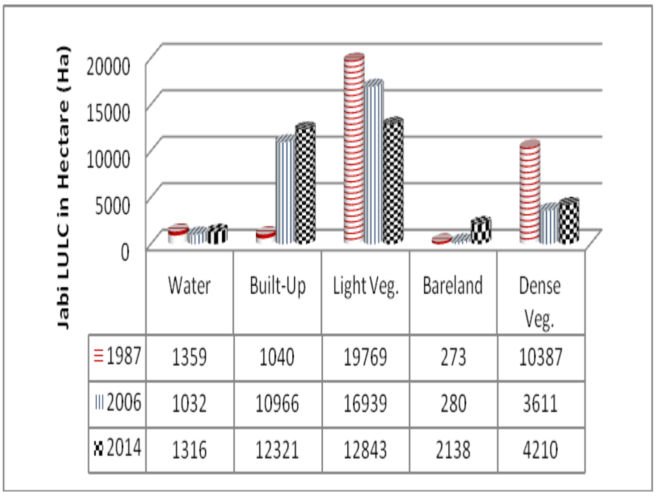

Figure 4. *Comparison of individual LULC change.*

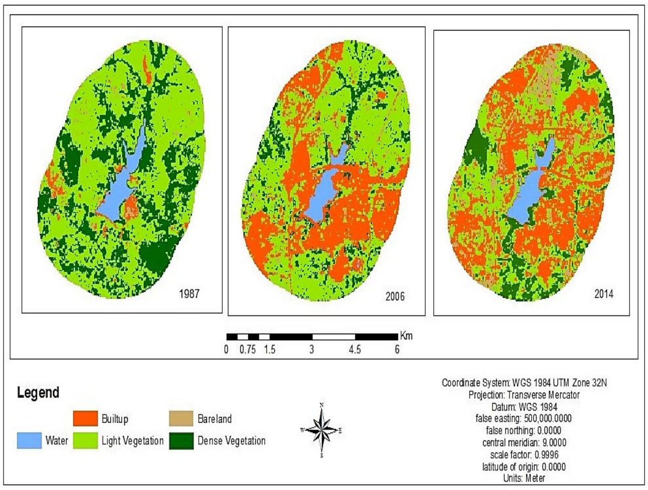

Figure 5. *Landuse/landcover change maps of Jabi Lake.*

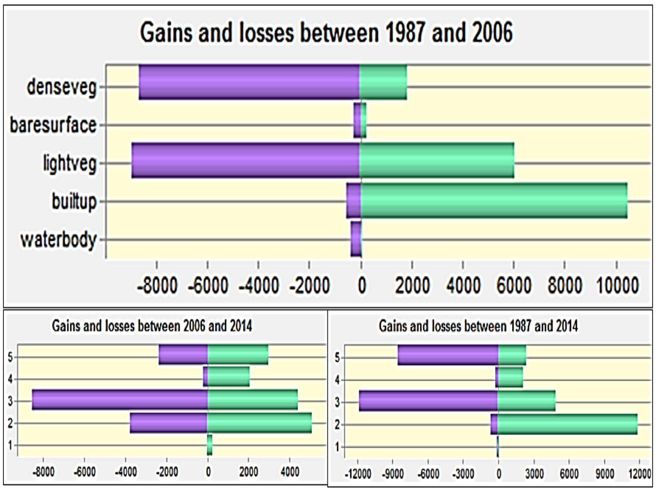

Figure 6. *Graph showing landuse/landcover Modeling: class gain and loss between 1987 and 2014.*

RESULTS AND DISCUSSION

Landuse/landcover dynamics: As far back as 1984, Abumere (1984) already envisaged population surge in Abuja in view of the significance of the city being the newly created federal capital. Table 1 further confirm the gradual increase in the landuse/landcover of the study area within the twenty-seven (27) year reviewed (1987 – 2014). From Table 1 and Figure 4 respectively, the study shows that out of the five land cover classes studied, only water did not experience a major change for the period examined. In 1987, the Jabi Lake water body constituted only 4.1% (1359 Ha) of the total landcover studied. It later decreased to 3.1% in 2006 and within eight years, the water body increased to 4.0% (1316 Ha). One can argue that regardless of urbanization due to migration into the study area, there has not been any remarkable change in the lake as the only period a decrease was noticed was in 2006 as shown in Figure 5. The lake has been converted to a resort thus highlighting its significance to the people's social health. This finding is similar to Smedley's (2013) work.

According to the Nigeria Hydrological Services Agency (NIHSA, 2015), in 2014, flood water occurred in most of the states in the country as collated in local government areas particularly the high flood risk areas and pockets of urban flood occurred in the FCT, Abuja and some neighbouring states. This could have been the major reason for the later increase in lake size noticed in between 2006 and 2014. Currently, more artificial drainage networks have been constructed to divert water from entering the lake, hence, the insignificant change observed. A more remarkable change was, however, observed in builtup land cover class. Table 1 and Figures 4 and 5 show that as at 1987, builtup in the study area was smaller in spatial size (3.17%, 1040 Ha) than the total area of the lake (4.1%). During this period, The Federal Capital City was still Lagos despite the fact that Abuja had been earmarked for development as the new Federal Capital Territory (Abumere, 1984). Thus, Civil servants and other top government functionaries were still based in Lagos making Abuja remain, more or less, a virgin land. This figure significantly increased to 33.4% (10966 Ha) in 2006 because more people had relocated to Abuja being the new Federal Capital Territory with different business and urban development activities. In 2014, the builtup areas further increased to 37.5%. Expectedly, the influx of people from different parts of the country and the world is largely responsible for the occupation of the hitherto unoccupied urban space. Socio-economically, FGDs revealed that a number of indigenous/settler structures (later referred to as 'illegal structures' since they had no government approval) were demolished to pave way for the more modern and regulated buildups by the government. Expectedly, the increase in builtups implies that other land cover especially agricultural land had given way. The erection of buildings; whether government or privately owned and other infrastructures, found expression in the concomitant reduction noticed in vegetation cover as equally shown in Table 1 and figures 4 and 5 respectively. Thus, in 1987, the light vegetation (which includes mostly farmlands) was 60.2% (19769 Ha) of the total landcover. This figure reduced to 51.6% (16939 Ha) and later drastically reduced to 39.1% (12843 Ha) within 8 years thus giving way for buildups and other construction activities.

This findings also finds expression and similarity in the argument presented by Henke (2015) on the 21st Century homestead. Similar result is noticed in dense vegetation which was initially 31.6% in 1987, 11% in 2006 and further increased slightly to 12.8% in 2014 because most of the artificially planted trees had matured to reflect dense vegetation spectral signature as captured by the satellite. Common vegetation types found in this region include; bombax costatum, oliveri, khaya, Afzelia, Africana anogeissus, uapaca togoensis, leiocarpus, butyrospermum paradoxum, daniella senegalensis, vitex doniana, prosopis africana, albizia, zygia, and pterocarpus erinaceus.

The study further revealed that as a result of continuous urbanization, more bare surface area were opened for construction, hence the noticeable increase in Bare surface from 0.8% (273 Ha) in 1987 to a slight increment of 0.9% (280 Ha) in 2006 and drastically to 6.5% (2138 Ha) in 2014. The implication of these findings is that, should more buildngs be erected, there is the concomitant effect of losing more vegetation cover (including agricultural lands) which actually helps to balance the oxygen demand of the environment. This, no doubt, may further lead to urban heat island as well as heat stress that may result to different kind of diseases such as meningitis. Jabi Lake may also be severely polluted due to effluence discharged from domestic and semi-industrial waste especially now that Shoprite shopping mall and more houses are encroaching on the lake.

Landuse/landcover change: Image differencing/ cross-tabulation analysis: Tables 2a, b and c respectively show details of what happened to the various land cover that either in the past changed or not. In specific, Tables 2a, b and c show a cross-tabulation result of image difference between 1987 and 2006, 2006 and 2014, as well as between 1987 and 2014 respectively. The result shows that water changed the least without acceding to bare surface in 2006 and 2014. However, because vegetation has water content and support plant growth, one can understand while most changes gave way to builtup areas.

Accuracy assessment: To ascertain the level of confidence to place on the landuse/landcover image classification results, the figures tabulated in Table 3 show the error matrix for the three epochs examined. The study shows an overall accuracy of 93% while the user's and producer's accuracy are 95.7% and 90.2 % respectively for 1987 image.

The geographic agreement of the result to ground truth shows a Kappa of 0.9 (very high) results. In similar manner, the 2006 and 2014 classification shows overall accuracies of 94.9% and 93.4% respectively while their Kappa statistics equally revealed very high agreements of 0.92 and 0.88 to geographic reality respectively. The obtained classification accuracies are considered good enough hence, the result (maps) can be reliably accepted and used for policy planning and implementation as far as Jabi Lake and environs are concerned. The policy planning with lake is also inclusive of agricultural development and ecological management (Gupta, 2011; Henkel, 2015)

Jabi Lake functionality and impacts assessment: Table 4 shows that good view/ambience scenery (ranked 1st) as well as good and accessible road network (ranked 2nd) are the topmost positive centripetal impacts of the lake on the urban environment. Conversely, the main centrifugal reasons people are not attracted to the environment included expensive land purchase (ranked 1st) and expensive property rent (ranked 2nd). The implication of the above findings is that, if not for the high cost of land and rent, a lot of people would have moved to the area because of the beautiful scenery and the well navigable roads available. This re-emphasizes the importance of lakeside to people as corroborated by Smedley (2013). Thus, the field observation further revealed that the resort/park just beside the Lake has a remarkable site for relaxation and hosting of civic/social events. Recently, the Rio 2016 Olympic African final qualifier sporting event was held in the Jabi Park. There is also green vegetation along the bank of the lake that provides good atmospheric ambience which is considered as part of the centripetal force of attraction of people to the lake and its environs. The lake in particular offers facilities such as speed boat rides, canoe rides, horse rides and games such as draft, Ludo and scrabble. The FGDs further revealed that entrance fee to the park is free but payments are made for tickets to enjoy the recreational facilities available. Photographers are also on ground to help cover social events being hosted in the park.

A photograph cost an average of ₦200 (1USD) each while a horse ride cost an average of ₦300 per ride. The FGDs further revealed that Jabi Lake water is regulated through outlets based on lake size in different seasons. The field observation and FGD also confirmed that the Lake provides prime opportunities for recreation, tourism, economic and residential living as evident in the fast growing houses around the lake hence, the encroachment currently witness on the lake. The study also revealed that the lake is highly revered by many people for its historical and traditional values both for spiritual and domestic usage. Domestically, it serves as source of water for the Abuja Municipal Area Council (AMAC) water board. The lake also serves as a source of water for irrigation to the local farms around the lake. However, due to continued urban encroachment on Jabi Lake, waste and silt has remained main sources of water pollution. Infrequent inundations are sometime observed as around the lake observed in similar study by Bryant and Rainey (2002).

It is, therefore, instructive to assert that as a very key component of the ecosystem, Jabi Lake is much more than just a simple body of water used by many people to enjoy recreational activities. Thus, the lake and its immediate urbanized neighborhood must be managed in a sustainable way so as to sustain a healthy balance of aquatic life, provide continuous recreation/leisure enjoyment, and help support socio-economic market for petty vendors and traders without compromising the interest of the future generation that may also enjoy the water resource.

Table 1. Landuse/landcover change analyses in the Jabi Lake area.

LULC Change (year)	Lake Water (ha)	% *Change*	Builtup	% *Change*	Light Veg. (ha)	% *Change*	Bareland (ha)	% *Change*	Dense Veg. (ha)	% *Change*	Total LULC (ha)
1987	1359	4.1	1040	3.17	19769	60.2	273	0.8	10387	31.6	32828
2006	1032	3.1	10966	33.4	16939	51.6	280	0.9	3611	11	32828
2014	1316	4.0	12321	37.5	12843	39.1	2138	6.5	4210	12.8	32828

Table 2. Cross-tabulation results for 1987, 2006 and 2014 classifications.

(a) Cross 1987/2006	1	2	3	4	5	Total
1	994	6	4	0	28	1032
2	259	491	7052	138	3026	10966
3	28	439	10827	100	5545	16939
4	0	12	200	13	55	280
5	78	92	1686	22	1733	3611
Total	1359	1040	19769	273	10387	44916

Table 2. *Contd.*

(b) Cross 2006/ 2014	1	2	3	4	5	Total
1	1021	233	23	0	39	1316
2	11	7206	4520	81	503	12321
3	0	2614	8425	98	1706	12843
4	0	610	1313	90	125	2138
5	0	303	2658	11	1238	4210
Total	1032	10966	16939	280	3611	44916

(c) Cross 1987/ 2014	1	2	3	4	5	Total
1	1226	40	7	0	43	1316
2	80	410	8140	127	3564	12321
3	38	398	7919	116	4372	12843
4	0	95	1453	11	579	2138
5	15	97	2250	19	1829	4210
Total	1359	1040	19769	273	1038	44916

Table 3. Error matrix result for 1987, 2006 and 2014 classification.

1987-LULC Types	Water body	Builtup	Light vegetation	Bare land	Dense vegetation	Total	User Accuracy
Water	22	0	0	0	0	22	100
Builtup	0	17	0	0	0	17	100
Light Vegetation	1	8	83	1	0	93	89.2
Bare land	0	0	4	83	2	90	92.2
Dense vegetation	0	0	0	1	33	34	97.1
Total	23	25	87	85	35	256	
Producer Accuracy	95.7	68	95.4	97.6	94.3		

Results: Overall Accuracy= 93, UA = 95.7%, PA = 90.2, Kappa Statistics= 0.9

2006-LULC Types	Water body	Builtup	Light vegetation	Bare land	Dense vegetation	Total	User Accuracy
Water	7	0	0	0	0	7	100
Builtup	1	82	1	0	4	88	93.2
Light Vegetation.	0	0	104	1	4	109	95.4
Bare land	0	1	2	44	0	47	93.6
Dense vegetation	0	0	0	0	5	5	100
Total	8	83	107	45	13	256	
Producer Accuracy	87.5	98.8	97.2	97.8	38.5		

Results: Overall Accuracy= 94.9, UA = 97.2%, PA = 84%, Kappa Statistics= 0.92

2014 LULC Types	Water body	Builtup	Light vegetation	Bare land	Dense vegetation	Total	User Accuracy
Water	8	0	0	0	0	8	100
Builtup	0	138	0	0	12	150	92
Light vegetation	0	0	6	0	0	6	100
Bare land	0	0	0	6	0	6	100
Dense vegetation	0	2	3	0	81	86	94.2
Total	8	140	9	6	93	256	
Producer accuracy	100	98.5	66.7	100	87.1		

Results: Overall accuracy = 93.4, UA = 97.2%, PA = 90.4%, Overall Kappa statistics = 0.88

Table 4. Impact assessment ranking of Jabi Lake and its environs.

Centripetal impact	Ranking	Centrifugal impact	Ranking
Good view/ambience scenery	1st	Expensive land purchase	1st
Good/accessible road network	2nd	Expensive property rent	2nd
Recreation (for leisure, tourism and inspiration)	3rd	Expensive lifestyle in the neighborhood	3rd
Peaceful environment	4th	Noise pollution from vehicles	4th
Rapid development with modern infrastructure	5th	Perceived Future congestion	5th
Boat/canoe/horse ride	6th	Water pollution	6th
Easy Transportation	7th	Rising Insecurity from touts/cab robbers	7th
Suitability for fishing	8th	Loss of cultural sites and heritage	8th
Good for business	9th	Micro-climate change/urban heat	9th
Water supply for irrigation farming near lake	10th	Siltation and Flooding	10th

Source: FGDs (2016)

Conclusions

The paper examined the relevance and impact of Jabi Lake on urban development and sustainable environmental management using a focused group discussion and field observation (with photographs) to complement the remote sensing-based landuse/landcover change analyses. A 2km buffered area of interest from remotely sensed medium resolution (30m) Landsat satellite images were utilized. The 1987, 2006 and 2014 epochs were further subjected to supervised classification analysis using the maximum likelihood algorithm in ERDAS Imagine and recoded with IDRISI software. With overall accuracies of 93%, Kappa = 0.9 (for 1987); 94.9%, kappa = 0.92 (for 2006) and 93.4%, kappa = 0.88 (for 2014) classifications, the study revealed no remarkable change in water body of the lake. However, significant proportion of the land which were hitherto undeveloped agricultural lands have been taken over by urban development as a result of that, builtups (mostly for residential landuse) experienced the highest landuse/landcover change from 3.17% in 1987 to 33.4% in 2006 and 37.5% in 2014. Consequently, light vegetation and dense vegetation reduced the most paving way for builtups. However, due to continuous urban development, bare surface also increased from 0.8% in 1987 to only 0.9% in 2006 and sporadically to 6.5% in 2014. The perceived ambience scenery and accessible good road network are ranked as the first and second centripetal forces responsible for the influx of people into the study area while expensive land purchase and high rent of properties were ranked first and second as the most negative centrifugal forces impacting the lake and its environment. From the above findings, it is recommended that there should be continuous monitoring of the progression of urban development so as to safeguard the lake and its immediate environment from congestion and urban blight. Practice of basic ecosystem maintenance through individual and collective efforts are expected to go a long way in protecting the serenity of the lake and its environs. The idea of creating Lake Buffer plantings around the edge of the water is considered a protective and productive approach to sustainable development and urban management. In addition, preventing effluents from flowing down lake from sewers is a good way to prevent pollution**.** As an asset, proper foresight and informed decision making will continue to make the lake a model of environmental beauty to behold through proper protection, restoration and innovation which space science and technology can ably provide as demonstrated in this paper.

ACKNOWLEDGEMENTS

The authors wish to express no competing conflict of interest. The authors are also grateful to all those who participated in the FGDs as well as those whose materials were consulted in the preparation of this paper.

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