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Time Series Analysis Of Landcover Change from 1986 to 1999 in the Tropical Rainforest of Southwestern Nigeria

Shehu, Basiru Gwandu
Agricultural Research Council of Nigeria,
Agricultural Research House,
Plot 223D Cadastral, Zone B6,
Mabushi, Abuja-FCT.

Aminu, Hadiza
Nigeria Hydrological Services Agency,
Foundation Plaza,
Plot 22, Shetima Ali Monguno Crescent,
Utako, Abuja-FCT.

Abstract:- Deforestation is one of the major environmental problems in Nigeria, drastically reducing the amounts of green cover in the country and eroding the economic, environmental and social values of the plant communities. It is pertinent to understand the extent and distribution of this degradation, including the dynamics in the other related land uses such croplands. Remote sensing data, tools and methods are effective in determining and documenting these land dynamics. Two satellite imagery of 1986 and 1999 were analysed to determine land changes that occurred between these two periods in an area covering about 500,000 hectares in the rainforest area of southwest Nigeria. Thus, the method applied was image processing using Erdas-imagine software. The process involves pre-processing of the imagery, classification and accuracy assessment. The result shows that 17, 472 hectares of forest were removed during the period under review. The extent of surface water bodies, settlements and bare ground increased by 1,131, 9,073 and 15,565, respectively. Agricultural land decreased by 8,296 hectares which could be related to the urban expansion and other infrastructural development in the area. This analysis was constrained by time, resources and the techniques. However, it provided some idea about change in the plant cover in the area from 1986 to 1999. This work could be scaled to national scope.

Keywords:- *Land cover change, satellite imagery, image processing, deforestation, tropical rainforest, southwest, Nigeria.*

I. INTRODUCTION

Food and Agriculture Organisation (FAO) defined deforestation as the conversion of forest areas to non-forest land use or long-term reduction of tree canopy cover beyond 10% threshold within an area of at least a half hectare(Tejaswi, 2007). In Nigeria, vegetation cover is broadly classified into savannah and forest. One of the forest subclasses in the country isTropical Rainforest which is the most specie-rich type of vegetation. This irreplacable vegetation cover is drastically being reduced (FAO, 2009). The reduction happens especially on the northern fringe where the encroaching savannah (derived savannah) expands deforestation extent, togather with land clearing for production of staple crops, timber and other tree-related products and infrastructure development (Okorie, 2012). Despite increased understanding of the importance of forests, forest clearing have not reduced(Njungbwen and Mbakwe, 2013). One of the reasons might be that large part of the West African rain forests is linked to the lives and livelihoods of people, providing food, fuels, fibre and other ecosystem services(Ken et al., 2010).

While noting the importance of remote sensing in documenting landcover change on both regional and global scales,Daniel and Ayobami (2007), pointed out that there is a need for development of basic datasets providing quantitative and spatial landcover information in Nigeria and particularly southwest. The study area in this analysis covers about 500,000 hectares and it is one of the major timber production centers for decades, especially towards the southern part of the area. This study is geared towards identifying areas where deforestation had occurred, together with change in the other land uses such as croplands. This was achieved through application of remote sensing technology. The temporal scope of the study is between 1986 and 1999 – a period of about 13 years.

II. MATERIALS AND METHODS

Two satellite imagery were aquired from the United States Geological Survey (USGS). The first image was captured on the 15th of November, 1986 and the second was captured on the 13th of December, 1999. The first image is a landsat5 TM image of 30 metres spatial resolution in all the bands except band 6, the resolution of which is 120 metres. Also, the spatial resolution f the second image is 30 metres in all the bands save band 6 and the image is from Landsat7 ETM+. Both the imagery were downloaded from the Landsat archive of the USGS as geotiff and the header file revealed that they were projected to UTM (WGS84) Zone 31, resampled using cubic convolution and are both from 8-bit quantized sensors. Due to remoteness of the study area and the limited time frame for the study, google earth/map was used as means of selecting training areas and ground validation. The analysis software used was ERDAS-Imagineto run the classification algorithms and ArcGIS 10.3 was used in producing the maps.

A step-wise methodwas adopted in executing the analysis. The imagery were preprocessed as suggested in Zhi-Hua et al., (2011).A classification scheme,as could be found in some published workssuch as Mengistu and Salami, (2007), Adediji and Ajibade, (2008), Okrie, (2012) and John, (2014), was adoptedin producing landcover (thematic) maps from the two imagery. Following FAO,

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(2010) and Adedeji and Adeofun, (2014), the area of each land cover was calculated and compared between the two imagery to identify the changes in the forest landcover. The major methodological steps include preprocessing of the raw data, classification of the imagery and assessing the accuracy of the classifications.

III. PRE-PROCESSING

The two imagery were imported into the ERDAS-Imaginesoftware. The two imagery, though from different satellites (Landsat5 and Landsat7), have similar bands 1 to 7. For both the imagery, band 1 to 5 and 7were stacked; band 6 was excluded because it differed in spatial resolution. As mentioned earlier, UTM (WGS84) Zone 31was the projection, while the resampling technique was cubic convolution. The spectral bands are shown in table 1.

Band	Name	Band width (µm)	Spatial resolution
1	Blue	0.45 – 0515	30m
2	Green	0.525 – 0.605	30m
3	Red	0.63 – 0.69	30m
4	Near IR	0.75 – 0.90	30m
5	Shortwave IR-1	1.55 – 1.75	30m
6	Thermal IR	10.4 – 12.5	60m/120m
7	Shortwavw IR-2	2.09 – 2.35	30m
8	Panchromatic	0.52 – 0.9	15m

Table 1: Landsat 5 and 7 spectral bands

The capturing satellite path and the row of the imagery used in this analysis are 190 and 55, respectively. The imagery covered an area extent too large than required for this study.Therefore, there was need for subsetting as suggested in Adedeji and Adeofun, (2014). Initially, southern part of the image was intended. However, due to cloud cover in both the imagery northern part of the imgery was subsetted. Inquire box was used in the process taking XY coordinates of two corners – 635370 (ULX), 890820 (ULY), 715050 (LRX) and 828720 (LRY). Figure1 and 2 show the subsets and their imagery.

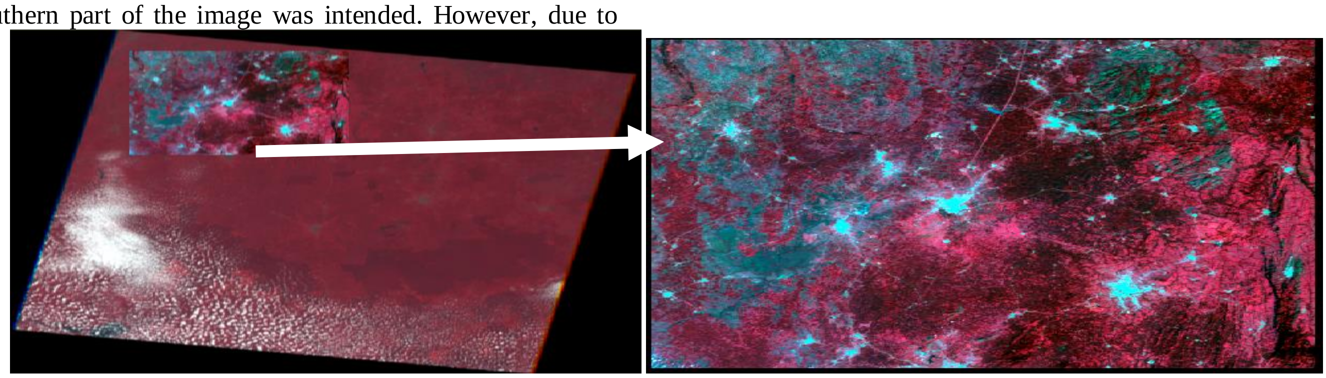

Fig. 1: Landsat5(1986) and its subset

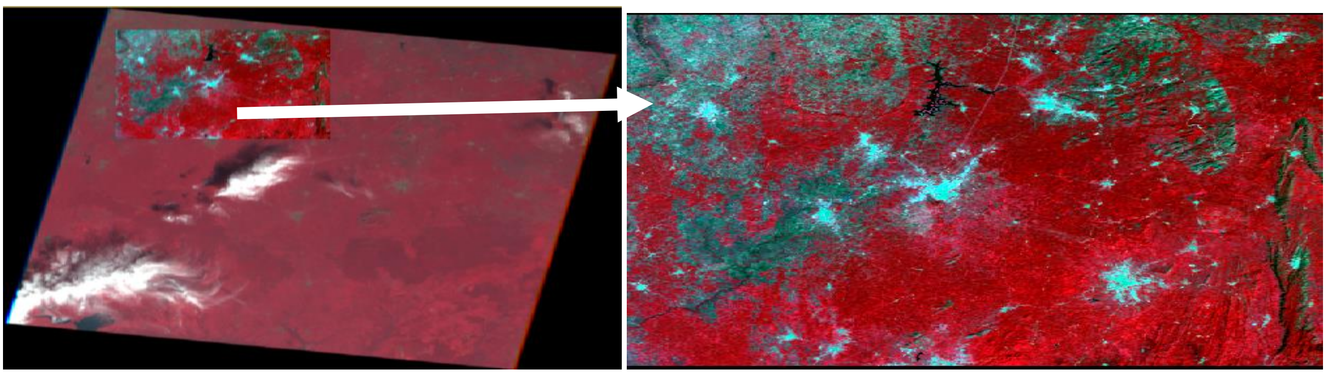

Fig. 2: Landsat7(1999) and its subsets

After subsetting, the raw digital numbers (DN) would need to be converted to at-surface reflectance (Zhi-Hua et al., 2011). For the Landsat7 image, the algorithm in ERDAS for radiometric conversion was applied using Lmax/Lmin technique to correct it to at-sensor reflectance. Then COST model was applied using dark object subtraction to correct the image to at-surface reflectance. For Landsat5 image, the algorithm cannot be applied to TM5. Therefore, model maker was used to convertthe raw DN to at-sensor reflectance (DN to radiance and radiometric correction).

Figure 3 shows the conversion model developed in the Erdas modeller. Figure 4 shows the model developed to correct the imagery to at-surface reflectance. The figure shows the COST model applied using dark object subtraction to calibrate the image to surface reflectance.

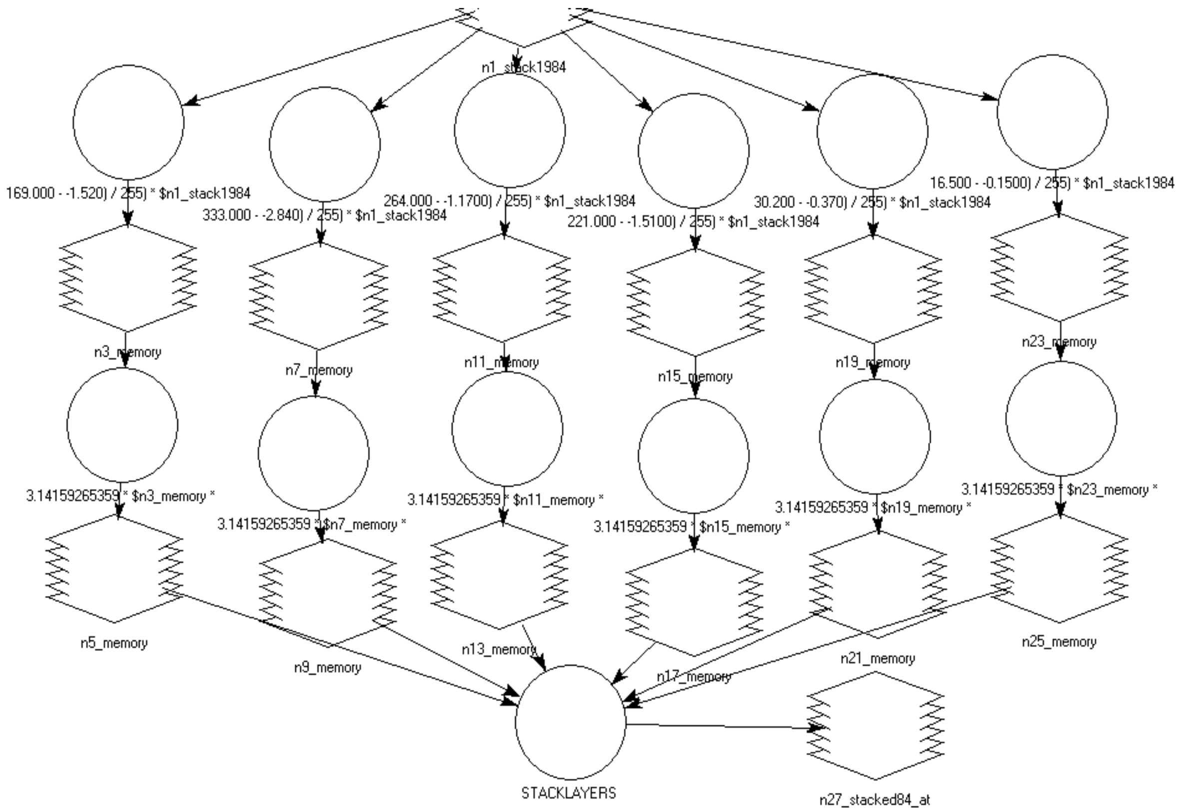

Fig. 3: Raw DN to Radiance and to At-sensor Reflectance

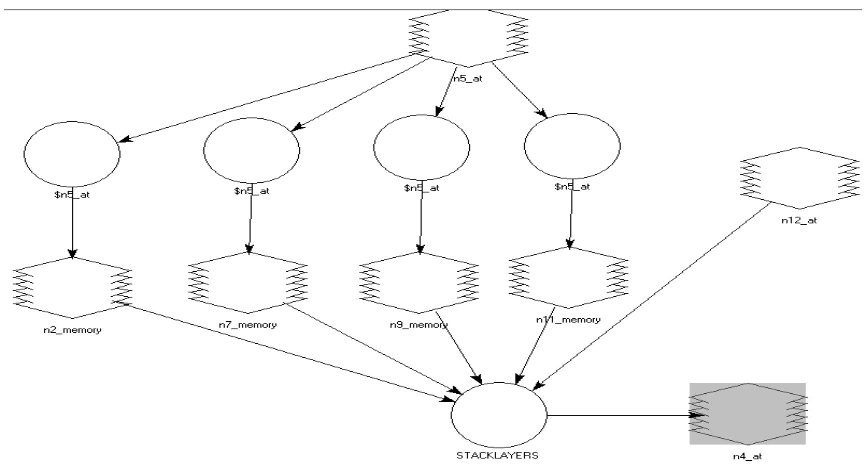

Fig. 4: Cost Model for surface reflectance calibration

The pattern of the spectral classes in the imagery were investigated using unsupervised classification. This was done to examine the possibility of using the spectral signatures for information classification. For both the imagery, isodata technique was used with different number of classes and other parameters – iterations, convergence and so on. Convergence never reach 0.70 even with 40 iteration. Therefore, K-means technique was applied using 8 classes, 20 iterations and 0.970 convergence threshold. Figure 5 shows the spectral classes. Some of these classes are sensible (did not merge different features as one) for exampleclasses 6 and 8 in 1986 image and classes 7 and 8 in the 1999 image. Some of the classes are not sensible for example class 1 in the 1986 image and class 3 in the 1999 image.

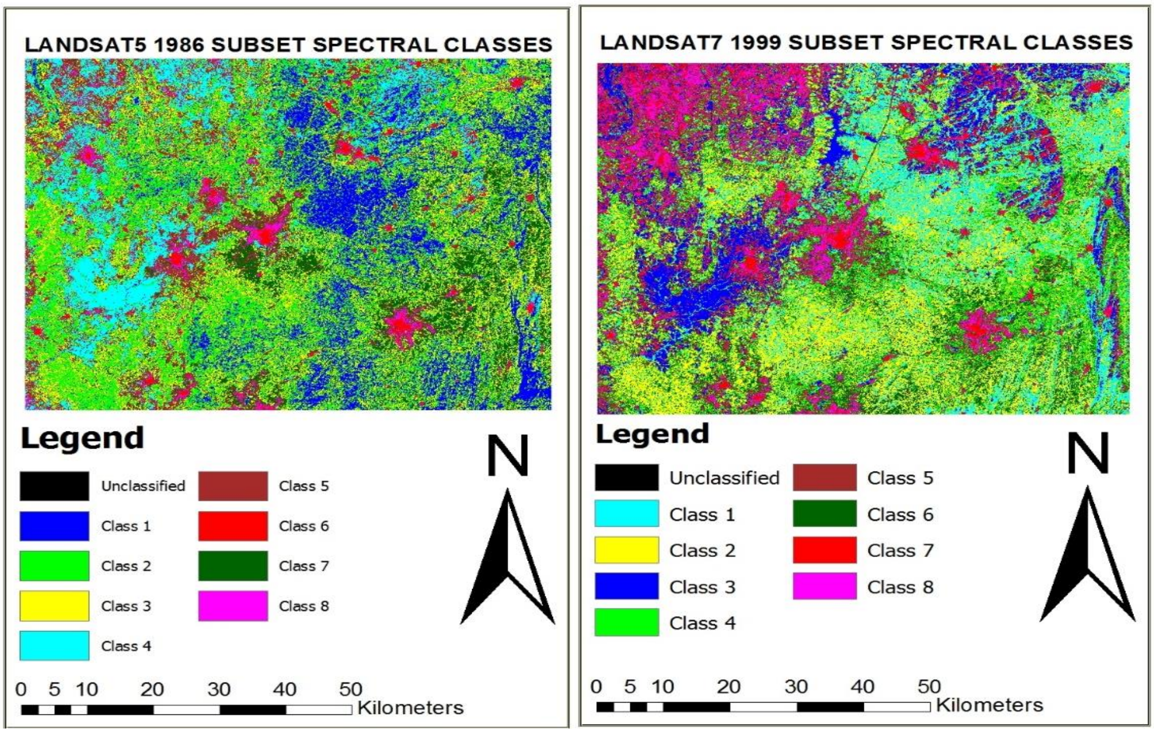

Fig 5: Spectral classifications

IV. INFORMATION CLASSIFICATION

The conclusion from the spectral classification was that the spectral classes cannot be used for supervised classification due to missclassification. Therefore, Signature editor was used to create signatures using information from google map/earth. Different training areas were created for each image and classes were established. The nine classes comprised of deep water, shallow water, dense forest, light forest, arable land, grassland, dense urban, suburban and open ground. The classifier was successfully executed for both the two imagery. However, due to higher errow probability in this method of extracting signature, using Area of Interesst (AoI) was explored.The two classes of water (deep and shallow) were merged to one class 'water'. For each class, an area of interest (AoI) was separately created in order to use the same AoI for the two imagery. For water class, three AoIs were created and merged into one. The AoIs of each class were then used to create signatures for both the imegery. The classes are light forest, dense forest, mixed wood/grass, arable land, dense urban, suburban, bare ground and water(figure 6). Image alarm was displayed to evaluate the signatures using pattern recognition. Jefferies Matusita was used to evaluate the separability between the classes. For Landsat5 the minimum separability was 1314 and the average was 1392. For Landsat7, 1162 was the minimum and 1357 was the average. Since the minimum required is 1000, the classification was executed. Maximum likelihood algorithm in the Erdas Imagine software was applied.

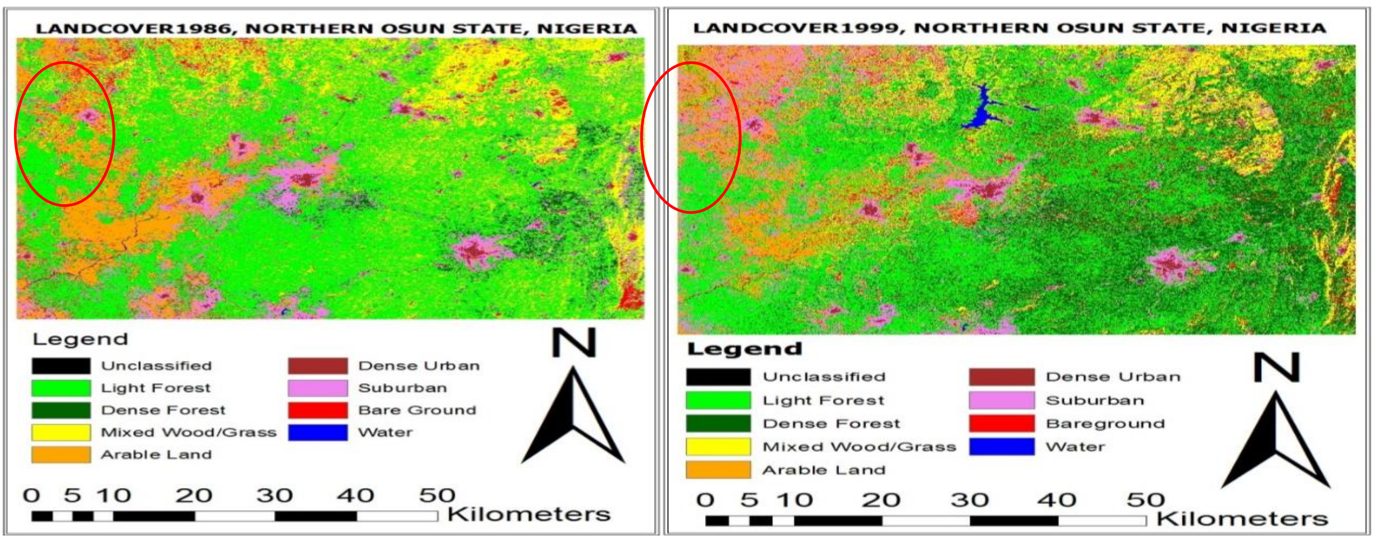

Fig. 6: Maximum Likelihood Classification

V. ACCURACY ASSESSMENT

For the 1986 image, 256 random pixels were selected by the software and the assessment showed the overall accuracy was 72.66%. However, dense urban and water classes were not captured. Therefore, another 140 pixels were added using stratefied sampling and the accuracy increased to 75.25%. For the 1999 image, 140 random pixels were selected and the overall accuracy showed 72.66%. Also, the two classes were could not be captured. Thus, 10 random pixels were added using stratefied sampling within the two classes (water and dense urban) only. The overall accuracy was thus 72.67%.

VI. CALCULATING CLASS AREAS

S/N	Class Name	1986 Area (ha)	1999 Area (ha)	Change in Area (ha)
1	Light Forest	237919	190228	-47691
2	Dense Forest	18836	102079	+83243
3	Mixed Wood/Grass	106802	53778	-53024
4	Arable Land	49106	40810	-8296
5	Dense Urban	3565	5601	+2036
6	Suburban	54586	61622	+7036
7	Bare Ground	23892	39457	+15565
8	Water	532	1663	+1131

Table 2: Change in land cover area between 1986 and 1999

In both the two imagery, spatial resolution for all the bands used is 30metres. Therefore, each pixel has an area of $900m^2$. Since 1 hectare equals $10,000m^2$, each pixel in this analysis has an area of 0.09 hectares. Thus for each lancover, 0.09 was multiplied by the histogram (number of pixels) to get areas in hectares. A column was added in the attribute table of both the imagery for the values of the calculated areas. A decrease was observed in the light forest, mixed wood/grass and arable land. While an increase was observed in the rest of the classes (table 2).

There might be a missmatch between spectral definition of dense forest in the two image. While it is clearly obvious from the maps (figure 7) that forest is more dense in the 1986 map than in the 1999, the calculated areas showed increase in dense forest rather than decrease (table 2) over the period under consideration in this study. Therefore, a recoding system was applied to get a clear perspective of the forest cover change between the two images. Light forest, dense forest and mixed wood/grass were merged and recoded as forests. Dense urban and suburban were also merged to form settlements class (figure 7). Thus, a final land cover map was produced with fiveclasses comprising of Water, Settlements, Forests, Bareground and Arable land.The area of each of the classes was recalculated (table 3).

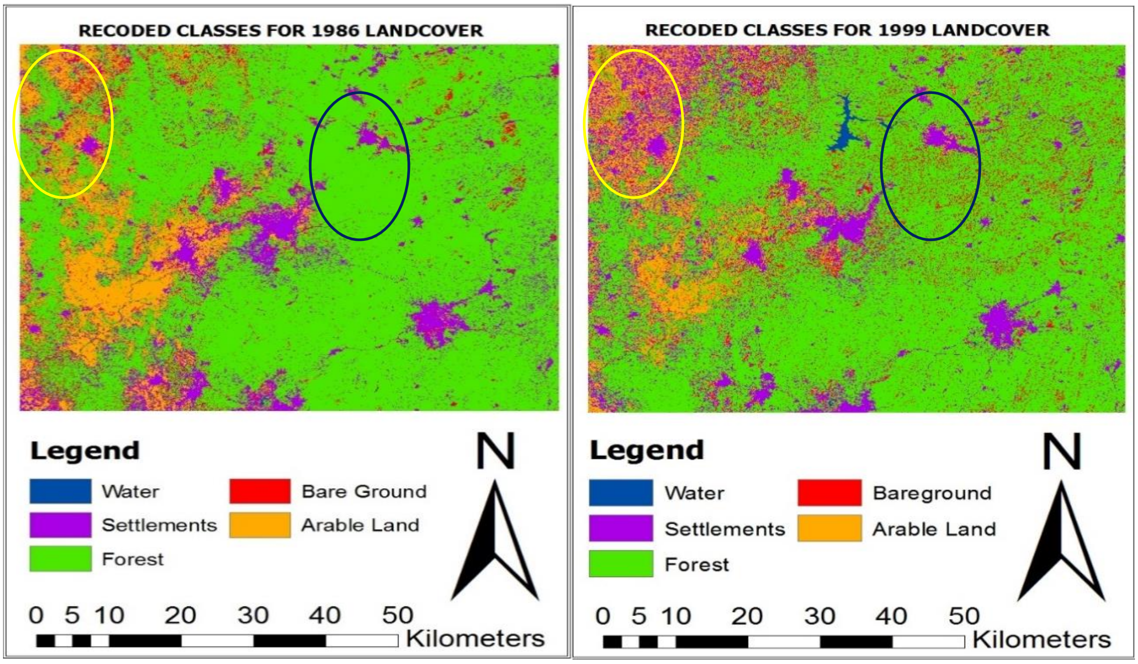

Fig. 7: Recoded Land cover Classes

VII. RESULTS AND DISCUSSION

Figure 7shows that during the period under review, forest cover and arable lands decreased in the study area, while settlements, bareground and water surfaces increased. From table 3, the magnitude of this decrease in forest cover (deforestation) is clear,covering 17,472 hectares between 1986 and 1999. It is obviously noticeable in figure 7 that the strands of forest in the northwestern corner of the 1986 map are almost cleared in the 1999 map. The densely packed forests around the centre in the 1986 map is less dense in the 1999 map. Water bodies expanded by 1,131 hectares in the area. This change in surface water bodies is also clearly visible comparing the two maps in figure 7. The water body at the north central part of the 1999 map was a vegetated area in the 1986 map. The water displaced the vegetal cover due to the Ede Erinle Dam/Reservoir which was designed in the early 1980s by the old Oyo State Water Corporation. According to Adedeji and Ajibade (2008), the reservoircovers about $14km^2$ at the normal water level and about $15km^2$ at the maximum water level (figure 9). It was expanded to improve water supply system to Osogbo (the capital of the current Osun State) and other cities and towns around. The GoogleEarth image shows the dam structure and the map shows the position of the dam as published by Adedeji and Ajibade (2008).

S/N	Class Name	1986 Area (ha)	1999 Area (ha)	Change in Area (ha)
1	Forests	363557	346085	-17472
2	Arable Land	49106	40810	-8296
3	Settlements	58150	67223	+9073
4	Bare ground	23892	39457	+15565
5	Water	532	1663	+1131

Table 3: Change in land cover area between 1986 and 1999

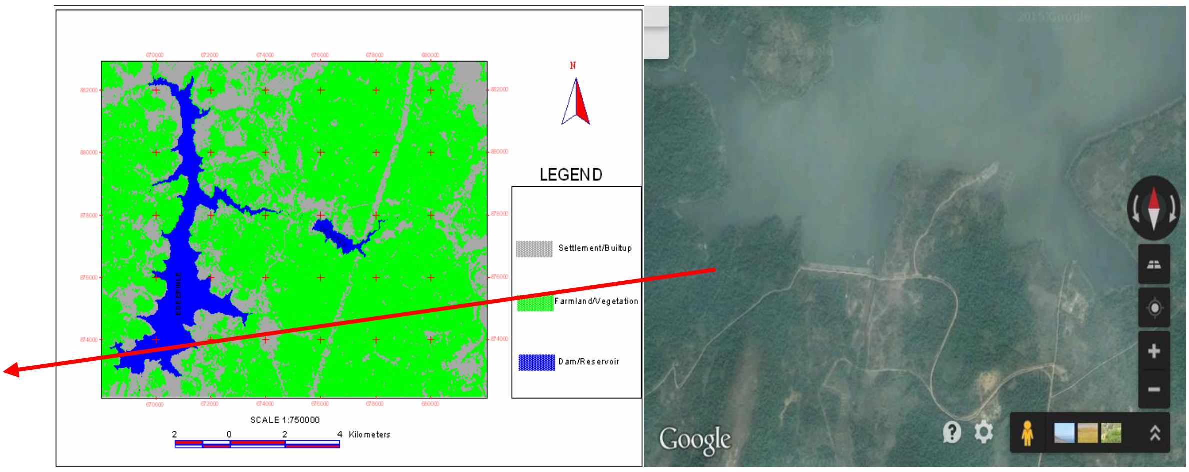

Fig 8: Ede Erinle Dam/Reservoir, after Adediji and Ajibade (2008)

Increase was observed for Settlements and bareground to the tune of 9,073 and 15,565 hectares, respectively. Deforestation due to agricultural expansion, urban growth, industrial expansion and pressure from an increasing population has reduced the extent, diversity and stability of the Nigerian forests(Omofonmwan and Osa-Edoh, 2008). Acccording to Daramola and Ibem (2010), urban sprawl leads to depletion of green areas resulting in the loss of biodiversity especially where the development is haphazard and without proper planning. Typical in developing countries, rural-urban migration contributes to the rapid expansion of cities and abandoning of the farmlands in the rural areas. This may be the reason for the decrease in arable land as shown in table 2 and 3 (8,296 hectares).Also, it may partly be the result of cities expansion into the farm lands around due to construction of roads, buildings and so on. In addition, in the whole of the Nigeria's lowland rainforest, logging, farming and hunting were identified as the three most prevelent activities for forest exploitation(Ikemeh, 2013). Other forms of activities, according to him, include collection of *Thaumatococcus daniellii* (broad leaf used for wrapping food), *Irvingia gabonensis* (edible seed), *Garcinia mannii* (chewing stick), and *Carpolobia lutea* (*sanda* stick).

VIII. LIMITATIONS, ERRORS AND UNCERTAINTIES

Google earth/map was the basis forselecting training areas as mentioned earlier.Thus, the techniques of photo interpretation such as shape, pattern, and so on were used to identify and differentiate land cover types. Several parts of the study area is converted to plantation and this study did not take the account of that; not all the forest covers are natural as suggested by Adedeji and Adeofun (2014). Attempts were made to use imagery of similar dates, but that was not possibledue to the availability of the satellite imagery and the problem of cloud cover. However, both the images used were aquired within the short dry season of the area (November and December). The assumption from the experience was that one month difference will not cause considerable seasonal effects. Also the imagery were both pre-resampled using cubic convolution, so there was no possibility of applying other algorithm like nearest neighbour. The classification accuracy assessment was based on the computer-generated random pixel samples; the accuracy indicates only the match or otherwise between the thematic map and the input image instead of the actual land cover on the ground. However, it is believe that the input imagery provide good representation of the actual land covers.

IX. CONCLUSION

Although there were limitations and uncertainties, it was concluded from this study that huge area of forest have been removed without replacement between 1986 and 1999 in the study area. Some of the areas were covered by the expanded water reservoirs andexponential urban expansion.Some of the forests were exploited for fuel, commercial and other domestic uses. This research could be scaled up to cover the whole country in order to get general understanding of how much plant cover changed over the decades and where these changes occurred.

X. ACKNOWLEDGEMENT

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