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Detecting Land Cover Changes in the Volta River Catchment using GIS and Remote Sensing Methods

Saviour Mantey and Naa Dedei Tagoe
Department of Geomatic Engineering, University of Mines and Technology,
P.O. Box 237, Tarkwa, Ghana

Abstract: Over the years, the Volta River Basin has undergone significant changes in diverse ways. Human activities such as farming and infrastructure development as well as afforestation projects have led to changes in the land cover. The objective of this study was to monitor land cover change within 6 km buffer of the Volta Lake. The shapefile of the study area was co-registered with the Land sat images. Hybridized classification of multi-temporal images was carried out based on unsupervised classification, Normalized Difference Vegetation Index (NDVI), visualization of true/false color composite as well as local knowledge from ground truthing. Readings were taken for 50 geographical positions and corresponding classes of vegetation for estimating classification accuracy. Overall accuracy for the classified 2013 ETM+ image was 88.42%. The results revealed a significant increase in the surface area of the Volta Lake from 4173.34 km^2 in 1985 to 5052.99 km^2 in 2013. An increase of dense vegetation from 367.06 km^2 in 1985 to 1035.07 km^2 in 2013 and a significant decrease is sparse vegetation from 3604.71 km^2 in 1985 to 2784.01 km^2 in 2013 were revealed. However, when sparse and dense vegetation was considered as one class, an overall decrease of 152.69 km^2 was obtained. Areas with virtually no evidence of vegetation increased from 2029.93 km^2 in 1985 to 1303.08 km^2 in 2013.

Keywords: Image classification, land cover, NDVI, vegetation, volta lake

INTRODUCTION

Over the years, the Volta River Basin has undergone significant changes in diverse ways. Human activities such as farming, infrastructure development and settlement around some portions of the Basin have led to significant changes to the land cover in the immediate catchment of the river. According to Huth *et al*. (2012), land use/land cover is characterized by anthropogenic activities to modify, manage and use certain types of land cover. It is therefore important to ascertain the effect of these changes in other to facilitate proper environmentally conservative decisions. Also vegetation abundance influences air quality and human health (Wagrowski and Hites, 1997).

According to Ghana Statistical Board, the population in the Basin is expected to increase by 80% within a twenty-five year period (2000-2025) due to the high average population growth rate of 2.54%. There is also evidence that the River has expanded.

This project seeks to employ remotely sensed satellite images and GIS to effectively map spatio-temporal land cover changes which have occurred within a 6 km buffer of the River over the past 27 years (1985 to 2013).

MATERIALS AND METHODS

Study area: The Volta River Basin spreads over six different countries in West Africa. 85% of its 400000 km² lie in Ghana and Burkina Faso with the remaining area in Benin, Mali, Ivory Coast and Togo. One of the dominant features in the Basin is the Volta Lake, which is one of the largest man-made rivers in the world covering about 4% of total area of Ghana. The Volta Lake lies between longitudes 5º 30´ W to 2º 00´ Eand latitudes 5°30´ N to 14°30´ N (Andah *et al*., 2003). The River is estimated to cover an area of about 8500 km^2. The vegetation around the Lake is mostly coastal savanna, moist semi-deciduous forest, the transition zone and the guinea savanna. Daily temperature changes ranges from 32-44°C, whereas night temperatures can be as low as 15°C.

Research data: Data for the study included Landsat images of path/row 194/55 (Level 1 product) -Landsat TM 5 of March 6, 1985 and Landsat ETM+ of January 6, 2013-downloaded from the United States Geological Surveys (USGS) website using the Global Visualization Viewer (GloVis) (http://glovis.usgs.gov accessed: January 6, 2013), land cover map of the study area and a shapefile of the Volta Lake. In this study, only the

Corresponding Author: Saviour Mantey, Department of Geomatic Engineering, University of Mines and Technology, P.O. Box 237, Tarkwa, Ghana

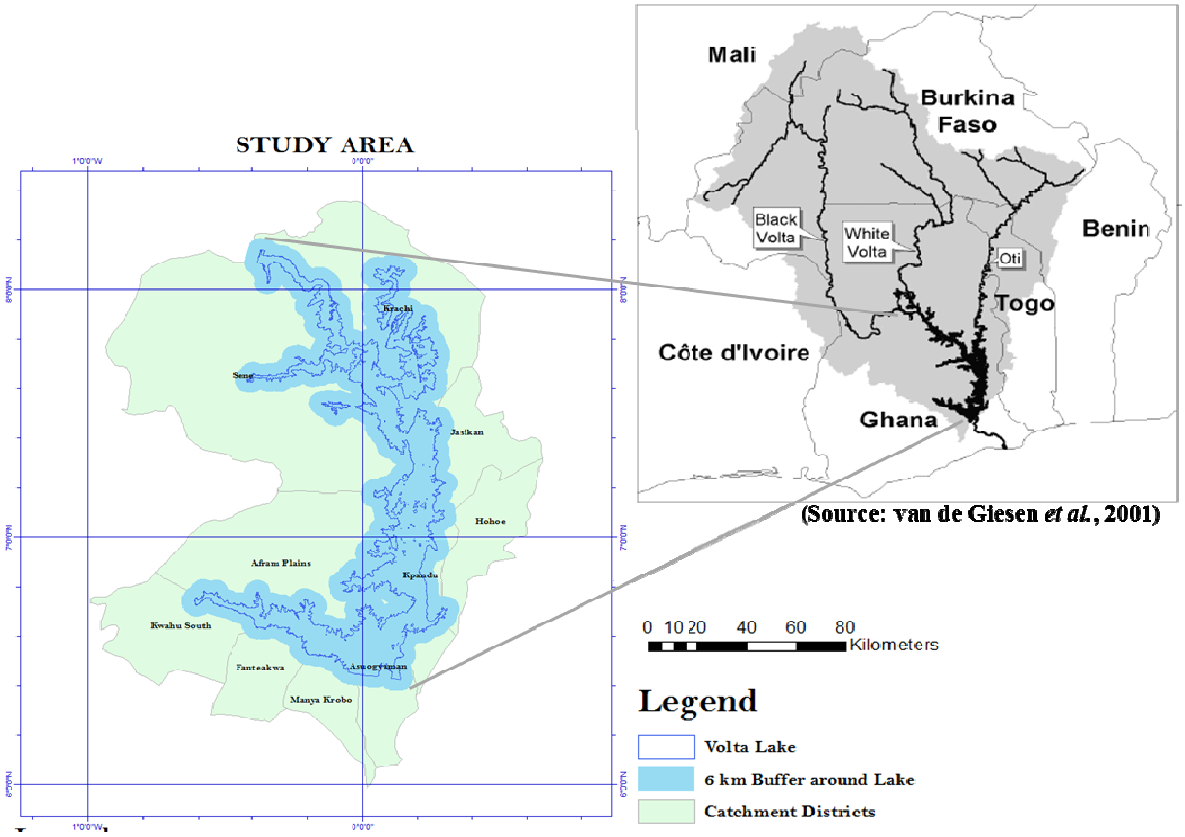


Fig. 1: Map of study area

Ghanaian parts of the Volta Lake within the path/row 194/55 of the acquired Landsat images were considered (Fig. 1).

Image pre-processing:

Georeferencing and co-registration: The Landsat images used in this study had been accurately rectified to Universal Transverse Mercator UTM 30 N based on WGS 84 projection. For this reason, there was no need for georeferencing; however the shapefile of the Volta Lake was co-registered to the Landsat images to conform to the same projection as described by Mather (1987). Figure 2 shows the flow chart of the procedure employed.

Radiometric calibration: In standard comparative analysis of multi-temporal images acquired on different dates and by different sensors radiometric calibration is an inevitable step. Every sensor has its own calibration parameters in recording digital numbers and therefore the same digital numbers recorded by different sensors will represent different radiance and reflectance values. Since this study aims at comparing multi-temporal satellite images to detect change, the equations presented by Chander *et al*. (2009) for converting calibrated Digital Numbers (DNs) to absolute units of At-sensor spectral radiance and Top-of-Atmosphere (TOA) reflectance were applied. Calibrated Digital Numbers (DNs) of both the TM and ETM+ images were converted to absolute units of At-sensor spectral radiance using Eq. (1). To minimize scene variability and correct for the variation in the Earth-Sun distance between different Landsat image acquisition dates, At-sensor spectral radiance values (L_λ) were subsequently converted to Top-of-Atmosphere (TOA) reflectance ($\rho\lambda$) using Eq. (2):

$$L_\lambda = G_{rescale} * Q_{cal} + B_{rescale} \quad (1)$$

$$\rho\lambda = \frac{\pi * L_\lambda * d^2}{ESUN\lambda * \cos\theta_s} \quad (2)$$

where,

L_λ = The spectral radiance
$G_{rescale}$ = Band-specific rescaling gain factor
$B_{rescale}$ = Band-specific rescaling bias factor
Q_{CAL} = The quantized calibrated pixel value in digital number for each band
$\rho\lambda$ = The Top-of-atmosphere reflectance
d = The distance from the earth to the sun in Astronomical Units (AU)
$ESUN\lambda$ = The mean solar exoatmospheric irradiance
θ_s = The solar zenith angle

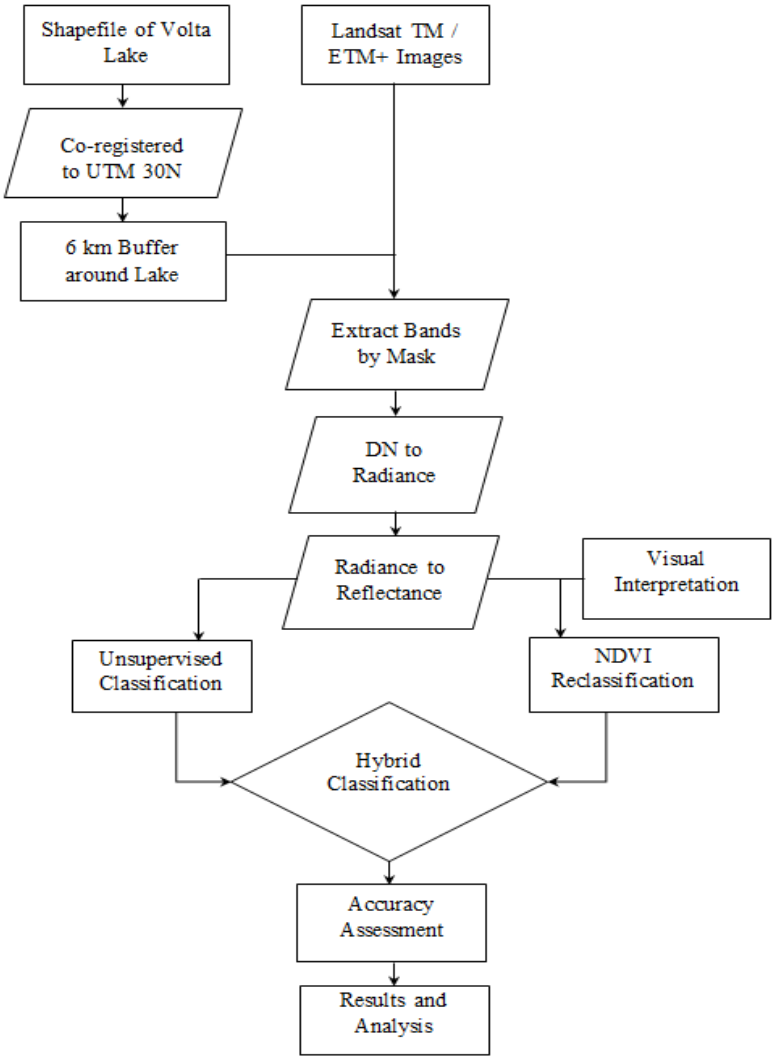


Fig. 2: Flow chart of procedures

Visual interpretations of land cover changes: Prior to image classification, true color composite of bands 321 for Red Green Blue images and false color composite of bands 432 for Red Green Blue images of the study area were composed to visually analyze the land cover types of the study area. Figure 3 shows both the true and false color composite of 1985 Landsat images. Vegetated areas appeared as shades of green, in the true color composite as opposed to shades of red in false color composite. Water bodies on the other hand appeared as shades of blue in both true and false color composites.

Normalized Difference Vegetation Index (NDVI): NDVI is a robust technique for quantifying vegetated and non-vegetated areas based on absorption features in the red portion of the electromagnetic spectrum and high reflectance in the Near Infrared (NIR) portion of the electromagnetic spectrum. NDVI values range from -1.0 to 1.0 (Lillesand and Kiefer, 1994). To assist in image classification, NDVI was computed for both 1985 and 2013 using Eq. (3):

$$NDVI = \frac{NIR-Red}{NIR+Red} \quad (3)$$

where,
Red = The reflectance of Landsat Band 3
NIR = The reflectance of Landsat Band 4

High NDVI is an indicator of vegetation abundance while low and negative NDVI values indicate the absence of vegetation. Negative values were mainly recorded in the Volta Lake while low values were generated from built-up areas, bareland and wetland. Moderate to high NDVI values (0.2 to 0.653774) represented vegetated areas (grassland, farmlands, shrub and forest) (Fig. 4).

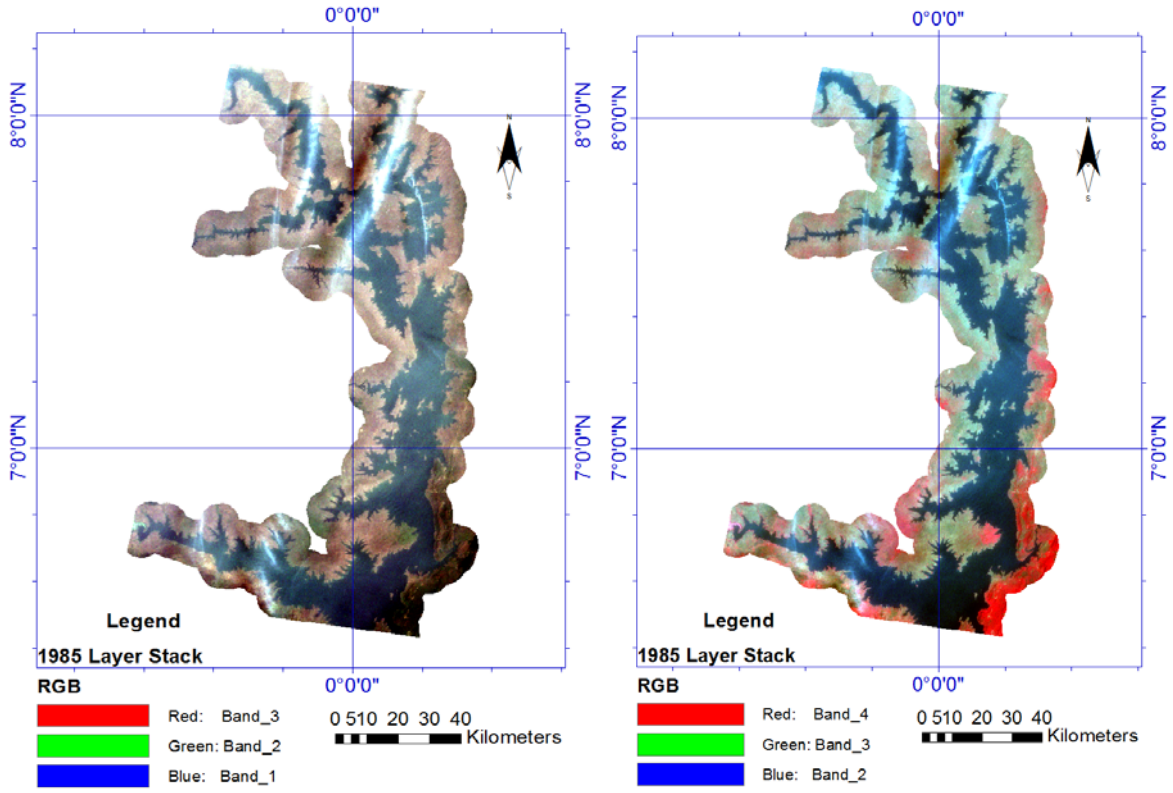


Fig. 3: True colour composite (left) /false colour composite (right)

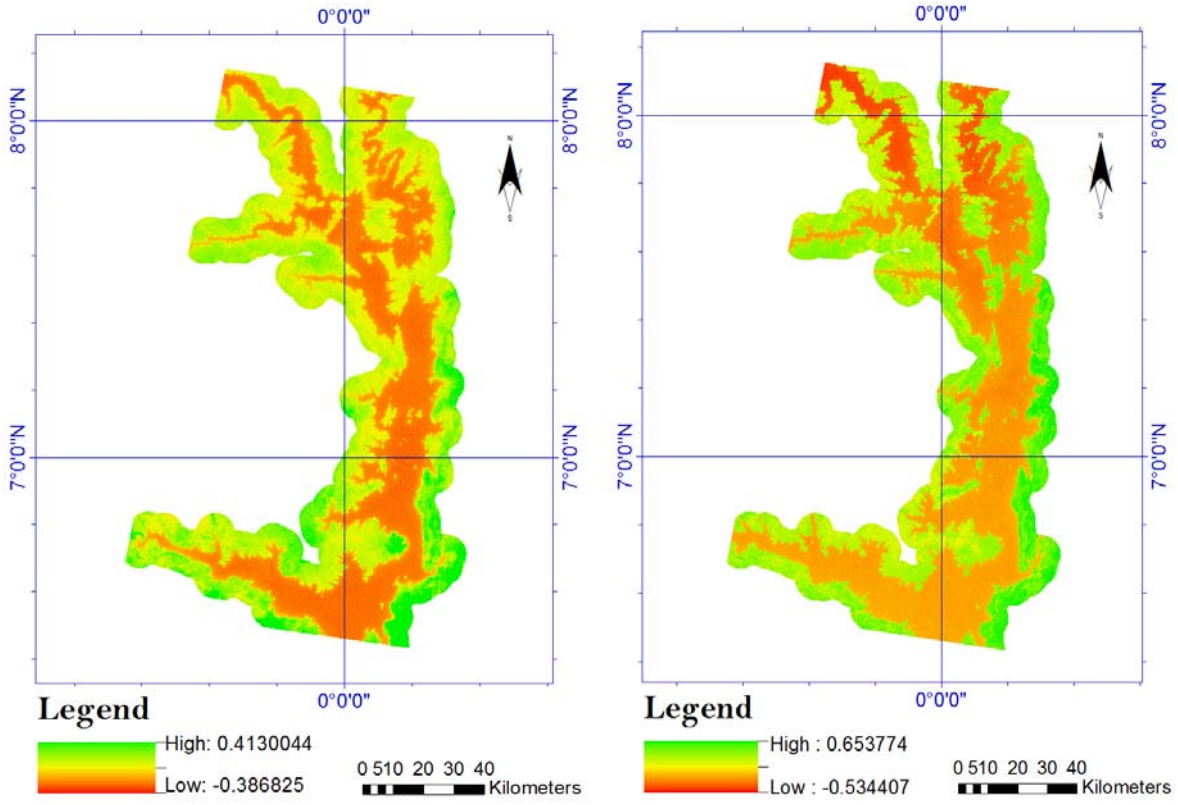


Fig. 4: NDVI for 1985 (left) /NDVI for 2013 (right)

Table 1: Description of land cover types

Class	Description
Water	Lake, river and reservoirs
Dense vegetation	Dense shrubs and forest
Sparse vegetation	Grassland and farmlands
No vegetation	Bareland, built-up area and wetland

Image classification: A hybridised classification approach was adopted. Training signatures were selected based on unsupervised classification, NDVI and visual interpretation of the true/false color composite of Landsat images as well as local knowledge of study area. A land cover map with four broad classes; water, sparse vegetation, dense vegetation and no vegetation were generated. Table 1, briefly describes the constituent of the four land cover classes. Finally, assuming that the reflectance pixels forming the training signatures were normally distributed, the stacked reflectance bands (Landsat band 1-5 and 7) was reclassified using the well-known supervised classification algorithm, thus the maximum likelihood algorithm (Jensen, 2000).

Accuracy assessment: Accuracy assessment was carried out after classification of each image. The land cover map of the study area was pre-loaded onto a Juno SB hand-held GPS receiver. The map was subsequently geo-referenced for ground-truth delineation of land cover classes of the classified images. Readings were taken for 50 geographical positions and corresponding classes of vegetation for estimating classification accuracy. Accuracy report was generated after each image classification. The results of the accuracy assessment in this study were reported in the form of error matrix as described by Story and Congalton (1986).

The overall accuracies obtained were 79.32 and 88.42% for 1986 and 2013, respectively. Anderson *et al*. (2001) stated that accuracies of 85% are required for land-use data for resource management. The accuracy obtained for the 1986 image was less than 85% as the ground truthing was only done in February 2013.

RESULTS AND DISCUSSION

The results of the study are shown in Fig. 5 to 8. It can be observed from Fig. 5 that the four major land covers in the study area were water, dense vegetation, sparse vegetation and no vegetation. The water class dominates the landscape while the no vegetation class constitutes the smallest land cover.

From Fig. 5 and 6, the study revealed an increase in dense vegetation from 367.06 km^2 in 1985 to 1035.07 km^2 in 2013 and a decrease of sparse vegetation from 3604.71 km^2 in 1985 to 2784.01 km^2 in 2013. However, when sparse and dense vegetation was

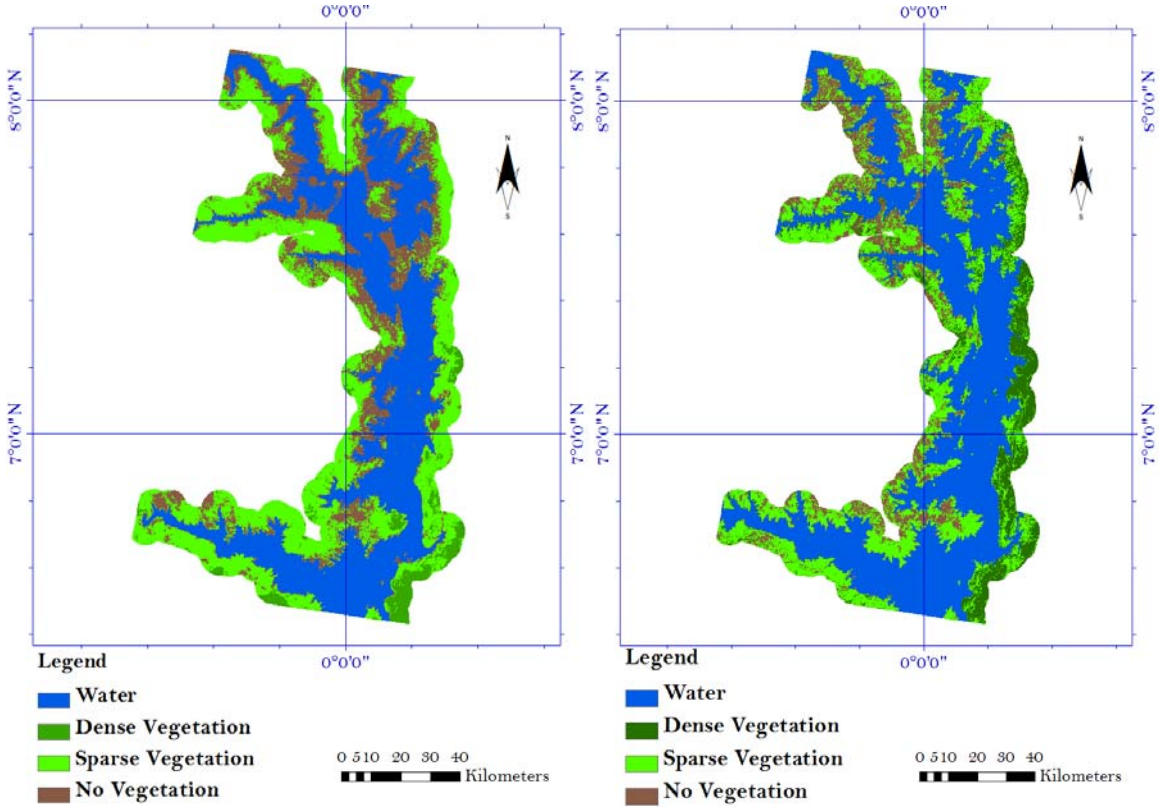
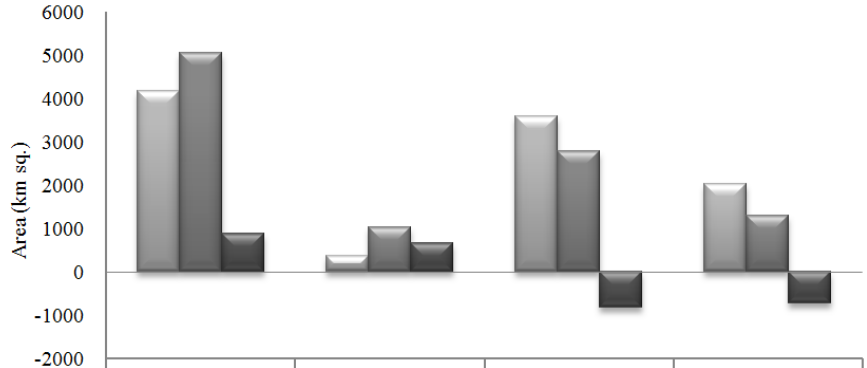


Fig. 5: Land cover maps for 1985 (left) and 2013 (right) based on 4 classes



	Water	Dense Vegetation	Sparse Vegetation	No Vegetation
Year 1985	4173.3414	367.0641	3604.707	2029.9266
Year 2013	5052.9906	1035.072	2784.0096	1303.0803
Difference (1985 - 2013)	879.6492	668.0079	-820.6974	-726.8463

Fig. 6: Land cover statistics for 1985 and 2013 based on 4 classes

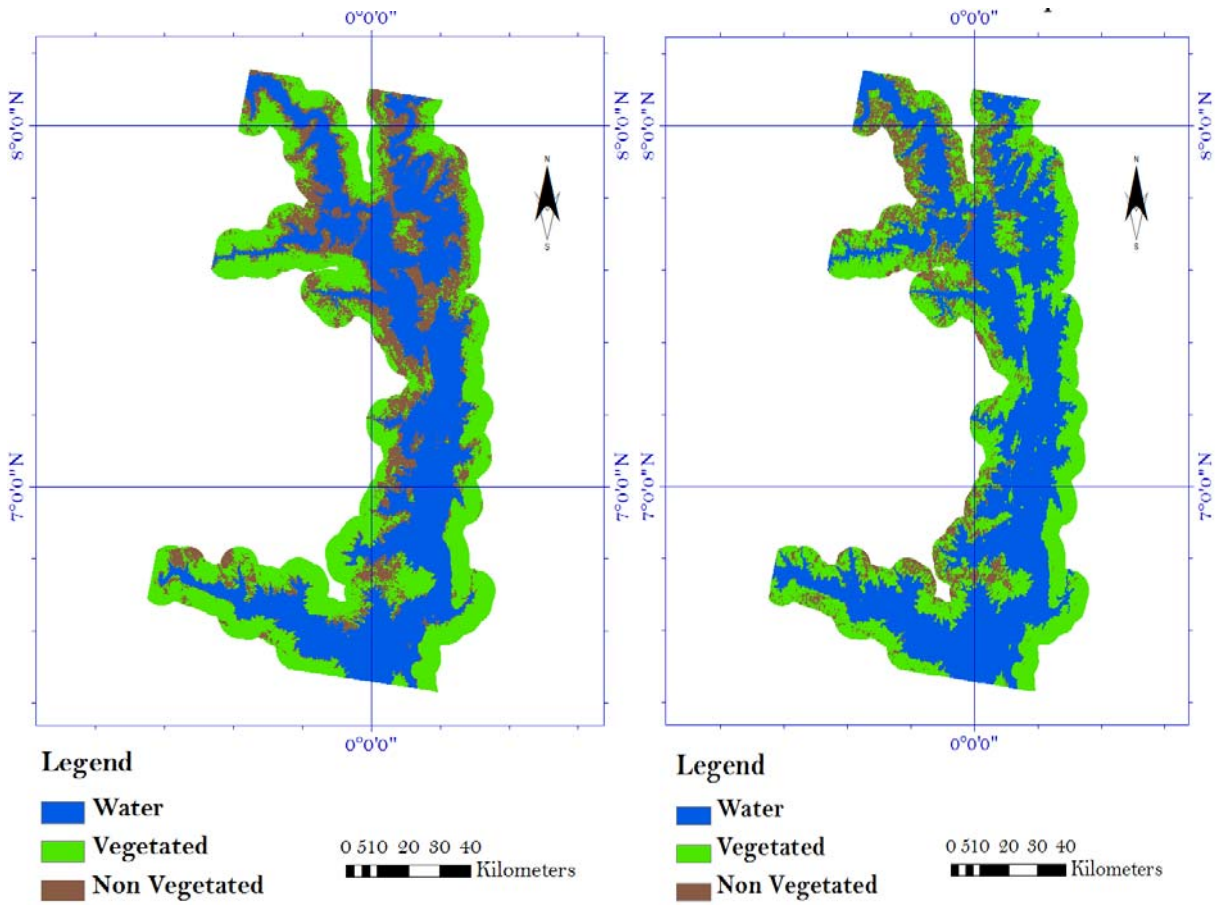
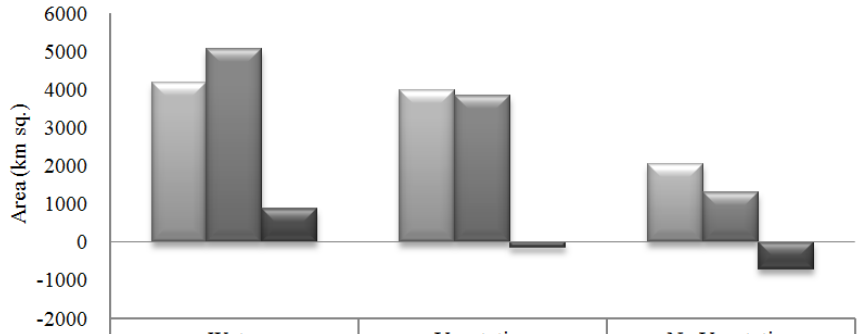


Fig. 7: Land cover maps for 1985 (left) and 2013 (right) based on 3 classes

considered as one class (Fig. 7 and 8), an overall decrease of 152.69 km^2 in the vegetated class (sparse and dense vegetation) was obtained. Areas with virtually no evidence of vegetation (bareland, built-up areas and wetland) increased from 2029.93 km^2 in 1985 to 1303.08 km^2 in 2013 (Fig. 5 to 8).

Another obvious change is the size (surface area) of the Volta Lake increasing from 4173.34 km^2 in 1985



	Water	Vegetation	No Vegetation
Year 1985	4173.3414	3971.7711	2029.9266
Year 2013	5052.9906	3819.0816	1303.0803
Difference (1985 - 2013)	880	-153	-727

Fig. 8: Land cover statistics for 1985 and 2013 based on 4 classes

to 5052.99 km^2 in 2013. This increase accounts for decrease in the no vegetation class (bareland, built-up area and wetland). The phenomenon also led to the creation of new islands in places formally considered to be dry lands.

CONCLUSION AND RECOMMENDATIONS

Remote sensing and GIS techniques have successfully been used to detect Land cover changes in the Volta River catchment using multi-temporal satellite images. This research further confirms the importance of Earth observation and geo-information techniques in effective management of global land cover changes. Though results of land cover generally indicate decrease in vegetation cover, it must be observed that the loss of vegetation would have been worse without good management practices of the Basin. The authors therefore wish to recommend and encourage the government and stakeholders of the basin to continue with their efforts in maintaining the Volta River Basin.

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REFERENCES

Andah, W.E.I., N. Giesen and C.A. Biney, 2003. Water, Climate, Food and Environment in the Volta Basin. Contribution to the Project ADAPT Adaptation Strategies to Changing Environments. pp: 44. Retrieved from: http://www. weap 21. org/downloads/ADAPTVolta.pdf.

Anderson, J.R., E.E. Hardy, J.T. Roach and R.E. Witmer, 2001. A land use and land cover classification system for use with remote sensor data. Geological Survey Professional Paper 964, United States Government Printing Office, Washington, pp: 40.

Chander, G., B.L. Markham and D.L. Helder, 2009. Summary of current radiometric calibration coefficients for landsat MSS, TM, ETM+ and EO-1 ALI sensors. Remote Sens. Environ., 113: 893-903.

Huth, J., C. Kuenzer, T. Wehrmann, S. Gebhardt, V.Q. Tuan and S. Dech, 2012. Land cover and land use classification with TWOPAC: Towards automated processing for pixel- and object-based image classification. Remote Sens., 4: 2530-2553.

Jensen, J.R., 2000. Remote Sensing of the Environment: An Earth Resource Perspective. Prentice-Hall, New Jersey, pp: 181-529.

Lillesand, T.M. and R.W. Kiefer, 1994. Remote Sensing and Image Interpretation. John Wiley and Sons, Chichester.

Mather, P.M., 1987. Computer Processing of Remotely-Sensed Images: An Introduction. Wiley and Sons, Chichester, pp: 352.

Story, M. and R.G. Congalton, 1986. Accuracy Assessment: A User's Perspective. Photogr. Eng. Remote Sens., 52(3): 397-399.

Wagrowski, D.M. and R.A. Hites, 1997. Polycyclic aromatic hydrocarbon accumulation in urban, suburban and rural vegetation. Environ. Sci. Technol., 31(1): 279-282.