Geo-spatial analysis of land use and land cover changes in the Lake Bosomtwe Basin of Ghana

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Abstract

This paper examines forest degradation and biodiversity loss in the Lake Bosomtwe Basin of Ghana between 1986 and 2008 from a geospatial perspective. The study was conducted using an integrated approach with Remote Sensing and GIS techniques, and supported with socio-economic data for forest cover change detection and biodiversity loss. A supervised per-pixel classification approach using a maximum likelihood algorithm was employed to generate land cover maps from Landsat Thematic Mappers of 1986 and 2002, as well as ETM+ of 2008 imagery. Statistical analyses of the land cover classifications indicate that forest cover around the basin has experienced remarkable loss in the past 22 years. Specifically, between 1986 and 2008, the basin lost 18.0% of the total forest cover as a result of anthropogenic activities. Land cover changes were mainly caused by extensive farming and building, with increases of 16224.5ha and 7139.3ha respectively. The paper concludes that the current state of forest cover and biodiversity loss in the basin results from human activities underpinned by complex interaction of socio-economic, institutional and technological processes at multiple scales. This provides a snapshot of the real situation of forest degradation and biodiversity loss in Ghana. Conservation efforts need to be in harmony with short- and long-term interests of the local communities and investors in the tourism and hospitality industry in order to reduce the environmental problems in the Lake Basin.

Keywords: Deforestation; forest degradation; land use; land cover; environmental sustainability; Lake Bosomtwe basin

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Introduction

Natural resources provide livelihood assets for many people in the world including 1.6 billion people that rely on forest and fishery resources for all or part of their livelihoods (Mayers & Vermeulen, 2002). Employment opportunities created from ecosystem services alone are approximately half of all jobs worldwide. Thus, access to this natural capital is a significant contributor to sustainable livelihoods and underpins poverty reduction in at least five key areas including food security, health improvements, income generation, reduced vulnerability and ecosystem services (Koziell & McNeil, 2002).

Regardless of their potential role as a buffer against poverty and vulnerability, these natural resources including forests are diminishing rapidly, and the degree of deforestation and forest degradation is more rapid and vast in developing tropical countries (FAO, 2005 cited in Forner, et al. 2006). The highest rates of forest loss in Sub-Saharan Africa occurred in West Africa - Ghana and Togo in particular (Perrings, n.d). This placed Ghana among the top ten countries with the highest absolute and relative deforestation and degradation rates in the world with deforestation rates of 2.3% and 2.1% per year in 1990 and 2010 respectively (FAO, 2010; FAO, 2005 cited in Forner, et al. 2006).

In Ghana, as in many other developing countries, the consequences of deforestation and forest degradation are being realized in the form of biodiversity loss. This costs about $520 million annually, representing 6.0 % of the annual GDP (Tokle & Danso, 2007). Various flora and fauna species such as Afromosia (*Pericopsi elata*), Odum (*Chlorophora /milicia excelsa*), Scarlet Red Star and Nannal Red Star species, Red Colobus, Diana Monkey (*Cercopithecus diana*) and forest elephants (*Loxondontaafrican cyclotis*) have become endangered or extinct in the country. Red Colobus and other flora species have become endangered because 43 percent of their main diet comes from commercial timber species including mahogany, odum, sapele, utile and makore, which are getting depleted (Benhin & Barbier, 2004). The loss of biological diversity through deforestation and forest degradation threatens not only the sustainable and harmonious development of the global ecosystem but also their economic and environmental value for human sustenance.

With the current rate of deforestation and forest degradation, it is anticipated that about three to eight million biological species, including a large number of yet unknown species, will be extinct by the end of the 21st century if measures are not put in place to address the rate of degradation (Kobayashi, 2004 cited in Baatuuwie et al., 2011). Regional analyses of deforestation have revealed forest cover loss across broad land-use categories in the country, but up to date, no complete forest inventory in Ghana, including the Lake Bosomtwe basin, exists (Baatuuwie et al., 2011; Stanturf et al., 2011; Benhin & Barbier, 2004). As a result, knowledge of the biodiversity of the basin is inadequate (Awortwi, 2010) to influence any environmental management decision in the district.

Remote sensing and Geographic Information Systems (GIS) have been widely used to assess deforestation and forest degradation at both regional and national scales (Chatelain et al., 1996). Nevertheless, their application in the forestry sector in Ghana is still in its early years.

As a result, data on the extent and severity of forest cover loss around the Lake Bosomtwe basin are still minimal and sketchy. Following an integration of GIS techniques and socio-economic data analyses, this paper examines the forest cover loss and landscape dynamics in the Lake Bosomtwe Basin. It focuses on the quantification and mapping of forest cover loss and other land use changes between 1986 and 2008 in a spatio-temporal context.

Conceptualizing forest degradation, biodiversity and land cover change

Perceptions of forest degradation are many and varied, and so are its drivers. It is difficult to find a common approach for defining forest degradation. Griscom et al. (2009) argue that one person's degraded forest is another person's livelihood. Nonetheless, forest degradation is defined as the reduction of the capacity of a forest to provide goods and services (Griscom et al. 2009). Similarly, the FAO (2007a) defines forest degradation as a process leading to a temporary or permanent deterioration in the density or structure of vegetation cover or its species composition. For the purpose of having a harmonized set of forest and forest change definitions which are also measurable with conventional techniques, forest degradation is assumed to be indicated by the reduction of canopy cover. Hence, an in-depth understanding of the processes of forest degradation is very necessary in monitoring deforestation and forest degradation (FAO, 2007b). Besides, deforestation and forest degradation contribute to adverse changes in biodiversity. Biodiversity underpins the health and vitality of forests (Secretariat of the Convention on Biological Diversity, 2010). Likewise, ecological diversity provides a foundation for many ecosystem services necessary for sustainable livelihoods and well-being.

Land-cover refers to the physical characteristics of the earth's surface, captured in the distribution of vegetation, water, soil and other physical features of the land, including those created solely by human activities, e.g., settlements (Ramachandra &Kumar, 2004). Hence, adequate knowledge of ecological diversity and ecosystem services can be considered as necessary.

Forest cover and biodiversity loss: theoretical perspectives

Explaining forest cover and biodiversity loss or general landscape dynamics often reflects different natural and social theories of environmental decay. A focus on a one-sided argument at times draws criticisms from scholars. Loss of forest cover and biodiversity has in some cases been linked to growing human population. It is argued that as population increases, a greater portion of the forest cover is converted to agricultural lands or fuel woods, especially within the rural milieu (Rahman, 1999). This is drawn from the Neo-Malthusians' theory on environmental decay.

Considering the man-environment framework, the Boserupian school of thought regarded population growth as a blessing or an asset and not a curse because population increases stimulate innovations in agriculture in the form of intensification, technological and institutional changes rather than the conversion of forests into farmlands (Mortimore & Turner, 2005; Rahman, 1999). In the Brundtland Report (WCED, 1987), poverty is considered an important driver of environmental decay. On the contrary, in a growing empirical literature on the so-called Environmental Kuznets Curve, it is argued that environmental degradation is induced not by poverty but by development (Barbier, 1997).

Pandy and Nathawat (2006), in a related study on land use and land cover mapping in Panchkula, Ambala and Yamunanger Districts of India, observed that the heterogeneous climate and physiographic conditions were behind the development of different land use and land cover changes in the Districts. This shows that neither population nor poverty alone constitutes major underlying cause of land cover changes worldwide. Rather, people's response to economic opportunities, international trade and agro-climatic factors, mediated by institutional factors, drive environmental decay and other land cover changes (Nkonya et al., 2004). Therefore, data on forest and biodiversity loss from the integrated approach of GIS and social survey are very important for monitoring change in forest cover and other landscape dynamics for policy direction.

A Change detection approach is very important because of its practical uses in various applications, including deforestation, damage assessment, disaster monitoring, urban expansion, planning and land management (Hussain et al., 2013). The general objectives of change detection in remote sensing include identifying the geographical location and type of changes, quantifying the changes, and assessing the accuracy of change detection results (Coppin et al., 2004; Im & Jensen, 2005; Macleod & Congalon, 1998). Different change detection techniques have been developed and evaluated in the past. However, the selection of the most suitable method for change detection is not easy in practice (Lu et al., 2004). There is no consensus as to a single method/ algorithm that is universally applicable. The most commonly used change-detection methods are either spectrally based (image-to-image) or classification-based (map-to-map) (Green et al., 1994; Loveland et al., 2002).

Most urban land-cover and land-use change studies used Landsat data due to the uniqueness of the dataset as the only long-term digital archive with a medium spatial resolution and relatively consistent spectral and radiometric resolution (Yang et al., 2003). Urban change studies using Landsat Multispectral Scanner (MSS) or Landsat Thematic Mapper (TM) data have been conducted mostly at regional scale encompassing several urban areas (Royer et al., 1988). Recently, long-term urban land-cover/land-use changes (over two decades or longer) have been studied using the methodology of post-classification comparison with the Landsat archive as a baseline data source (Chen et al., 2002; Yang & Lo, 2002).

In spite of the improvements in methodology, several weaknesses are noted with some of the commonly used change-detection techniques. The post-classification method identifies conversion from one land-cover/land-use type to another with little information on the intensity of such changes and limited detection of subtle changes within land-cover categories. This method often involves intensive manual interpretation and relies heavily on the skills of the interpreter. The spectrally based method of change detection provides quantitative information on spectral changes over time. However, interpretation of the spectral difference images with regard to the type of land-cover/land-use change is not always straightforward (Sohl, 1999;

Singh, 1986). Also, the majority of urban change studies using remotely sensed data assumed homogeneity within a single pixel, resulting in no quantifiable changes at the sub-pixel level. In most cases, Landsat pixels in urban areas are mixed and composed of several land-cover/land-use types, so overlooking the sub-pixel variation of Landsat imagery can lead to a spurious result (Hussain et al., 2013; Sohl, 1999). Other change techniques such as image subtraction, image ratio, image overlay, principal component analysis and change vector analysis make it easy to monitor land cover change at different times (Jensen, 1986). But these methods are either limited with regard to reflecting changes in categories, unable to supply any information as to the nature of the change, or cumbersome to implement (Macleod & Congalon, 1998). Since no single change technique is universally applicable and entirely efficient, this study employed an integrated approach such as post classification (a GIS and Remote sensing approach) and social survey to efficiently integrate and quantify land cover dynamics in the study area between 1986 and 2008.

Case and Site Description

The study was carried out in the Lake Bosomtwe Basin of the Bosomtwe District in the forest zone of Ghana. The lake is one of the youngest, best preserved meteorite craters in the world (Grieve et al., 1995 cited in Karp et al., 2002). It covers an area of about 52 km^2 and is found within latitudes 6^0 24' and 6^0 43'N and longitudes 1^0 15' and 1^0 46' W. The lake exhibits a radial drainage system of 106 km^2, a diameter of about 11km at its widest part and a maximum depth of 78m (Turner et al., 1995). The Lake Bosomtwe Basin has a unique geologic and physiographic make-up of Upper, Lower Birimian and granite rock formation. The basin falls within the equatorial zone with a rainfall regime typical of the moist semi- deciduous forest zone. The mean rainfall is between 1600mm and1800mm. Temperature in the area is also uniformly high throughout the year, between 20ºC and 32ºC in August (Bosomtwe District Profile, 2010). These conditions give credence to the development of tourism facilities and cultivation of crops such as cocoa, cassava and onion around the basin. Fig.1 is the map of the Bosomtwe District showing the rural communities selected for this study.

Materials and methods

GIS data collection

Landsat images were used. The copyright of the images permits legal sharing among government departments, academia and donor agencies (Muller, 2004). The Landsat images of different years (1986, 2002 and 2008) consulted were Land Thematic Mapper (TM) and Landsat Enhanced Thematic Mapper (ETM+) satellite images. Images of different dates were selected to meet the requirement of a post-classification comparison change detection technique because it requires classifications of images acquired from different times (Jensen, 2004; Mas, 1999). These images were obtained from the United States Geological Survey website. Pre-processing operations were carried out to correct for radiometric and geometric distortion of the images because of curvature, rotation of the earth, atmospheric and sensor effects. The Haze reduction module in Erdas Imagine was used to correct haze on only 2002 and 2008 images since portions of these two images had some amount of haze which could potentially affect the classification. Haze was not corrected on the 1986 image since portions of the image with haze on them were few and hence could not affect the classification.

For geometric corrections, thirty ground control points (GCPs) were identified from a topographical map of the area. Even though the images were already registered unto the UTM WGS 84 projection system, it was realized after superimposing them that they had shifted and were lying at different locations. Since such displacement will cause false change areas in the scene, the images were corrected using GCPs extracted from the topographical map to ensure that all of them lie at the same location and extent. These GCPs were later used to register the 2008 image using the Nearest Neighbour Resampling technique. The three images were resampled to a 30 x 30m pixel resolution. Afterwards, the 2008 rectified image was used to rectify the 1986 and the 2002 images. Three of the bands (4, 3, and 2) of all the three images were combined into a single image using the Layer Stack Tool in Erdas Imagine Software before the images were rectified. The scan line off errors in the 2008 image were corrected using a 2002 image that contained no scan line off errors with the Nasa IDL Virtual Machine Application Frame and Fill. This application uses the image of a year without scan line off errors to correct an image which has errors, and thereby removes the lines.

Extraction of Subset (Study Area)

The images used for the study covered all parts of Kumasi. An area of interest (AOI) tool in Erdas Imagine was used to consider only the study area (i.e., 15km^2 of Lake Bosomtwe basin) and subsets from all the three images. The rectangular coordinates were used to define the boundary of the study area because it had no well-defined boundary. This necessitated the use of the rectangular coordinates as shown in Table 1.

Table1: Rectangular Coordinates of the study area.

Easting (m)	Northing (m)	Description
685918.67	709405.00	Lower Right Corner (LR)
665987.00	709343.16	Lower Left Corner (LL)
665927.87	729265.88	Upper Left Corner (UL)
685852.43	729329.43	Upper Right Corner (UR)

Source (Field Survey, Ghana, 2013)

Image Enhancement

Enhancements were done for easy understanding and visual interpretation of the images. Although radiometric corrections for illumination, atmospheric influences and sensor characteristics were done prior to the distribution of data by the USGS, the images were still not optimized for visual interpretation. A Histogram-Equalized Stretch that assigns wider range of displayed values for the frequently occurring portions of the histogram was employed to improve the images

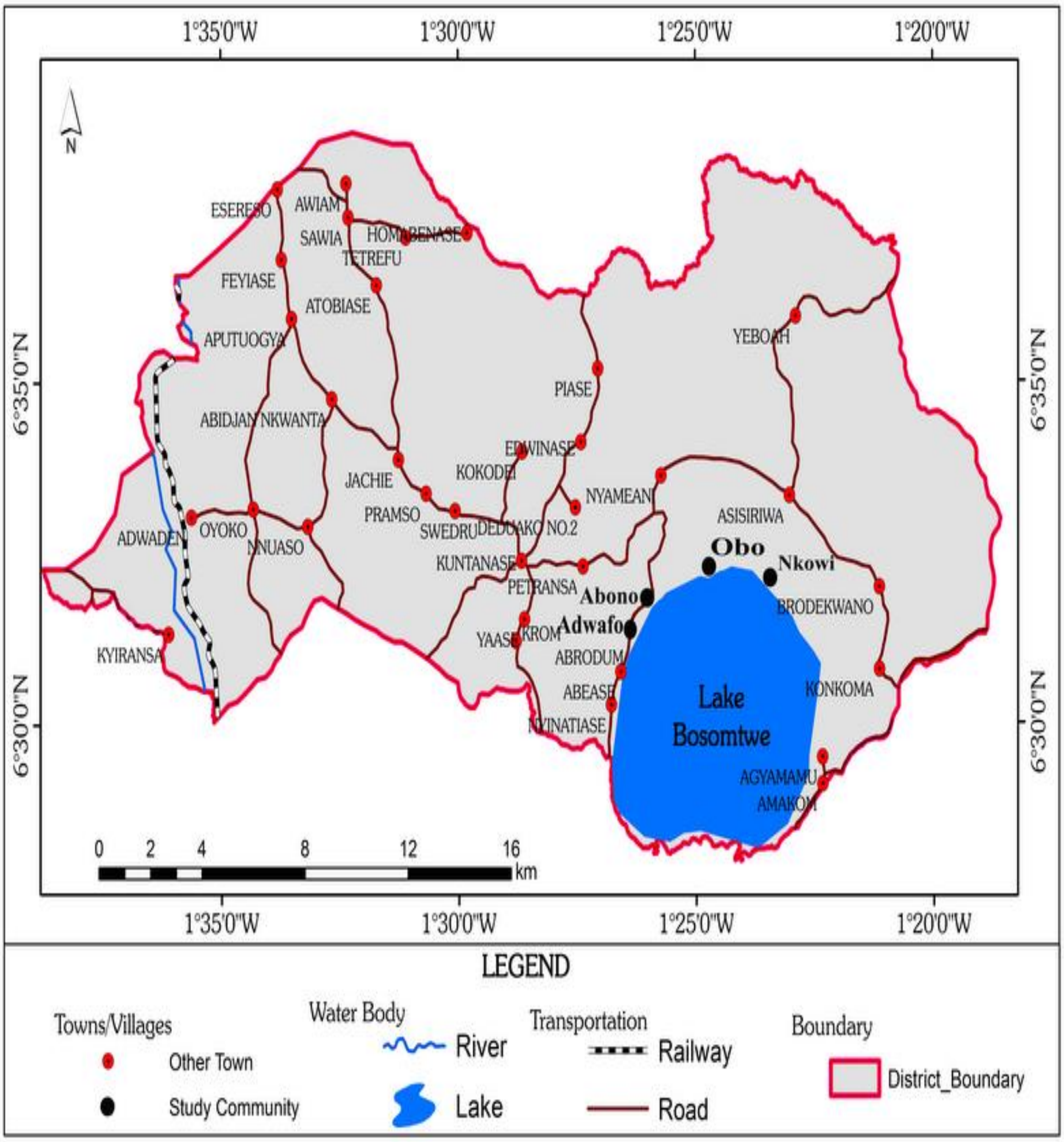

Fig.1 Map of the Bosomtwe District showing the sampled study communities

Source: Geography Dept. KNUST (2013)

Image Classification

Supervised classification was performed to classify the satellite image into various categories of land cover and land use changes as it is more accurate than unsupervised classification. A topographical map and an aerial photograph of the study area from Geomatic Engineering Department, KNUST, as well as training samples of identified land cover types were digitized using an area of interest (AOI) tool. These were used as ground truthing data in classifying the satellite images during the supervised classification using the Maximum Likelihood Algorithm. The Maximum Likelihood Algorithm method was employed because it is the most simple and efficient change detection technique as compared to other methods. It also allows for determining the difference between independently classified images from 1986-2008. Using Anderson's Classification Scheme by Anderson et al (1986), the individual images were classified into six different classes, namely: bare-land, built-up, farmland, Rangeland, Forestland and Water. An accuracy assessment of the images was done to ensure precise and accurate change detection analysis. To assess the accuracy of the classified images, one hundred random reference points were extracted from the 2002 aerial photographs and the 2008 topographical map to calculate the accuracy of the classified images of 2002 and 2008 (see Tables 4-5).

Finally, the status of changes (either increase or decrease in forest cover) during 1986-2002 and 2002-2008 was assessed by overlaying the land cover maps of the sampled periods (1986, 2002 and 2008) with the help of a Matrix Module in Erdas Imagine 9.3, ArcView 3.2 and ArcGIS 9.2. A transition contingency matrix was also generated to test the independence that exists between the land cover classes in the different years. The final maps that represent the forest cover, other land use and land cover changes during 1986, 2002 and 2008 (both area and percentage) were also generated. Table 2 gives a description of the land cover classes that were identified and used during the image classification.

Table 2: Description of Land Cover classification scheme used

Land Cover	Description
Built-up	Urban or Built-up Land comprises areas of intensive use with much of the land covered by structures. Included in this category are cities, towns,
Farmland	Farmland may be defined broadly as land used primarily for production of food and fibre and other commercial and horticulture crops.
Rangeland	Rangeland has been defined as land where the potential natural vegetation is predominantly grasses, grass-like plants, forbs or shrubs.
Forestland	Forest Lands have a tree-crown areal density of 10% or more and are stocked with trees capable of producing timber or other wood products.
Bare-land	Bare-land is land of limited ability to support life and in which less than one-third of the area has vegetation or other cover.
Water	This includes lakes, stream and reservoirs.

Source: Anderson et al. (1986)

The socio-economic data were on such subjects as livelihood activities, state of forest cover and biodiversity in the study area. They were collected through a focus group discussion guide from 250 households in the Abono, Adwafo, Nkowi and Obo communities. A simple random sampling technique was employed using the lottery approach to arrive at the selected households to be interviewed in each community. This technique was employed to ensure accurate and equal representation of households chosen for the study. The head of each selected household acted as the unit of inquiry for the household. The study adopted a mixed research strategy to minimize the weakness of each approach. Descriptive statistics such as frequency tables with the help of SPSS (version 20) and Microsoft Excel were employed to analyse the data.

Study Results

The spatial resolution of the Landsat TM and ETM images was relatively low (medium); however, it provided vital maps for monitoring land use and land cover changes in the study area. Table 3 shows extensive changes that occurred between 1986 and 2008 in almost 50% of the total area. The greatest change with regard to the change in area occurred in rangeland as it decreased by 1.6% annually within the 1986-2008 period. This corresponds to 10.4 ha of the rangeland (secondary forest) cleared annually. Between 1986 and 2002, 0.84 % of forest cover was lost annually. In the later period of 2002- 2008, the forest area witnessed an insignificant decline in annual deforestation rate by 0.83%. During the period of 1986-2008, the total forest loss was 7782.62ha, showing an overall annual loss of 0.80% of the total forest area. This shows that the Lake Bosomtwe basin lost almost 1% of its forest cover annually between 1986 and 2008. Although farmland and built-up classes occupied a small area in 1986, they increased significantly by 1.40% and 0.30% respectively between the 1986 and 2002 periods. Moreover, the overall increment in size of farmland and built-up areas constituted 16224.52ha and 7139.33ha respectively within the 1986-2008 periods. This depicts an overall annual rate of 1.9% and 0.80% since 1986 (see Table 3). The area occupied by water also reduced yearly by 0.03% since 1986. Thus, as rangeland, primary forest and water decreased in size, farmland and built-up areas increased in size.

Table 3: Rate of change in Land cover classes from 1986 to 2008 (Area unit in % ha)

Land Cover Classes	**Rate (%)**	**Annual**	**Rate (%)**		**Land Cover**
	1986-2008	1986-2008	1986-	2002-2008	1986-2008
Water	0.03	10.4	0.04	0.07	227.76
Rangeland	1.60	640.1	0.73	4.00	14082.89
Bare-land	0.20	80.5	0.11	0.50	1707.58
Forestland	0.80	331.0	0.84	0.83	7782.62
Farmland	1.90	737.5	1.40	3.11	16224.52
Built-up	0.80	324.5	0.30	2.22	7139.33

Source (Field Study, Ghana, 2013)

Comparing the land cover map of one year to another, the changes are not easily noticeable. However, other changes are conspicuous and can easily be distinguished. Figures 2 to 4 portray a decreasing trend in forest cover. Meanwhile, farmland and built-up areas increased within the 22 year period whilst forest and rangelands reduced. Thus, from 1986 to 2008, land cover classes such as water, rangeland, forestland and bare-land decreased in size while farmland and built-up areas increased. Between 1986 and 2008 much of the forestland and rangeland was cleared and converted into other land uses such as farmland and built-up areas, as indicated in Figures 2- 4. The red and brown areas on the land cover map of 2002 and 2008 show the areas of forest, rangeland and bare land that have been converted into farmland and built-up areas respectively. The land cover map of 2008 shows that the basin has lost almost 18.0% of its forest cover since 1986. Housing (built-up area) and other social amenities on the other hand expanded in all directions in Abo, Adwafo and Obo communities. Agriculture has taken much of the forest which was scattered over the entire map but concentrated around the Southern and Eastern parts of the study area (see Fig. 4).

Table 4: Error matrix of the 2002 Land-use/land-cover map

Class Name	**Reference totals**	**Classified totals**	**Number Correct**	**Producers Accuracy**	**Users Accuracy**	**Kappa**
Unclassified	0	0	0	---	---	-----
Water	16	15	15	93.75%	100.00%	1.0000
Rangeland	47	50	44	93.62%	88.00%	0.7736
Bare-land	5	5	4	80.00%	80.00%	0.7895
Forestland	12	7	6	50.00%	85.71%	0.8377
Farmland	15	18	14	93.33%	77.78%	0.7386
Built-up	5	5	4	80.00%	80.00%	0.7895
Total	100	100	87			
Overall Accuracy	87.00%					
Overall Kappa Statistics	0.8144					

Source (Field Survey, Ghana, 2013)

Generally, the majority of the residents in the lake basin are subsistence farmers, although a few are commercial cocoa farmers. This explains why the agricultural lands are in clusters and subdivided into small farms. Lake Bosomtwe is the only visible water body observed apart from other rivers such as the intermittent river Ebo. This however does not imply that there are no rivers in the area. The low resolution of the Landsat TM and ETM+ is likely to be the reason for such a minimal display of the other water features. Furthermore, outside protected areas (Bosomtwe reserve) at the south, primary forests and rangelands have completely disappeared leaving behind a few patches of forest at the southeastern part of the lake. The land cover maps of 2002 and 2008 had overall Kappa statistics of 0.8144 and 0.8236 above the minimum 0.40 and 0.80 (40 to 80%) range necessary for monitoring change detection in forest cover. Tables 4-5 show the Error Matrix of the 2002 and 2008 Land-use/land-cover maps.

Table 5: Error Matrix of the 2008Land-use-land-cover map

Class Name	Reference totals	Classified totals	Number Correct	Producers Accuracy	Users Accuracy	Kappa
Unclassified	0	0	0	---	---	-----
Water	16	15	15	93.75%	100.00%	1.00
Rangeland	47	50	44	93.62%	88.00%	0.77
Bare-land	5	5	4	80.00%	80.00%	0.78
Forestland	12	7	6	50.00%	85.71%	0.83
Farmland	15	18	14	93.33%	77.78%	0.73
Built-up	5	5	4	80.00%	80.00%	0.78
Total	100	100	87			
Overall	87.00%					
Overall Kappa Statistics	0.8144					

Source (Field Survey, Ghana, 2013)

Changes have occurred within each of the land cover classes as a portion of one class has transformed into another since 1986. Much change occurred in rangeland as 26% and 6.0% of its size converted into farmland and bare-land respectively during 1986-2002 periods. About 62.3% of farmland transformed into rangeland within the same period (see Table 6). This shows that portions of farmlands that become infertile are abandoned to regenerate into secondary forest by local people. Forestland of about 41.9% and 23.2% also converted into rangeland and farmland respectively. A similar trend of conversion occurred among all the land cover classes in the study area within 2002-2008 periods. Some rangelands converted into farmlands and built- up areas constituting 55.2% and 11.1% respectively (see Table 8). Much of the forest transformed into rangeland and farmland. Table 9 also shows a similar trend of conversion as rangeland of about 53.7% and 23.7% transformed into farmland and built-up areas, whilst about 37.0%, 42.1% and 4.7% of forestland changed into rangeland, farmland and built-up area respectively within the 1986-2008 periods.

The reduction in rangeland and forest respectively resulted from the rapid expansion in farming activities and tourism facilities in the lake basin. Further, all the land cover classes witnessed changes from one class to another and forest conversion in particular has been intensifying in the study area since 1986 (see Fig.4). Following the rapid loss of forest, the study revealed that species such as odum, monkeys and antelopes have become scarce in the basin (refer to Table 7).

Table 6: 1986 – 2002 Transition Matrix (Area units are in hectares and %)

		1986						
	Class	**Water**	**Range Land**	**Bare Land**	**Forest Land**	**Farm Land**	**Built-up**	**2002 Total**
2002	Water	4864.7	8.21	0.20	0.00	0.00	0.05	4873.16
			0.02%	0.0009%	-	-	0.009%	
	Rangeland	0.00	13349.2	489.17	3687.89	476.10	43.61	18045.95
		-		23.4%	41.9%	62.3%	8.1%	
	Bare land	21.13	1375.74	454.5	57.13	50.45	50.11	2009.03
		0.4%	6.0%		0.6%	6.6%	9.3%	
	Forestland	0.00	412.38	0.70	2959.6	10.85	0.02	3383.57
		-	1.8%	0.03%		1.4%	0.004%	
	Farmland	2.79	6673.39	619.13	2041.70	195.8	55.22	9587.99
		0.06%	29.6%	29.6%	23.2%		10.3%	
	Built-up	28.31	759.80	527.24	45.27	31.14	388.9	1780.74
		0.6%	3.4%	25.2%	0.5%	4.1%		
	1986 Total	4916.9	22578.71	2090.93	8791.61	764.30	537.98	39680.4

Source (Field Survey, Ghana, 2013)

Table 7: Endangered species in the Lake Bosomtwe basin

Monkeys
Antelope
Porcupine
Elephant
Crocodile
Deer
Crab
Odum

Source (Field Survey, Ghana, 2013)

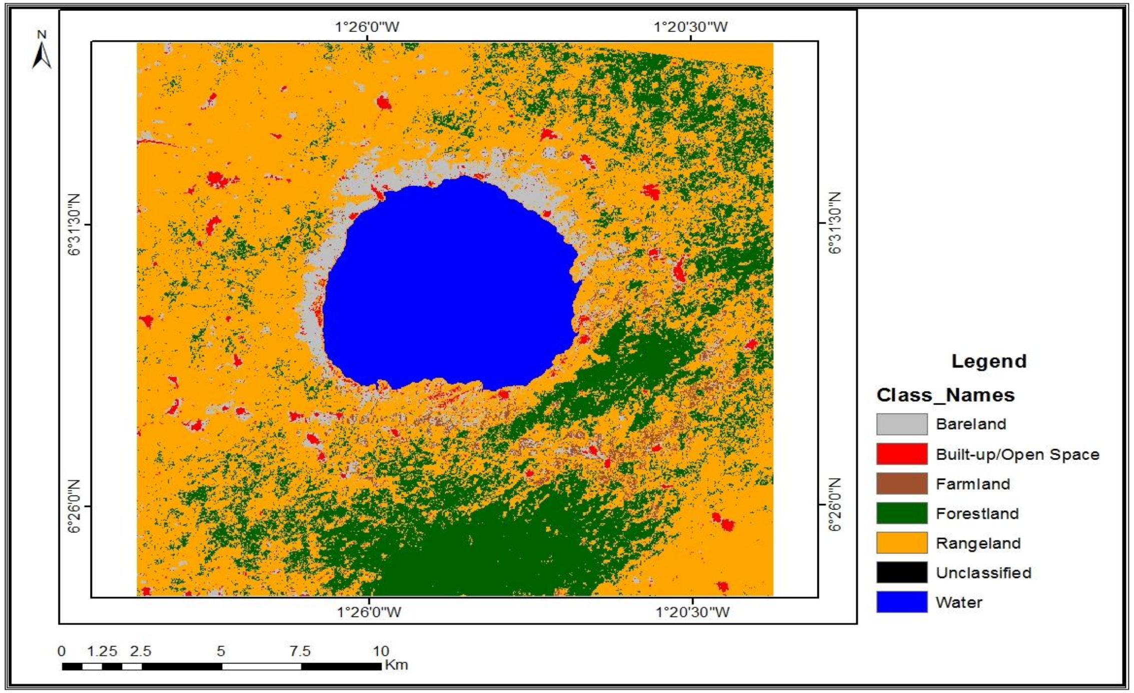

Fig. 2: 1986 Land cover map of the study area
Source (Field Survey, Ghana, 2013)

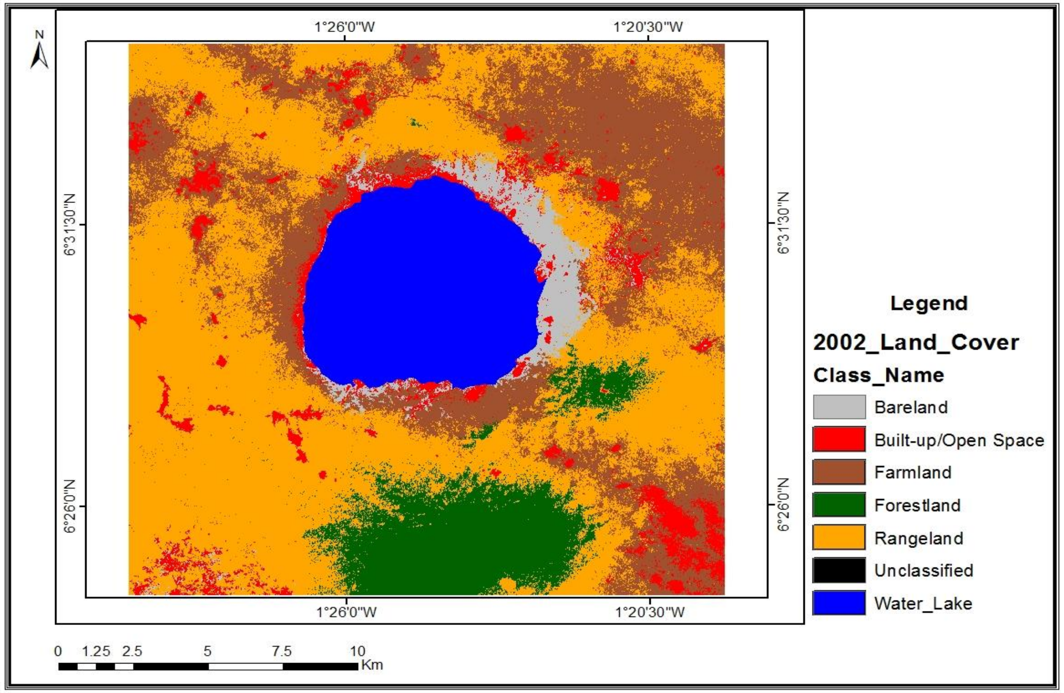

Fig. 3:2002 Land cover types of the study area
Source (Field Survey, Ghana, 2013)

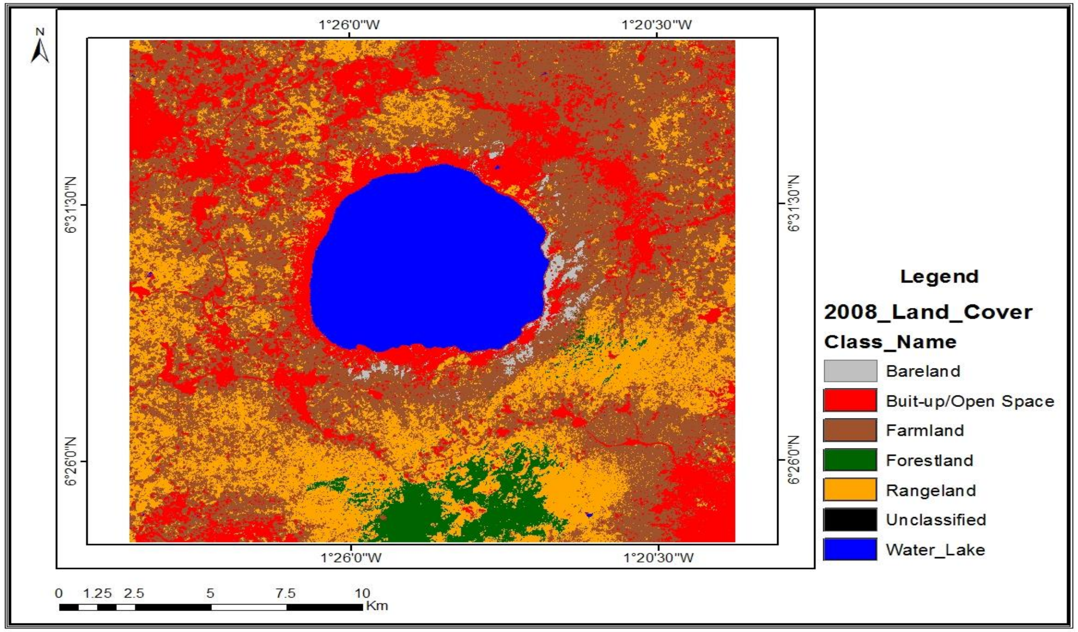

Fig. 4: 2008 Land Cover Map of the study area
Source (Field Survey, Ghana, 2013)

Table 8: Land cover change Matrix 2002– 2008 (Area units are in hectares and %)

				2002				
	Class	**Water**	**Rangeland**	**Bareland**	**Forestland**	**Farmland**	**Built-up**	**2008 Total**
	Water	4681.17	4.32 0.02%	1.8 0.10%	0.95 0.03%	0.99 0.01%	0.09 0.00%	4689.32
	Rangeland	0 -	5989.01	49.16 3.50%	1692.88 50.00%	761.09 7.90%	71.1 3.00%	8563.23
2008	Bareland	0.97 0.02%	18.88 0.10%	207.34	0.54 0.02%	79.4 0.80%	14.85 0.60%	321.98
	Forestland	0 -	61 0.30%	0.05 0.00%	1352.48	2.77 0.03%	0 -	1416.29
	Farmland	23.76 0.50%	9969.82 55.20%	579.44 41.60%	289.42 8.60%	5699.81	397.55 16.60%	16959.8
	Built-up	167.27 3.40%	2002.93 11.10%	555.3 39.90%	47.32 1.40%	3043.94 31.70%	1913.09	7729.83
	2002Total	4873.16	18045.95	1393.09	3383.57	9587.99	2396.68	39680.44

Source (Field Survey, Ghana, 2013)

Discussion

The overall accuracy for the 2002 and 2008 satellite images achieved was 87.0% and 88.0%. The 2002 and 2008 classified images are reliable because they are above the minimum accuracy assessment value of 85% stipulated by the United States Geological Survey (Adubofour, 2011).

The overlay of the classified maps of 1986, 2002 and 2008 indicates that the forest cover of Lake Bosomtwe basin and its environs has undergone serious and very profound changes. Agriculture and built-up areas experienced net expansion at the expense of the forestland between the 1986 and 2008 period due to the increasing demand for land for farming, residential and tourism facilities. Deforestation is very severe in Abono, Adwafo, Nkowi and Obo communities in the lake basin due to the high demand for tourism and hospitality facilities as the number of tourists visiting the basin increases every year.

Table 9: Land Cover Change Matrix 1986-2008 (%)

		1986					
	Class	Water	Rangeland	Bareland	Farmland	Built-up	Forestland
	Unclassified	0.00	0.00	0.00	0.00	0.00	0.00
	Water	95.08	0.02	0.08	0.00	0.02	0.04
	Bareland	0.13	1.06	1.15	0.38	0.66	0.53
	Forestland	0.00	0.13	0.00	0.07	0.00	15.67
2008	Rangeland	0.10	21.45	11.28	25.47	2.33	36.98
	Farmland	0.53	53.66	31.14	58.84	9.11	42.10
	Built-up	4.16	23.69	56.35	15.24	87.89	4.69
	Class Total	100.00	100.00	100.00	100.00	100.00	100.00
	Class Changes	4.92	78.56	98.85	41.16	12.11	84.34

Source (Field Survey, Ghana, 2013)

The expansion of farming activities and hotel facilities in particular is expected to continue as the local authorities often fail to regulate the activities of the investors and local people working in the lake basin. The results confirm a relatively high deforestation rate of approximately1.0% annually within the study area - only 15.7 % of the entire primary forestland remains unchanged (see Table 3 and 8). Moreover, the annual reduction in the size of rangeland (secondary forest) by 1.6% is likely to increase pressure on the forest resources within the Bosomtwe Reserve, leading to forest degradation or deforestation. Significantly too, changes in the structure of the terrestrial environment have shifted from a primarily wild to a primarily anthropogenic state between 1986 and 2008 as urban sprawl is observed in the study area. Thus, each land cover class is undergoing some changes over time throughout the basin. This situation has been stressed by Hens and Boon (1999) that the major characteristic of land use and land cover change in Ghana is a competition among the main economic sectors such as agriculture, mining and logging. The study's results reaffirm the findings of Repetto (1992) that forests in Ghana are "disappearing with increasing speed" (Repetto, 1992). Hence, the need to find realistic solutions to the emerging problems in the basin before the situation becomes irreversible (UNEP, 2007).

While remarkable expansions in farmland and built-up areas might seem the most important anthropogenic changes in the forest ecosystem over the years, agricultural activities encroached upon the forestlands more than other land use classes. This implies that the terrestrial environment in the study area is now being used intensively as compared to the past decades. With the current rate of change, much of the remaining forest in the basin would be lost in the next few years if measures are not taken to curb the problem of deforestation and forest degradation within the basin. Likewise, if the current deforestation rate is not stopped or reduced significantly, forest degradation is likely to become a major cause of increased carbon emissions once the primary forest in the basin is lost. This is because the potential of reducing emissions from deforestation depends on the amount of carbon stored in the remaining forest cover that can be saved by reducing or stopping deforestation (Forster, 2009).

Ghana is a signatory to the Convention on Biodiversity, 1992 Earth Summit in Rio de Janeiro (Brazil) and other conventions where issues of environmental conservation received much attention (EPA, 2005). However, this seems to have had no explicit result in the Bosomtwe District. Traditional laws existing to protect rivers, lakes and their tributaries from drying up (Akuoko, 2001) are facing stiff opposition with the introduction of practices associated with modernity and societal transformation such as increasing demand for space for commercial and residential facilities and defiance from emerging religious groups in the study area.

The considerable loss of forest and other landscape dynamics in the Lake Bosomtwe basin threatens the existence and functionality of biodiversity including the livelihoods of the local people. The lake itself, having a radial pattern, will be heavily impacted following the persistence of the observed degradation. Unless these trends change in the district, the consequences will be severe (Nellemann & Corcoran, 2010; Chomitz, 2007). Also, commitment in terms of efforts aimed at sustainable forest management is crucial to achieving the Millennium Development Goals and other poverty reduction goals by 2015. Nevertheless, the recent socio-economic pressure arising from population growth in the study area supports the conclusion that humans now dominate the biosphere and as a result change it in ways that threaten its ability to sustain the livelihoods of the present and future generations (Vitousek et al., 1997; Haberl et al., 2007; Steffen et al., 2011).

Success in sustainable forest management efforts requires that both novel and encroached ecosystems be the focus of much research, monitoring and conservation efforts, as their optimal management, community structure, habitat connectivity, ecosystem processes and dynamics remain poorly understood and cannot be reliably predicted from past trends (Hobbs et al., 2006; Lindenmayer et al., 2008; Chazdon et al., 2009; Jones & Schmitz, 2009). Of the many options currently considered around the globe, the Reducing Emissions from Deforestation and Forest Degradation (REDD+) scheme (Forster, 2009) could be given the needed support at all levels to address the threats of deforestation, forest degradation and climate change in the study area.

Policy lapses and recommendation

Environmental management efforts in Ghana date back to 1906. But environmental issues attracted policy attention after the United Nations Conference on Human Environment in Stockholm in June 1972 that underpinned the establishment of the Environmental Protection Council (EPC) in 1974, coupled with the National Environmental Policy. Recognizing the relevance of forest resources, various management efforts such as creation of permanent forest estates, forest reserves and the forest protection (amendment) law of 1986 as guidelines for forest resources management were made in the country (Forestry Commission of Ghana, 1994). These policies somehow helped to lessen the loss of forest resources in the country. However, most of the policies only focused on a sustained supply of timber for the wood industries and promoted over-exploitation that led to eventual degradation of unreserved forests and reduction of forest reserves. Further, such remedial measures as agro-forestry (modified taungya system), afforestation and restoration programs aimed at community forestry and livelihood sustainability have in some cases been unsuccessful due to limited financial resources and prioritization of the economic value of the forests at the expense of its intrinsic value by the intervening agents. Gaps between forest policy intent and the realities on the ground are apparent.

To curb the problem and ensure environmental sustainability, this study recommends proper enforcement of forest laws, a shift from conservation for sustainable supply of timber to conservation for carbon sequestration and community forestry through capacity building in the study area. Empowerment and an active community participation in the management of forest resources in a way that will help guarantee their sustainability for future generations should also be considered.

Conclusion

The integrated approach of GIS and social survey is viable for quantifying the extent and change over time of forests and other landscape features. The study confirms that deforestation and forest degradation in the Bosomtwe District are still high. Although forest cover loss occurred throughout the 22 year period (1986-2008), it was more severe in the 2002-2008 periods due to unsustainable agriculture and other uncontrolled development activities underpinned by complex interactions of social, economic and political processes. The ecological and economic implications of the present situation of loss of biodiversity involved the gradual disappearance of species such as elephants, monkeys, porcupines, crabs and odum, alongside the receding water level in the lake basin in recent times. The form and process of forest ecosystem in the study area would be threatened severely if realistic measures aimed at conservation for carbon sequestration are not considered. Hence, forest conservation measures should focus on creating a balance between the forest resource utilization and environmental sustainability. This is feasible if forest policies and laws are properly enforced and local people's capacity is built to enable them engage in other non-farm activities to reduce the socio-economic pressure on the natural capital in the lake basin.

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