Landcover Change Patterns in the Volta Gorge Area, Ghana: Interpretations from Satellite Imagery

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Abstract
In much of the developing world, shifting cultivation is the predominant agricultural system usually practised by farmers, which is associated with increasing the unit of land under cultivation in order to increase the output. This small-scale shifting agricultural practices based primarily on burning has been the factor responsible for the conversion of forest fringe vegetation into cropland and pasture and it initiates a continuum of changes in the land cover and consequently fragmentation of the landscape. Since the construction of the Akosombo Dam in 1965, the potential for farming and fishing has increased tremendously within the Volta gorge area and this has resulted in the influx of many settler farmers and fisher folk into the area. This brought so much pressure on the natural resource base of the area and has transformed the landscape accordingly. Within this paper we aim at the estimation of the trend in changes of the landscape using multi-temporal satellite image processing and spatial change analysis. We also seek to determine the land use / cover change in the Volta gorge area of the Volta basin of Ghana for the period 1975 to 2007. Land cover change and agricultural expansion was observed through digital processing and classification based on five multi-temporal medium resolution satellite imagery (Landsat: 1975, 1990, 2000, 2003, 2007) into five classes. From this, accurately classified pixel information was used to determine each landcover class size and the number of changed pixels into other classes through change detection. The study shows that significant changes in the landscape involved a general pattern of conversion of both Closed forest and Open forest and woodland into cropland, fallow lands, pasture, and Bare areas consisting of settlements, roads and exposed soil surfaces. For the period under consideration 1975-2007, the Agricultural class increased from 52,605 hectares in 1975 to become the land cover type with the highest proportion of cover at 221,567 hectares in 2007. The study concludes among others that the expansion of agriculture has increased in all directions with the amount of land devoted to cropland and pasture increasing for all slope categories but more especially for less steeper slopes.
Keywords: Landuse/landcover, Multi-temporal, Digital processing, Change detection

1. Introduction

Natural factors such as extreme climatic conditions and geological processes such as earthquakes and volcanoes are responsible for changes in land cover. However, it is mainly the interaction of humans with the natural environment to improve livelihoods, which have transformed land use and consequently land cover. Land cover change has long been viewed as continuous, but in fact it has distinct processes with periods of rapid change. It is often triggered by an event such as, forest fire, logging and settlement expansion, which can initiate a series of changes over a period (Lambin et al., 2000). Deforestation as a factor of land cover change has been attested to by many scientists (Yemefack, 2005; Angelsen,1991; Sader,1988). However, understanding the processes of land use and land cover change is important in predicting the extent of future change (Mertens et al., 2000).

Transformation of the natural environment through conversion of forest resources into other cover types has been thought as spatially homogenous and a simple linear process of degradation (Codjoe, 2005; Mertens and Lambin, 2000). However, different responses to biophysical environments, socioeconomic activities and cultural settings offer a more valid explanation of local land cover change. Additionally, local land cover change patterns attributable to local ecological and human induced drivers is an indispensable requirement for understanding changes at national, regional, and global levels (Pabi et al., 2005).

Land use changes are a major determinant of land cover changes; this is because it is human agents; individuals, households and private firms that take specific actions that drive land use change (Lambin et al., 1999). Increase in household size, migrant population and decrease in the economic wellbeing of the indigenes of an area compels agricultural expansion. However, the option for expansion outside of protected areas is becoming impractical and would soon not be sustainable strategy for increasing production of food (Wood et al., 2004).

Generally, there is a broad consensus that the expansion of cropped area and pasture constitute the major source of deforestation as against fuel wood extraction in Africa because cropping and pasturage also follow any removal of wood for charcoal, fuel wood and timber. Substantial evidence supports the assertion that increased demand for food and higher prices of crops stimulate forest clearing, that make agriculture more profitable (Angelsen, 1991). Expansion of Agriculture is the primary driver of land use/cover change in much of

West Africa because it is a key factor for the removal of forest (Wood et al., 2004). In addition, (Yemefack, 2005) argued that agricultural expansion has been one of the most significant causes of land cover modification in the tropical forest regions and this is attributable to varied factors such as land tenure system, increase in family size and macro-economic changes (Mertens et al., 2000).

The construction of the Akosombo hydro-electric project in 1965 and the inundation created by the impoundment resulted in massive and rapid change in the land covers. Large forested areas, communities and farmlands were lost and this together with the resettlement of about 80,000 people in 52 communities created a high demand for agricultural lands (Ayivor and Kuforgbe, 2001). These initial changes have created series of changes, as new migrant communities had to look for new farmlands accompanied by settlement expansion over time. The loss of farmlands as a result of the inundation and the unavailability of lands for migrants have resulted in the encroachment of forest lands even in areas designated as reserves (FORIG, 2003). Agriculture is the main economic activity of majority of the people living in the Volta basin but rapid population growth coupled with low economic standards of living have brought immense consequences on the natural resource base of the basin (Codjoe, 2005). Population and migration affect deforestation but the two demographic variables act in a complex nexus with other variables to explain the phenomenon of forest loss and cover change (Kaimowitz and Angelsen., 1998; Angelsen, 2001). This is an indication that the population size and rate of growth does affect the level of agricultural expansion in the entire Volta basin.

The aim of this study is therefore to estimate the trend in changes of the landscape using multi-temporal satellite image processing and spatial change analysis. The specific objectives designed to meet this aim are a) to determine the land use / cover change in the Volta gorge area of the Volta basin of Ghana for the period 1975 to 2007 b) to quantify the proportion of conversions between various land cover classes c) to examine the effect of slope on the extent of agricultural expansion and the consequent land cover change and d) to create land cover, change and slope and slope factor maps with a view of showing the extent of the changes in the landscape over the years as a result of environmental perturbation.

2. Methods

2.1 Study Area

The study area is within the Volta basin of Ghana and covers the entire Asuogyaman District which lies in the Eastern Region and has an area of size 699,900 hectares i.e. about 7000 km^2 (Figure 1). The Volta gorge area was selected because it is the site of the Akosombo Dam, a hydroelectric power (HEP) generation plant which supplies a large proportion of the energy needs of the country. However, the deterioration of the environment within the basin in general and the gorge area in specific has affected HEP generation. The occurring change in the environment has necessitated this research in the area.

The vegetation along the reservoir shore is moist semi-deciduous forest type. However, the slash and burn agriculture, intensive cultivation with short fallow periods and bush fires over the years have resulted in the degradation of the original forest (Forestry Research Institute of Ghana, 2003). This has resulted in the expansion of Savannah type of vegetation into the area. Dense forest, however, still persist at undisturbed sites. In most cases, the present vegetation is a mosaic of various units, comprising of natural re-growth, disturbed forest, and thicket composed of a tangle of shrubs and herbaceous species. Scrub vegetation consisting of stunted trees with very low undergrowth occupies the summit of most rocky slopes (Volta River Authority Report, 2005).

The study area falls within the Equatorial climatic zone with a rainfall of the Tropical Monsoon type, which has two rainfall peaks. The major rainfall season is between March to July with the peak rainfall in June/July, whiles the minor season commences in September and ends mid-November. In between the two rainfall periods is a spell of dryness in August. The mean annual rainfall for the area ranges between 1104 mm – 1510 mm. Temperature is generally warm and the maximum and minimum temperature is recorded in the months of February and August, respectively. The mean maximum and minimum temperature range are 28^0 - 33^0C and 20^0 - 23^0C respectively (Volta River Authority Report, 2005).

The topography of the area is composed of a range of hills located mostly along the reservoir shore with undulating plains behind it. The hills range between 50-150 metres high and have very steep gradients and sometimes with massive rock outcrops. At Akosombo, two ranges of hills have created a steep gorge which has been dammed for Hydro-Electric Power generation. Steep slope areas with gradients ranging between15-100% constitute about 23 percent of the landscape while gentler slope of between 0-14percent is about 77 percent (Forestry Research Institute of Ghana, 2003).

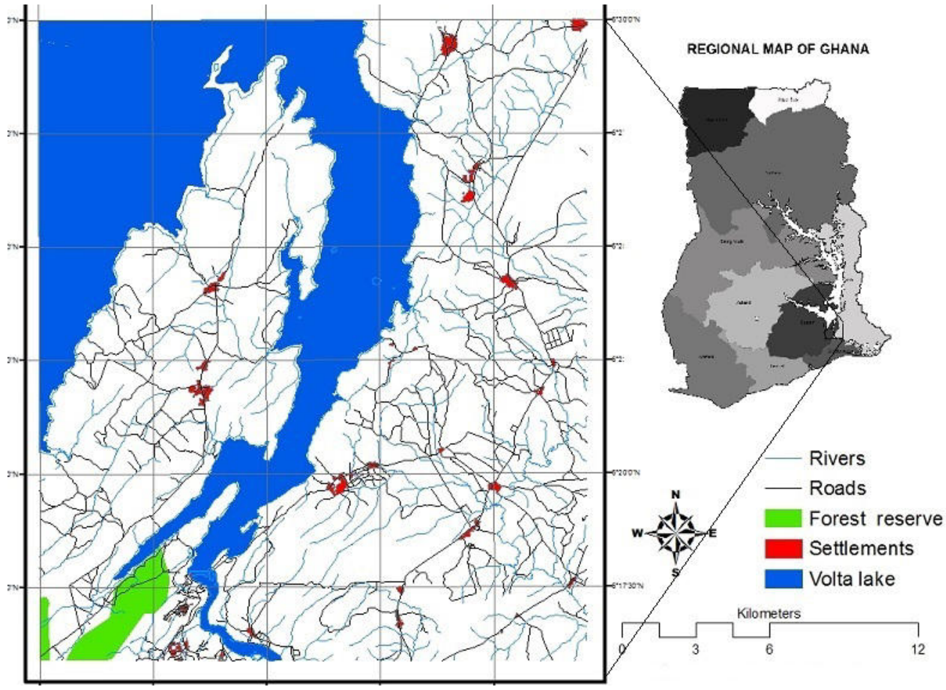

Figure 1. Map of Ghana showing the Volta reservoir system and the study area

2.2 Available data and software

The research, which is primarily a historical pattern change analysis necessitated the use of several multi-temporal and multi-sensor satellite imagery. Landsat images for the following dates 1975, 1990, and 2000 with different sensor and pixel resolution were used. ASTER images for the years 2003 and 2007 were used for the more recent analysis due to the unavailability of cloud free Landsat images for the study area. The Aster images were unavailable for the analysis for the earlier periods since it is a more recent development dating back to December, 1999. The satellite images selected and used were within the dry season and between the months of December and February. This was because of the difficulty in obtaining cloud free images in the rainy season in tropical regions. It also meant that data on land cover types in the cropping season was not captured as accurately as possible. Table 1 shows the data sets used for the research and their attributes.

Table 1. Data set and characteristics

Satellite/ sensor	spatial resolution(M)	acquisition data	Remarks
Landsat MSS	79	28 Dec. 1975	Dry season
Landsat TM	30	25 Dec. 1990	Dry season
Landsat ETM	30	13 Jan. 2000	Dry season
ASTER	15	13 Dec. 2003	Dry season
ASTER	15	7 Feb. 2007	Dry season

In addition to the data sets above, a slope map with a pixel size of 30 metres and a 1972 topographic map of the study area with a scale of 1:50,000 obtained from the Survey Department, Accra was used for ground-truthing as well as geo-referencing. The following softwares were used at various stages; DNR Garmin for GPS points, ERDAS® 8.7 for image analysis, ARCGIS® 9.1 for G.I.S. analysis and map making. Charts, graphs and statistical analysis were done using Microsoft® office applications (Excel, Visio). A slope map obtained from a contour map with a contour interval of 50 meters was used to cross a binary map of Non - Agricultural and Agricultural class cover for the various years to see the extent to which slope affects the extent of agriculture expansion.

2.3 Sampling and land cover classification scheme

Stratified random sampling was used to collect field data with an approximately equal sample size in each land cover class (Petit et al., 2001; Schreuder et al., 2004). This was used for the validation of the classification accuracy. Stable GPS readings were used to record samples representative of all cover types identifiable. A total of 131 samples were collected and used for the research. The satellite images used for the research were of multi-temporal, sensor and resolution, requiring that they are brought to a common domain particularly with regards to

their spatial resolution. The Landsat MSS 1975 (79m) and ASTER 2003 and 2007 (15m) were re-sampled to a common resolution of 30 metres to bring them at par with the Landsat TM 1990 (30m) and ETM 2000 (30m).
The designing of a classification scheme helped to generate detailed continuous information on the mechanism of changes which are either conversions or modifications between various cover types (Pabi, 2007). The classification scheme for this research was designed to meet the research objectives and modelled on the ITC system of Land use/cover classification (LUCC) (Gils et al., 1991). This classification system was very useful in that it is developed to respond to the tropical and local environmental conditions. Below is the Land cover classification scheme used for the research (Table 2).

Table 2 : Land cover classification scheme used for the study

Land cover	Description	sub-groups (Landuse)
Agriculture	Lands ever used for food production in whatever form, for which the natural vegetatation cover has been tampered with resulting in an irreversible change	1. Cultivated areas 2. Orchards 3. Abandoned / Fallow lands 4. Irrigated lands 5. Grazing land
Bare areas	Areas with no vegetation cover at all and exposed soil surfaces	1. Settlements 2. Roads 3. Exposed Rock surfaces
Closed forest	This includes secondary forest and some few untouched forest for which there is at least some canopy cover	1. Riverine Vegetation 2. Forest reserves 3. Sacred groves 4. Forest patches
Open forest & Woodland	This represents vegetation with no canopy and sparse distribution of trees	1. Grass and Shrub cover 2. Trees with no canopy
Water	Areas covered by water for most part of the year including the dry season	1. Rivers and streams 2. Volta lake

The agricultural class included the grazing and pasture lands because there are no strict lines of division between the two. In the dry season, some agricultural fields were used for grazing and conversely some grazing fields for cultivation in the growing season.

A supervised classification was used for classifying the five (5) images using the scheme outlined above for the five (5) cover types. A false colour composite of bands 4-3-2 of the Landsat images (1975, 1990, 2000) and bands 1-2-3 in the Visible Near–Infra Red (VNIR) of the ASTER images (2003, 2007) were evaluated for the ability to distinguish cover types. These colour composites provided the most optimal visualisation of the 5 cover types and was consequently loaded into the colour board RGB (Red, Green, and Blue) of ERDAS® Imagine version 8.6. An unsupervised classification was first done using the classification algorithm, Iterative Self-Organising Data Analysis Technique (ISODATA) with a maximum iteration of 6. This was used as guidance for the collection of training sample points on the field. The points were then overlaid on the images and used as guidance to define polygons to extract the signatures for the various land cover types. The actual classification was then done using Maximum likelihood classification (MLC) algorithm. Five time-series land cover maps for the following years; 1975, 1990, 2000, 2003 and 2007 was consequently produced from which the change detection, and slope analysis was undertaken.

2.4. Slope and land cover maps generation approaches

The slope map was generated by rasterizing a contour map of the study area into a Triangular Irregular Network (TIN) which is an interpolation function in ARCGIS 9.1®. From the TIN, the slope map was derived, however the interpolation function assigned slope to some of the areas covered by the reservoir water. These were masked out assigning slope to only the landmass. The slope map was consequently classified into 5 classes between 0 – 100%. This was after a visual appraisal of the slope map using various classes and comparing it to a topographical map of the area. The five class slope map with the default threshold values distinguished the various landforms better and was used accordingly. The binary map of the Agricultural class and Non-agricultural class for all the years was related spatially with the slope to see the effect of slope on agricultural expansion and also whether the expansion has occurred in every slope class. Figure 2 shows the processes described above for the image analysis for this research.

The study employed digital change detection to observe the change in the land cover. This is because temporal series of satellite remote sensing imagery increases the accuracy with which tropical deforestation and other land cover changes can be mapped (Alves and Skole, 1996). Post classification change detection was preferred to other change detection techniques such as image differencing, Vegetation index differencing, Selective principal component analysis, and direct multi-date unsupervised classification. This is because it offers the most accurate procedure and presents the advantage of indicating the nature of the change. Methods based on Post-classification were found to be less sensitive to spectral variations and more accurate when dealing with data captured at different times of the year (Mas, 1999). From the classified maps for the years 1975, 1990, 2000, 2003, 2007, post-classification image differencing change detection was done. The change detection was done with the matrix function in ERDAS 8.6® software by overlaying the various land cover maps. Land cover change maps were produced for the following periods; 1975-1990, 1990-2000, 2000- 2003, and 2003-2007. The change maps were subsequently recoded into 6 classes of changes and no change to highlight the major land cover conversions. This provided the level of transfers among the various classes (Figure 2).

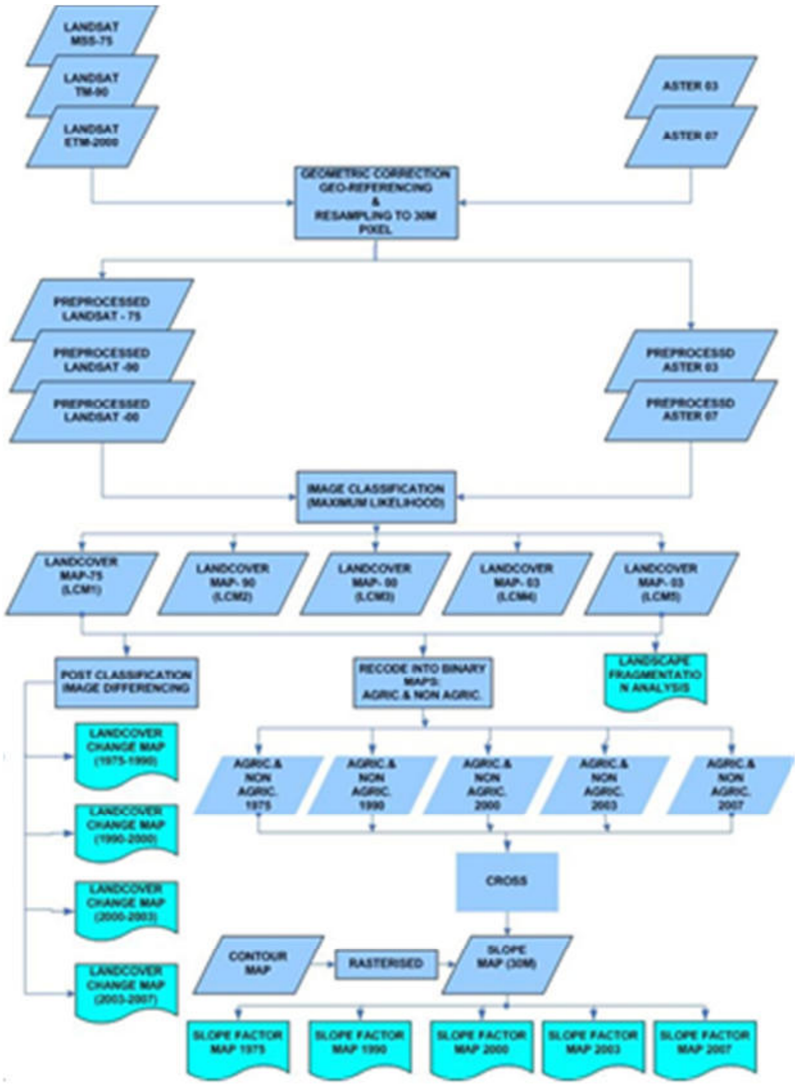

Figure 2: Procedure for Image Processing and analysis

3.0 Results and Discussion

3.1 Land cover map

Land cover maps and Classification Accuracy Land cover maps for 1975, 1990, 2000, 2003, and 2007 were produced for the area (Figure 3) to observe the changes in the landscape. Figure 3 shows the changes that have

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occurred in the Volta Gorge since 1975. In the maps, the spread of Agriculture class is widespread while Closed forest decrease is observed. In the years 2003 and 2007 one observes the dominance of the Agriculture class as against the decrease in Closed forest and Open forest and woodland in almost all places.

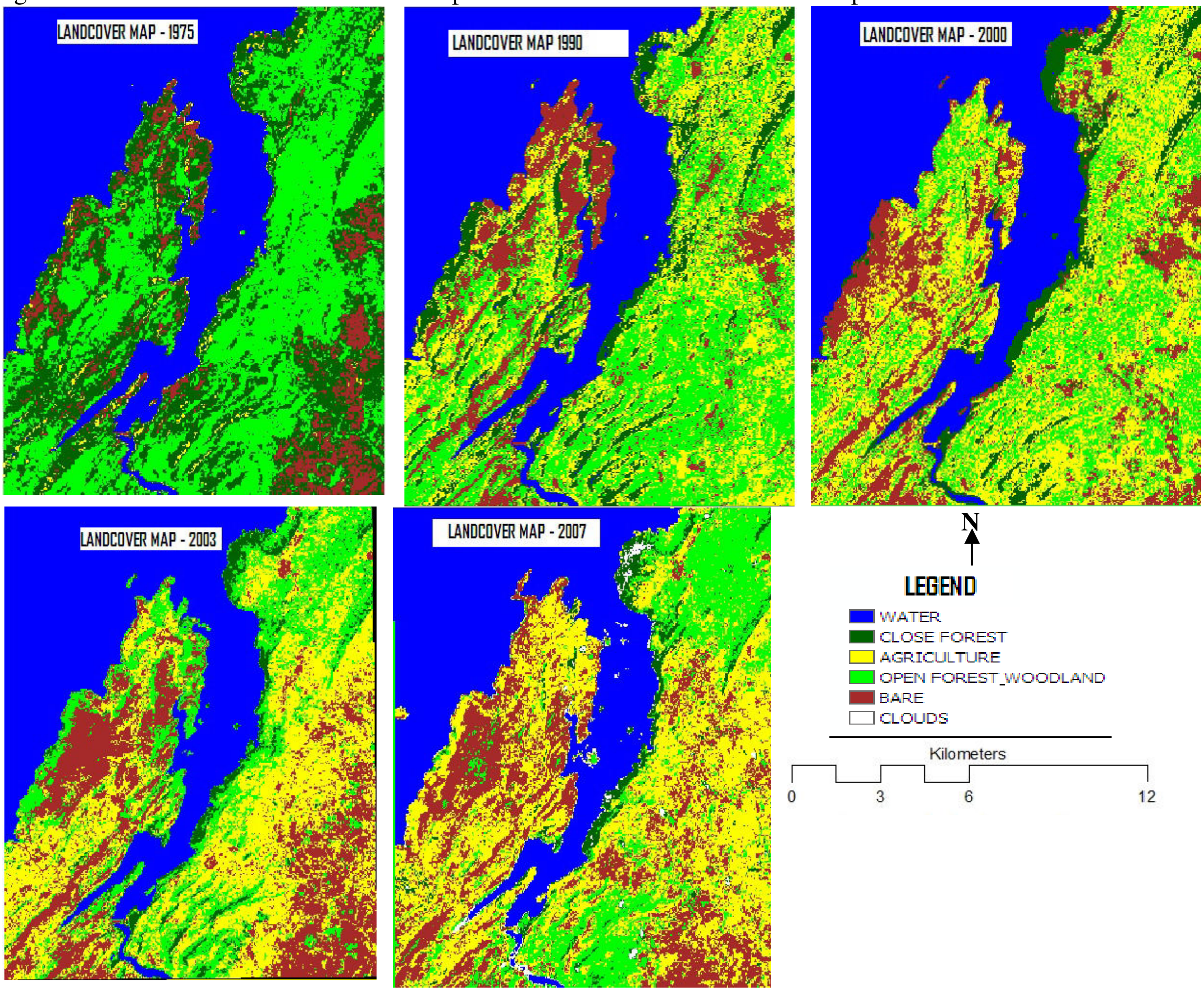

Figure 3: Land cover maps; 1975, 1990, 2000, 2003 and 2007

The remnant Closed forest could be found along the reservoir shore in the steep sloped areas particularly along the eastern shore. Validation of the classified ASTER 2007 image was undertaken with a total of 131 sample points of cover types. Accuracy assessment was only feasible with the 2007 image as a result of the unavailability of validation samples for the other years. The classified image produced an accuracy of 69.47% with a Kappa Statistic of 0.5985 (Table 3). Agriculture had the highest user's accuracy of 91% with Kappa statistic 0.85 whiles Bare class has the highest producer's accuracy of 71% with the lowest kappa statistic of 0.40.

Table 3: Accuracy Assessment for classified Aster image 2007 of the Volta Gorge area

LAND COVER CLASS	REFERENCE TOTAL	CLASSIFIED TOTAL	NUMBER CORRECT	PRODUCER'S ACCURACY (%)	USER'S ACCURACY (%)	KAPPA (K) FOR EACH CATEGORY
Water	13	10	10	76.92	100	1.0000
Closed Forest	16	14	10	62.50	71.43	0.6745
Open Forest &woodland	17	23	13	76.47	56.52	0.5004
Agriculture	51	34	31	60.78	91.18	0.8555
Bare Area	34	48	27	79.41	56.25	0.4091
Total	131	131	91	**OVERALL CLASSIFICATION ACCURACY (%)**		**OVERALL K STATISTIC (%)**
				69.47%		0.5985

3.2. Trends in total area per land cover

The period of 1975-2007 witnessed a steady decline of Closed forest from 151,285 hectares to 28,379 hectares representing a decrease of about 81% (Table 4). During the same period Open forest and woodland has also decreased from 170,460 hectares to 93,789 hectares. Very significant level of change of closed forest occurred for the period of 1975-1990 when there was a decrease by about 56% while Agriculture increased by about 183% for the same period. Closed forest and Open forest and woodland had both reduced tremendously in all the period under consideration except the period 2003-2007 where there was a marginal increase of about 5% for Closed forest. Figure 4 shows the general trend of change in land cover.

From Table 4, the proportion of Agricultural cover expanded from 52,605 hectares in 1975 to about 221,567 hectares in 2007, becoming the cover type with the highest proportion in the year 2007. The decrease in Closed forest and Open forest and woodland cover types corresponds with the increase in the proportion of land cover for Agriculture and marginal increases for Bare areas. Throughout the entire period under consideration the percentage of Water cover has experienced very little change except in the period 2003- 2007 where there has been a little drop by about 5 % (Table 5). The proportion of the Bare class has not changed as much as the other classes, it's proportion has ranged from 14% to 19% for the entire period except in the year 1990 when it dropped to 12% (Table 4). For all the cover types, the proportion of increment has not been very uniform for all the periods.

Table 4: Land cover class proportions in hectares (ha) 1975-2007

COVER TYPES	1975		1990		2000		2003		2007	
	ha	%	ha	%	Ha	%	ha	%	ha	%
WATER	220,772	32	220,244	32	220,750	32	220,303	31	208,451	30
CLOSED FOREST	151,285	22	66,540	10	44,340	6	28,375	4	28,379	4
OPEN FOREST & WOODLAND	170,460	24	179,665	25	128,441	18	123,645	18	93,798	14
AGRICULTURE	52,605	8	148,930	21	209,245	30	197,283	28	221,567	33
BARE	104,778	14	81,747	12	96,124	14	130,537	19	132,901	19

Table 5: Proportional change of cover for four periods – 1975-2007

COVER TYPES	1975-1990		1990-2000		2000-2003		2003-2007	
	ha	%	ha	%	Ha	%	Ha	%
WATER	-528	0	506	0	-447	0	-11,852	-5
CLOSED FOREST	-84,745	-56	-22,200	-33	-15,965	-36	4	0
OPEN FOREST & WOODLAND	9,205	5	-51,224	-29	-4,796	-4	-29,847	-24
AGRICULTURE	96,325	183	60,315	40	-11,962	-6	24,284	12
BARE	-23,031	-22	14,377	18	34,413	36	2,364	2

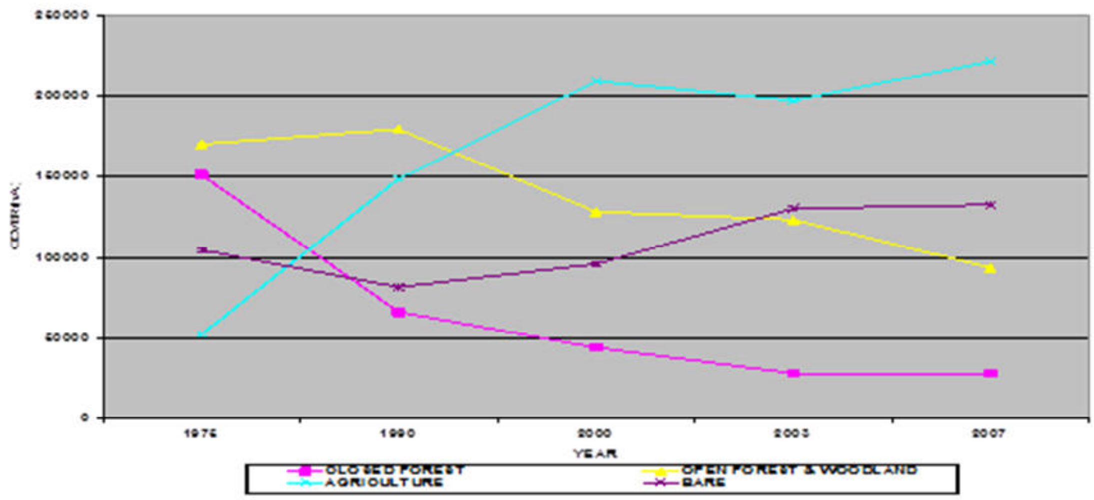

Figure 4: Trend in Land Cover Change (1975-2007)

3.3 Land cover conversions into Agriculture and Bare Classes

The general trend in land cover conversion among various classes shows a high but decreasing proportion of forest cover (Closed forest and Open forest and woodland) to Agriculture from 1975 to 2007 (Figure 4). Conversion from Closed forest into Agriculture was from a high of 60,738 hectares between the periods 1975-1990 to a low of about 3,762 hectares for the period 2003-2007. On the other hand Open forest and woodland has also witnessed some transfers into Agriculture throughout the entire period under consideration. Apart from the period 1975-1990, the proportion of Open forest and woodland into Agriculture has been higher than Closed forest into Agriculture (Table 6). This shows that Open forest and woodland class is the land cover type that has experienced the most transfers into Agriculture followed by Closed forest. However, Figure 5 shows that there have also been some moderate transfers from Closed forest into Open forest and woodland.

The level of forest transfers to Bare class have been lower than conversions into Agriculture, however there are significant transfers from Agriculture into Bare as well. Closed forest into Bare class was high for the periods 1975-1990 and 1990-2000 at about 39,642 hectares and 87,337 hectares, respectively. This cover conversion type was very low for the periods 2000-2003 and 2003-2007 at 404 hectares and 230 hectares, respectively. Transfers from Open forest and woodland to the Bare class is significantly higher than the transfers from Closed forest into Bare class. There is very marginal conversion of Open forest and woodland into the Bare class from 1975-1990 representing just about 500 hectares increase. However, it decreases from 26,243 hectares for the period 1990-2000 to 19,389 hectares for 2000-2003 before it decreases further to 12,742 hectares for 2003-2007. As seen in Figure 5, Agriculture to Bare class represents the smallest proportion of conversions into Bare.

The 'No Change' category represents situations where the cover types have remained the same from the initial year to the later year for a particular period under consideration. Results of the change detection analysis shows that for the period 1975-1990, approximately 61,765 hectares of the total landscape remained unchanged, this increased to 182,484 hectares for 1990-2000, 189,201 hectares for 2000-2003 before it reaches its highest proportion of 255,441 hectares in 2007. The pattern shows that the total area of the landscape in the same condition and unchanged under the various periods increased, suggesting very little re-conversion of a cover class after it has been changed (Table 6).

The increasing proportion of 'No Change' category for the various periods is contrasted by decreases in the proportion of the 'Other changes' category (Figure 5). The 'Other changes' includes changes between land cover classes other than conversions between the Forest classes into Agriculture and Bare classes and from Agriculture into Bare. The proportion of change within this category in the land cover conversion decreased tremendously from 145,971.4 hectares in 1975 to about 99,192 hectares representing a decrease of about 37%.

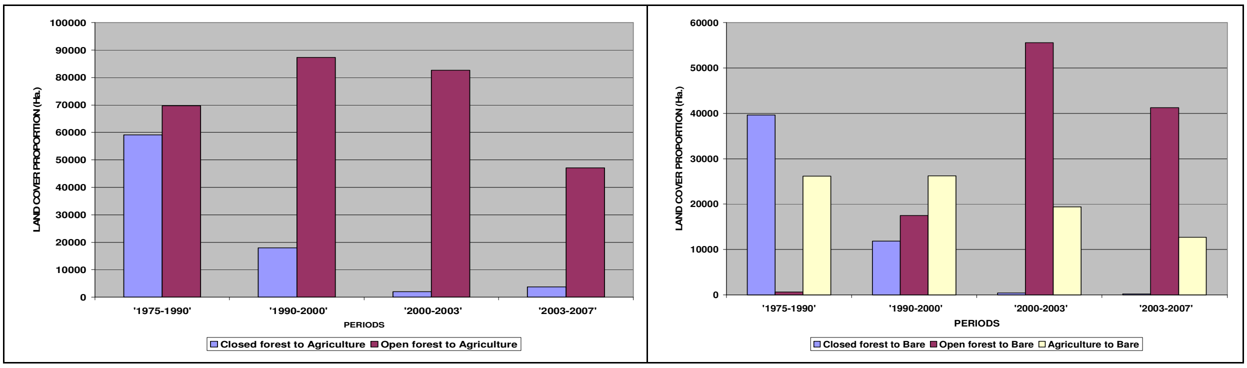

Figure 5: Forest conversion to Agriculture and Bare

Table 6: Land cover conversions 1975-2007

LAND COVER CONVERSIONS 1975 -2000 (HECTARES)				
	1975-1990	**1990-2000**	**2000-2003**	**2003-2007**
CLOSED FOREST TO AGRIC.	60,738.11	18,012.9	2,029.05	3,762.45
OPEN FOREST TO AGRIC.	69,699.3	87,337.3	82,616.8	47,100.9
CLOSED FOREST TO OPEN FOREST	52,117.7	8,527.77	17,875.2	9,047.43
CLOSED FOREST TO BARE	39,642	11,843.1	404.01	230.31
AGRIC. TO BARE	12,648	17,499.3	55,578.5	41,229.7
OPEN FOREST TO BARE	26,164.3	26,243.4	19,388.8	12,742.2
NO CHANGE	61,765.43	182,483.6	189,201.2	255,441.4
OTHER CHANGES	145,971.4	116,798.9	101,652.6	99,191.87
TOTAL LAND AREA	46,8746.2	46,8746.3	46,8746.2	46,8746.3

3.4.Effect of slope on Agriculture expansion

The slope map for the study area (Figure 6) was classified into five classes according to gradient. The steepest slope class located mostly along the edge of the reservoir shore constitutes just about 1% of the total area. Class 1 and 2, the gentler gradients were between slope gradient of 0 -12% and constituted about 77% of total land area of the study area. Class 3 and 4, represent moderate and steep slopes classes and constitute 15% and 7% respectively of the land area of the gorge.

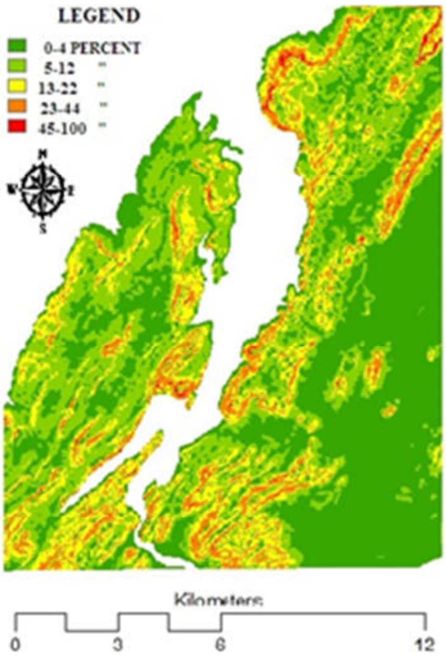

Figure 6: Slope map of the study area

Table 7: Slope Class characteristics

SLOPE CLASS	GRADIENT (PERCENT-%)	DESCRIPTION	AREA (ha)	PROPORTION OF LAND MASS (%)
1	0-4	Very flat terrain	218,366	47
2	5-12	Gentle and flat	136,500	30
3	13-22	Moderate slope	71,473	15
4	23-44	Steep	32,652	7
5	45-100	Very Steep	8,755	1

Much of the increases in cultivable areas occurred in the gentler gradients (Class 1 and 2), accounting for more than an annual average of 80% of the total cultivable areas for most years except the year 1975 where it represents about 63% (Table 7). This shows that the natural preference for gentler slopes for agriculture is still a choice in the decision for allocating farmlands. This is because gentler slope are less susceptible to erosion and are easy to till

The Slope Class 3 (Moderate; 13-22%) has a total land area of about 71,473 hectares representing 15 percent of the entire landscape. However, an average 14.3% of the total landscape in this class has been under crop cultivation yearly. For example in the year 2007, the highest cultivable area ever used for agriculture was attained at 29,073 hectares. The last Slope Class (45-90%) is normally not conducive to agriculture because of its high slope gradient, however in the various years under consideration there has been some form of agricultural activity in this slope class. The land under cultivation in this Slope Class for the various years has increased gradually from 3,111 hectares in 1975 to about 7,650 hectares in 2007 (Table 7).

Generally, there were increases in land under cultivation for all slope classes with the gentler slopes experiencing more increases than the steeper slopes. Table 8 shows the proportion of land devoted to agriculture for all slope classes for the period under consideration. It shows increase for all slope classes for all years but the year 2003. Significant proportions of cultivable land for the various years are within Class 1 and 2. Table 8 shows agricultural expansion in all slope classes for all years.

In the maps (Figure 7), there is conversion of non-agricultural areas to cultivable areas for all years with significant change occurring for the period 1975 to 1990. Increase is observed for all slope classes but the percentage of increase is very subtle for the steep slope classes of 4 and 5. In the later years, the areas of non-agricultural activity are found to be at the very steep slopes mostly along the lake shore.

Table 8: Land under cultivation in various Slope Class (hectares and %)

SLOPE (%)	1975		1990		2000		2003		2007	
	ha.	%	ha.	%	ha.	%	ha.	%	ha.	%
0-4%	21,110	40	74,535	50	98,070	47	98,617	50	108,707	49
5-12%	12,701	25	45,179	30	66,717	32	60,576	31	64,148	29
13-22%	8,150	15	16,322	11	28,159	13	23,977	12	29,073	13
22-44%	7,533	14	8,393	6	10,713	5	9,730	5	11,989	5
45-100%	3,111	6	4,501	3	5,586	3	4,383	2	7,650	3
Total	52,605	100	148,930	100	209,245	100	197,283	100	221,567	100

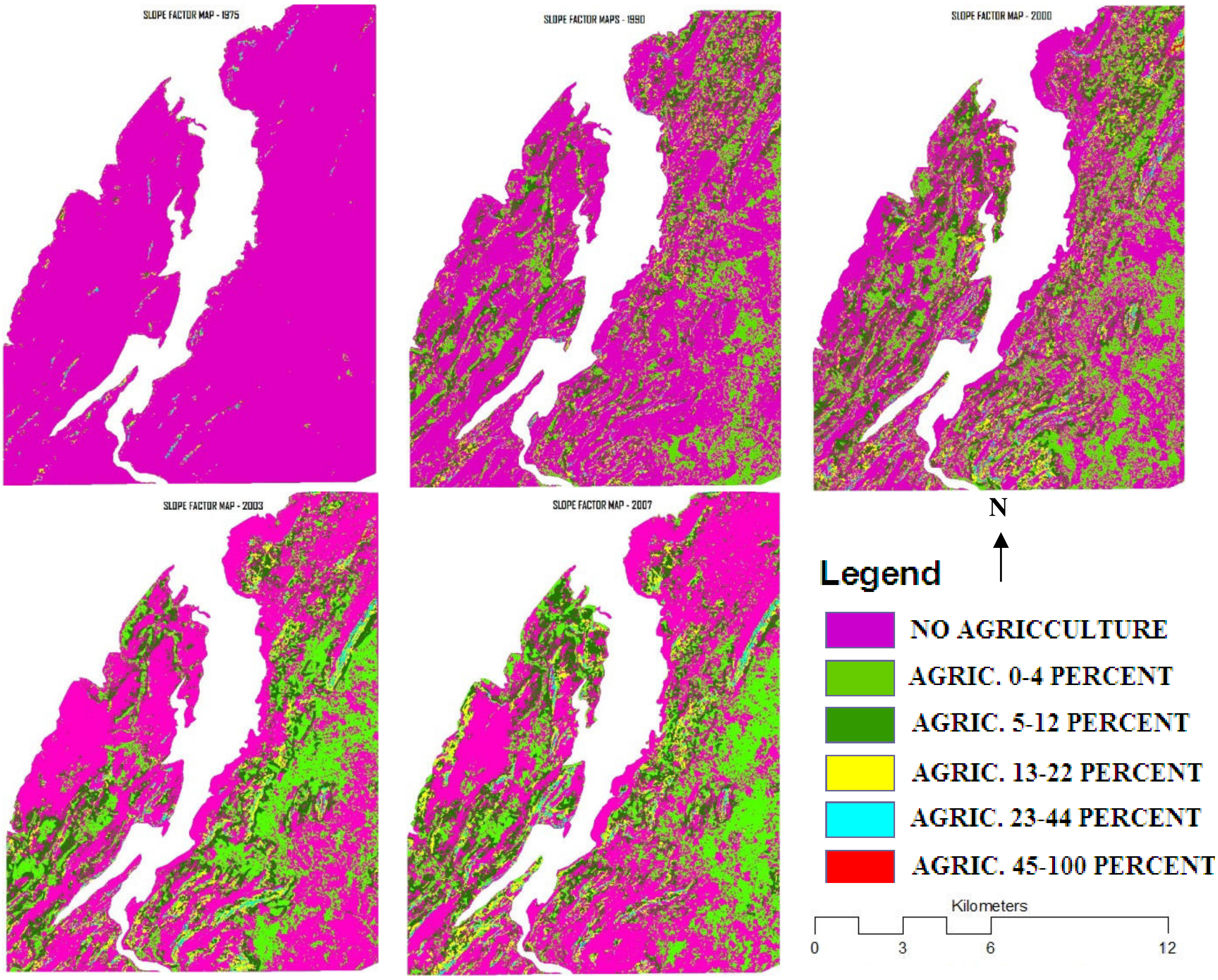

Figure 7: Slope factor maps

4.0. Conclusions

This study has shown that agricultural expansion has been the significant land cover change occurring in the Volta Gorge area. The observation of changes from time-series land cover maps revealed a trend in land cover conversions of various cover types.

The construction of the Akosombo Dam created the Volta reservoir which has resulted in a net increase in the population of the area. This is because of the emerging potential for farming and fishing which has encouraged migration to the area. The increased population has brought immense pressure on forest resources with the net effect being the conversion of such resources into Agricultural fields and settlements.

The interplay of economic, socio-cultural and the physical factor of slope explain the phenomenon of Agricultural expansion and land cover change. Agricultural expansion measured in terms of yield, crop acreage, and image data has increased over the period of consideration from 1975 to 2007.

The post-classification change detection analysis showed that 'Closed Forest to Agriculture' and 'Open forest and woodland to Agriculture' are the major land use / cover transfers over the entire period. This is followed by 'Closed forest to Bare class', Open forest and woodland to Bare class' and 'Agriculture to Bare class'. The conversions into the two cover types, Agriculture and Bare constitute more than 75% of the total landscape change for the period under consideration. The pattern in the conversion from Bare to Agriculture and back to Bare is due to the seasonality of crops cultivated.

The change in the proportion of land cover for the various years shows a decrease in the Closed forest and Open forest and woodland classes and an increase in the proportion of Agriculture and Bare classes. The proportion of the cover of water for the period has experienced very little change except the latter period 2003-2007 when it dipped by about 5%. The conversion into Agriculture from Open forest has been higher than from Closed forest for all the periods under consideration. For the period 1975-2007, 'Closed forest to Agriculture' has decreased from 60,738 to 3,762 hectares whiles 'Open forest and woodland to Agriculture' has also decreased from 69,699 to 47,100 hectares.

There has been a significant increase in the level of agricultural land from 52,605 hectares in 1975 to about 221,567 hectares in 2007 representing an increase of about 96%. The expansion of agriculture that is occurring in the Class IV and V (slope gradient 22-44% and 45-90%) is very significant to note. Farmlands in the slope class V more than doubled from 3,111 hectares in 1975 to 7,650 hectares. The continuous increase in Agriculture activity in Class V though it represents a very small proportion of the total Agricultural area (1%) is an indication of the extent of the demand for land for agriculture. These steep slope gradients are not conducive for agriculture and in the absence of terrace bunds there are high rates of erosion which present a lot of difficulty in soil tillage. However, for the years under consideration, land devoted to Agriculture in these classes increased though gradually. Population pressure has resulted in the high demand for farmlands which had not been restrained by very steep slopes. This also means the demand for farmlands far exceeds the supply of agricultural lands from the much lower slope gradient lands of Class I and II which are more suitable for farming and grazing. Areas of significant cover change are thus more found within gentler slopes where agricultural activity is predominant. The remaining areas of Closed forest and Open forest and woodland cover are limited to steep slopes where accessibility is very limited. In summary, the change in the land cover is occurring in all directions. However, high slope gradient have restrained the speed of conversion of forest resources. Generally, steep sloped gradient does restrain agricultural expansion, on the contrary, the increased population has led to the increase in agricultural activity in the steepest slope class (45-100%) within the Volta Gorge.

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