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THE NEXUS OF POPULATION CHANGE, AGRICULTURAL EXPANSION, LANDSCAPE FRAGMENTATION IN THE VOLTA GORGE AREA, GHANA

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Abstract
The research combines a spatio-temporal analysis of observed changes in a time-series landcover mapping for the years 1975, 1990, 2000, 2003, and 2007 with socio-economic variables such as data on agricultural productivity and population parameters to explain the phenomenon of change in the Volta gorge area. It reveals the pattern of change in landscape and how that corresponds to human factors such as increased population, demand for food and consequent expansion in agricultural activity in the modification of Landscape. The period under consideration (1970-2007) witnessed an increase in population size and household number by about 48% and 42% respectively, though household sizes did not witness a comparable change. The population size correlated positively and very strongly with the crop yield (r^2=0.85), cropped area (r^2=0.53), agricultural cover class (r^2=0.74) but negatively with Closed forest (r^2=0.91) indicative of the high level of conversion of forest resources. Fragmentation analysis using the following indicators; Number of patches (NP), Largest Patch Index (LPI), Patch Density (PD) and Mean Patch Size (MPS) was computed with the FRAGSTATS® software. These metrics generally reveal the varied change within and among classes and also from year to year. For example increase in conversion of forest into cropland corresponds to the increase in the number of patches for the initial years and a decrease for the latter years.

Key Words: *Population, Landcover, fragmentation, Agriculture, Volta gorge*

Introduction

Anthropogenic factors are the main reasons for the change in landscape resulting in the increase or decrease in the size and number of patches (Kamusoko and Aniya, 2007; Loza, 2004; Southworth *et al*., 2004). Fragmentation resulting from landcover change and their relationship with human activities and with socio-economic processes could help explain the factors influencing the process of deterioration of forest ecology (Loza, 2004). Therefore analysing the spatial pattern of landscape change over time facilitates the identification of the social and biophysical processes driving changes in landcover (Brown *et al*., 2000). The construction of the Akosombo

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dam in 1965 at the Volta gorge and the inundation by the lake resulted in massive and rapid change in landcover. 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. These initial changes 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 (F.O.R.I.G., 2003).

Although agriculture is the main economic activity of majority of the people living in the Volta basin, rapid population growth, coupled with low economic standards of living, has also contributed in bringing dire consequences on the natural resource base of the basin (Codjoe, 2005a). It has been shown that there are moderate to strong correlations between population and agricultural landuse in the Volta gorge and, though there may be some degree of agricultural intensification, expansion is the major process of landuse change (Codjoe, 2005b). Population and migration do 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 *et al*., 1998; Angelsen and Kaimowitz, 2001). This lends support to the fact that population size and rate of growth do have effect on the level of agricultural expansion in the entire Volta basin.

Agriculture is the main economic activity of majority of the population in Ghana and the inhabitants of the Volta basin are no exception. It contributes over 40% of the Gross Domestic Product (G.D.P.) and employs about half of Ghana's labour force (G.S.S., 2000 and G.S.S., 2010). Increase in agricultural output has been achieved under farm size expansions, which have resulted in significant transformation of the landscape in the entire Volta basin (Codjoe, 2005b). Access to agricultural land in smallholder agricultural areas that were formally land-abundant has become limited as a result of population increase. This has been as a result of traditional response to declining land productivity, which has been to abandon existing degraded pasture and cropland and move to new lands (Kabubo-Mariaria, 2007). Other factors, which have influenced agricultural frontier expansion, have included easy access to land and favourable market conditions (Pacheco, 2006). Under well functioning economic markets, as land resources become scarce, people are urged to farm previously unused land (extensification) and to increase production per existing unit of land (intensification) (Ruttan, 1991). However, in most developing countries, prevailing land tenure systems do not encourage agriculture intensification but rather encourages expansion to forest lands in response to increase demand for output (Kaimowitz and Angelsen, 1998).

Increased population growth and migration to the area has increased the population tremendously and, consequently, the number of households and household size (Ghana Statistical Service, 2000). The increased population growth, coupled with limited availability and access to farmlands and pasture, has resulted in the development of small-scale agriculture within the frontiers of forested areas. Intense cultivation and fragmentation under poor land management systems has lead to low productivity, which have consequently necessitated the need for the development of new farms.

Population in terms of size, rate of growth, density and household number and size have been cited by various authors as the underlying factors in deforestation (Wolman, 1993). Population density and the percentage of land in forest are generally negatively correlated at the national level, however, there are other variables, which simultaneously affect both population and landcover (Kaimowitz *et al*., 1998). Increasing population has been associated with the shortening of the fallow period and regenerative period for forest re-growth and soil restoration (Wolman, 1993). Usually, the study of the relationship between population and landuse change reveal the existence of a strong, direct relationship between the amount of arable land available and the number of people that could be supported by the agricultural production of the area; that is the carrying capacity (Lutz *et al*., 1993). Rapid population growth, low economic standards of living and consequently growth in per capita consumption have brought in its wake a lot of consequences for agricultural and land resources in the basin as a whole (Codjoe, 2005a).

Landscape fragmentation involves the change in structure of the landscape; it is the breaking of the landscape elements into smaller parcels (Yemefack, 2005). Landscape fragmentation analysis is useful in interpreting the impact of landuse/cover change on a particular cover type, by calculating for each landuse/cover class a range of landscape metrics to describe fragmentation and spatial distribution of classified satellite images. It provides more information not just on extent, but also pattern of landcover changes (Southworth *et al*., 2004). The comparison of landscape metrics reveals spatial characterisations and, therefore, the pattern of landcover modification and transformation for the classified images (Kamusoko and Aniya, 2007; Southworth *et al*., 2004). The Fragmentation analysis is, therefore, useful in understanding the pattern of change and the structure in terms of the size and configuration of patches for the various landcover classes. This helps to observe the changes within and among classes and, consequently, identify the dominance of the various cover type for various periods. A high number of patches for a particular class would, for example, be an indication of the intensity of the landuse as a result of increasing population.

Assessing the driving forces behind landuse / cover change in the gorge and the determination of the extent of loss of forest cover is the object of this research. In general, this involves determining the extent to which the scarcity of land and increasing agricultural expansion have contributed to the loss of forest cover and, consequently landcover change in the Volta gorge area in Ghana. This is necessary if past patterns are to be explained and used to forecast future patterns. The study investigates linearity between agricultural expansion defined in terms of increase in output and/or cropped area, population (growth rate, household size, and density) and the loss of forest cover. The specific objectives to be addressed by the paper are: to ascertain the economic and socio-cultural factors which drive landcover change in the Volta gorge; to determine the level of fragmentation of the landscape as a result of agricultural activity.

Materials and Methods

Study Area

The study area is within the Volta basin of Ghana and covers the entire Asuogyaman District in the Eastern Region and has an area of the size of 699,900 hectares (Figure 1). The selection of the Volta gorge area is because it is the site of the Akosombo Dam, a hydroelectric power (HEP) generation plant which supplies a greater 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 (Ampofo *et al.*, 2015). The coverage of the study area is within latitudes 6°31'31.15"N and 6°15'54.594"N and longitudes 0°0'10.293"W and 0°12'1.846"E.

The study area falls within the Equatorial climatic zone with rainfall of the Tropical monsoon type, which has two peaks. The major rainfall season is between March and July with the peak rainfall in June/July, while the minor season commences in September and ends in 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 and 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 - 33°C and 20 - 23°C respectively. Relative humidity is generally high throughout the year. The monthly figures range between 77% and 98% in the morning to about 76% in the afternoon (VRA Report, 2005).

The vegetation zone along the lake shore is the 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 (F.O.R.I.G., 2003). 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, broken 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 (VRA Report, 2005).

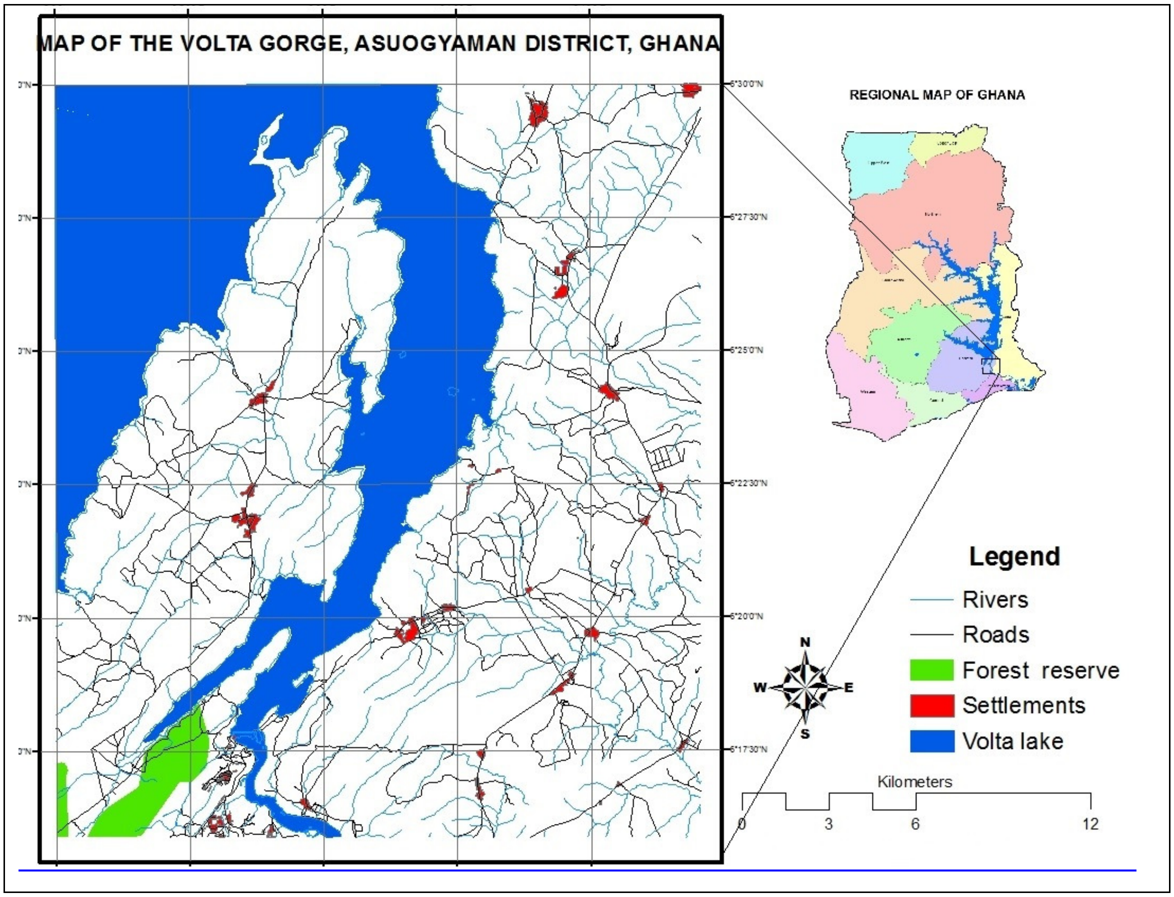

Figure 1: Map showing the study area

Data Sets

Data sets used for the research were obtained from both primary and secondary sources and are not only socio-economic but also include physical data obtained from classified satellite imagery (Table 1). The research combines both socio-economic and physical characteristics to determine relationships as to how people have contributed to the change in the landscape and what have been the determinant factors. This is on the simple assumption that it is people who affect pixel characteristics (Evans and Moran, 2002).

Table 1: Data sets used for the research

DATA	TYPE	SOURCE
Data from classified imagery	Secondary	Ampofo *et al*. (2015)
Agricultural output	Secondary	S.R.I.D.
Demographic data	Secondary	G.S.S.

In addition to the above secondary data were obtained from relevant reports and documents of Ministry, Departments and Agencies (MDA's) in the study area.

Also, demographic and agricultural output data on the following were obtained from the Ghana Statistical Service (Ghana Living Standards Survey and Ghana Population Censuses) and the Statistics Research and Information Directorate (S.R.I.D.) of the Ministry of Food and Agriculture (M.O.F.A.):

Population, Households (number and size), Agricultural productivity (output, acreage). Apart from the year 2000, where census data exist for the research, population data for the other years under consideration (1975, 1990, 2003 and 2007) were obtained from projection from the 1970, 1984, and 2000 census data. The unavailability of segregated data at the district level for 1975 and 1990 necessitated the estimation of the output for those years from the national output using the average proportion of the district for years that data were available on the national estimates. The 2006 data were used to relate to the 2007 image as a result of the unavailability of the 2007 production estimates and also because the January 2007 dry season image corresponds better with the production estimates of the previous year.

Data from Classified Satellite Imagery

The data below (Table 2) from Ampofo *et al*. (2015) shows proportion of landcover class proportions in hectares and percentage. This is correlated with the socio-economic data of population, agricultural output and cropped area.

Table 2: Landcover class proportions in hectares (ha.) and percentage (%) 1975-2007

	1975		1990		2000		2003		2007	
Cover types	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

Source: Ampofo *et al*. (2015)

Landscape Fragmentation Analysis

FRAGSTATS 3.3® software, which is a spatial pattern recognition programme for categorical maps, was used for the quantification of the areal extent of patches within the landscape. This was done by converting and exporting the ERDAS 9.1 Imagine® images into Generic Binary format with a signed 16 bit integer. The five images of landcover representing the 5 dates were subsequently loaded into FRAGSTATS 3.3® together with a class property file. The following Landscape metrics were computed using a cell size of 30 metres;

- Number of patches (NP) - Total number of patches in each class.
- Patch Density (PD) - Patch Density (PD) which measures the NP per 100 hectares is an index that measures the level of fragmentation within each class.

- Largest Patch Index (LPI) - Area of the largest patch in each class as a percentage of the total landscape area.
- Mean Patch Size (MPS) – Average Patch size in each class.

The indices of LPI, NP and MPS gave the estimation of the degree of fragmentation for different landcover types. The Number of Patches (NP) in particular is an excellent measure of the fragmentation of a given class within the landscape; since the landscape size is constant, the greater the number of patches, the greater the degree of fragmentation. The comparison of these spatial characterisations therefore reveals the pattern of landcover modification and transformation for the classified images (Southworth *et al*., 2004).

The major crops cultivated in the district are staples such as cassava (*Manihot esculenta*), maize (*Zea mays*), rice (*Oryza sativa*), yam (*Dioscorea* spp.), plantain (*Musa x paradisiaca*), and vegetables such as okra (*Hibiscus esculentus*), pepper (*Capsicum baccatum*), and tomato (*Lycopersicon esculentum*). The unavailability of segregated data at the district level for 1975 and 1990 necessitated the estimation of the output for those years from the national output using the average proportion of the district for years that data were available on the national estimates. The 2006 data were used to relate to the 2007 image as a result of the unavailability of the 2007 production estimates and also because the January 2007 dry season image corresponds better with the production estimates of the previous year. Besides the above primary and secondary data, demographic and agricultural output data on the following were obtained from the Ghana Statistical Service (Ghana Living Standards Survey and Ghana Population Censuses) and the Statistics Research and Information Directorate (S.R.I.D.) of the Ministry of Food and Agriculture (M.O.F.A.):

- Population
- Households (number and size)
- Income level Etc.
- Agricultural productivity (output, acreage)

Apart from the year 2000 where census data exist for the research, population data for the other years under consideration (1975, 1990, 2003& 2007) were obtained from projection from the 1970, 1984, and 2000 census data. The growth rate and population estimates were estimated using the approach by Codjoe, (2005a);

$R= \ln (P_2/P_1)\ 1/t$ ……………. (1)

Where, P_1……. Is the population of the initial census year

P_2……..Is the population of the latter census year

t ……...Time interval

R………Population growth Rate

The population projection for the years 1975, 1990, 2003 and 2007 was estimated using;

$P_x= P_y \times e^{tr}$ ………………....(2)

Wher, e P_x……..Projected population for year x

P_y……..Census population for year y

e^{tr}……...Time interval as a factor of growth rate

Statistical Analysis

Ranking the explanatory variables of landcover change according to the degree of importance in explaining the spatial variation of landcover was attained using correlation and Pearson's Product Moment coefficient. Pearson's Product moment correlation coefficient (r), a dimensionless index that ranges from -1.0 to 1.0, inclusive, and reflects the extent of a linear relationship between two data sets was done to determine the relationship among the various predictor variables; agriculture yield, farm size expansion, population size and density and the dependent variables which are data from time series remote sensing images for the years 1975, 1990, 2000, 2003, and 2007. Pair-wise ranking and weight assignment was used to rank the responses of the household heads in the social survey. Simple bar graphs and charts were used to show the percentage cover of various landcover types for all the years under consideration and the level of change for the time series landcover change maps.

Results and Discussion

Socio-economic Factors of Landcover Change

Population Growth

The population change as a factor of change in cover was considered under parameters such as, population size, density, households and household size. The periods 1960-1970, 1970-84 and 1984-2000 experienced a national growth rate of about 2.9, 1.9 and 1.7% respectively (Ghana Statistical Service, 2002). These growth rates for the country for various periods formed the basis for population projections of the study area. For the period under consideration, there was a steady rise in the population of the study area from about 47,111 in the year 1975 to about 82,845 in 2007, representing an increase of about 76% (Table 3). Between the years 1975 and 1990, a period of about 15 years, there was an increase in the size of the population by as much as 31%. About 23% of the population increase was attained between 1990 and 2000, 2.6% in the period 2000 -2003 and lastly 6% between 2003 and 2007. The Asuogyaman district has the least population in the region with just about 3.6 % of the population of the region. However, it has a very small land mass, since a significant proportion of the district is covered by the Volta Lake (58%). The real population density calculated from the land area excluding the lake component is very high and is projected to be 130 persons/ km² (Table 3).

Table 3: Estimated population size, density and household size

Year	Population size	Population Density: 1507 km²	Population Density: 640 km²	Household size	No. of households
1970	43,024	28	67	5.0	8,605
1975*	47,111	31	74	5.1	9,237
1984	55,825	37	87	5.1	10,946
1990*	61,519	41	96	5.2	11,831
2000	75,920	49	119	5.0	15,184
2003*	77,904	50	121	5.2	14,982
2007*	82,845	55	130	5.6	14,812

Source: G.S.S.; Population and Housing Census (2000)
*Projected population and household estimates

Agricultural Productivity in the Asougyaman District

About 60% of the population are engaged in farming at the subsistence level with a few commercial fruit production estates. The total cultivable land area was estimated at 633 km², representing about 42% of the total land area, and this, in combination with the high population size and population density, explains the low average farm size of about 2.5 acres. The major crops cultivated were mainly staples, which formed a greater part of the dietary requirements of the inhabitants of the area. These were mainly cassava (*Manihot esculenta*), maize (*Zea mays*), yam (*Dioscorea* spp.), cocoyam (*Xanthosoma sagittifolia*) and plantain (*Musa x paradisiaca*). The pattern of crop yield showed very high and disproportionate contribution of cassava to the total output. It had an annual average output of 92,560 metric tonnes, while rice had the lowest of just about 355 metric tonnes. This was followed by maize, yam, plantain, cocoyam and rice in that order (Table 4). The disproportionate contribution of cassava production as against the other crops is indicative of the fact that it is the number one food item for all the ethnic groups in the area and is very easy to cultivate with no demand for application of fertiliser.

Table 4: Annual crop production-Metric tonnes (1975-2006)

YEAR	MAIZE	RICE	CASSAVA	YAM	COCOYAM	PLANTAIN	TOTAL
1975	4,481	100	48,649	1,987	2,513	4,075	61,805
1990	7,215	114	55,121	2,284	2,005	2,614	69,353
2000	12,800	850	135,450	11,080	3,000	5,840	169,020
2003	14,200	-	175,450	15,750	3,950	7,600	216,950
2006	12,271	-	140,690	12,326	4,120	13,631	183,038
TOTAL	50,967	1,064	555,360	43,427	15,588	33,760	

Source: Statistics Research and Information Directorate (S.R.I.D.) of M.O.F.A.

The unavailability of segregated data at the district level for 1975 and 1990 necessitated the estimation of the yield for those years from the national output based on the average proportion of the district for years that data were available on the national estimates. Generally, there has been a moderate rise in the total area under cultivation in the Volta gorge (Table 5). The period between 1975 and 2006 witnessed a very gradual rise in cropped area from 17,305 to 20,641 hectares, with 2003 experiencing the highest level (25,760 hectares), which corresponds to the highest output of 216,950 metric tonnes of food production over the period. Cassava production contributed 75% of the total output for the various years but had only 56% of the share of the total cropped area, indicating that output per hectare for cassava is very high. The proportion of cropped area for the various crops for the period under consideration as depicted in Table 5 differs from the Agriculture class from the image data (Table 2) because the data from S.R.I.D. of M.O.F.A. excludes the component for pasture.

Table 5: Annual cropped area estimates-Hectares (1975-2006)

YEAR	MAIZE	RICE	CASSAVA	YAM	COCOYAM	PLANTAIN	TOTAL
1975	4,078	291	9,433	1,160	689	1,654	17,305
1990	5,857	327	10,666	781	475	929	19,035
2000	8,000	500	10,500	800	500	800	21,100
2003	8,760	-	14,500	900	600	1,000	25,760
2006	7,816	-	9,978	747	535	1,565	20,641
TOTAL	34,511	1,118	55,077	4,388	2,799	5,948	

Source: Statistics Research and Information Directorate (S.R.I.D.) OF M.O.F.A

Agricultural Productivity and Population Growth

The relationship between population size and density for the years under consideration was correlated to cropped area (hectares) and yield (metric tonnes). There appears to be some linearity between the observed variables assessed using Pearson's product moment. The Pearson's Product Moment (r) between population and crop yield and cropped area are both positive and strongly related at 0.92 and 0.72, respectively (Figure 2). The correlation between agricultural variables of yield and cropped area with population density shows a similar trend, with r being 0.92 and 0.70, respectively. This is an indication that much of the agricultural expansion is very much explained by population growth, and that an incremental change in crop output and cropped area has been as a result of the increase in population size and density.

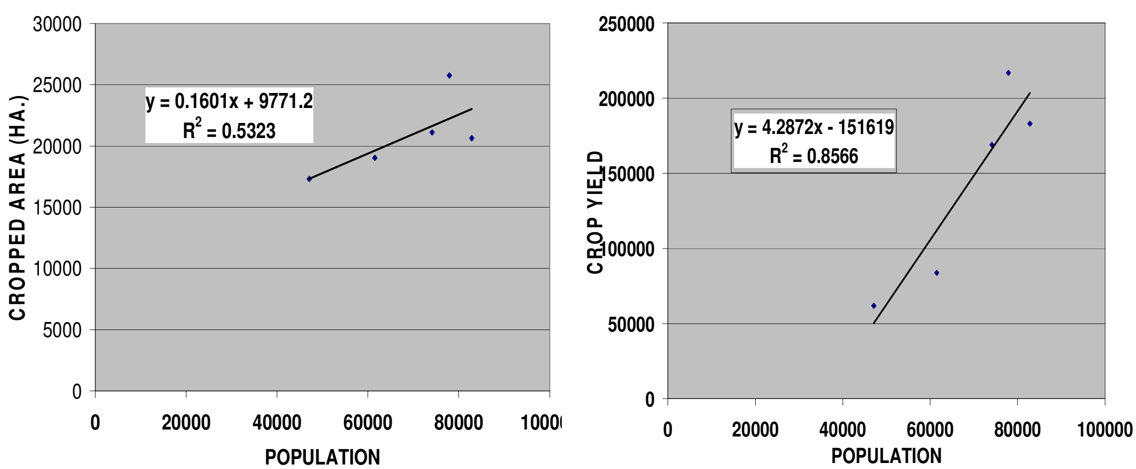

Figure 2: Relationship between population and cropped area and yield

Relationship between Agricultural Productivity, Demography and Image Data

The dependent variables, which are sequences of landcover change data from time series of remotely sensed images obtained from Ampofo *et al.* (2015), were related with independent variables which are determinants of landcover and landuse change. The variables used are population parameters (size and density) and agricultural expansion variables (output and cropped area). Closed forest and Open forest classes have both very strong but negative relationship with the predictor variables. On the other hand, Agriculture and Bare classes have very strong and positive relationship with the same predictor variables as indicated by their Pearson's Product moment coefficient in the Table 6. The inverse relationship means that the increase in Agricultural and Bare classes as a result of the predictor variables corresponds to a decrease in Closed forest and Open forest. The conversions of the landscape are therefore between these two groups of classes. The summary result of the correlation between the two sets of variables is presented in table 6. Cropped area has a positive correlation with the Agriculture and Bare classes and negative correlation with Closed forest and Open forest & woodland. However, the level of relationship of cropped area to all the classes is very low compared to that of other variables (crop output, population size and density). The low level of correlation is because the Agriculture class in the image data includes pasture and fallow land, while the cropped area is that of estimated cropland under actual cultivation. Figures 3 show the correlation between Agricultural cover class and crop output and population size. The coefficient of correlation (r^2) is 0.7403 and 0.9478 for both Crop output and population respectively, which means that 74% and 94% of the increase in the Agricultural class is explained by crop output and population, respectively. Closed forest and Open forest on the other hand has an inverse relationship with both population and cropped area (r^2= 0.9197 and 0.3197, respectively) (Figure 4).

Table 6: Pearson's product moment (r) between demographic, agricultural and landcover data

INDEPENDENT VARIABLES	DEPENDENT VARIABLES -TIME SERIES LANDCOVER data			
	AGRICULTURE	CLOSED FOREST	OPEN FOREST	BARE
CROP OUPUT	0.860427	-0.86062	-0.86329	0.705088
CROPPED AREA	0.670012	-0.74855	-0.5654	0.578277
POPULATION SIZE	0.973531	-0.95903	-0.88413	0.58978
POPULATION DENSITY	0.979889	-0.95375	-0.88758	0.562645

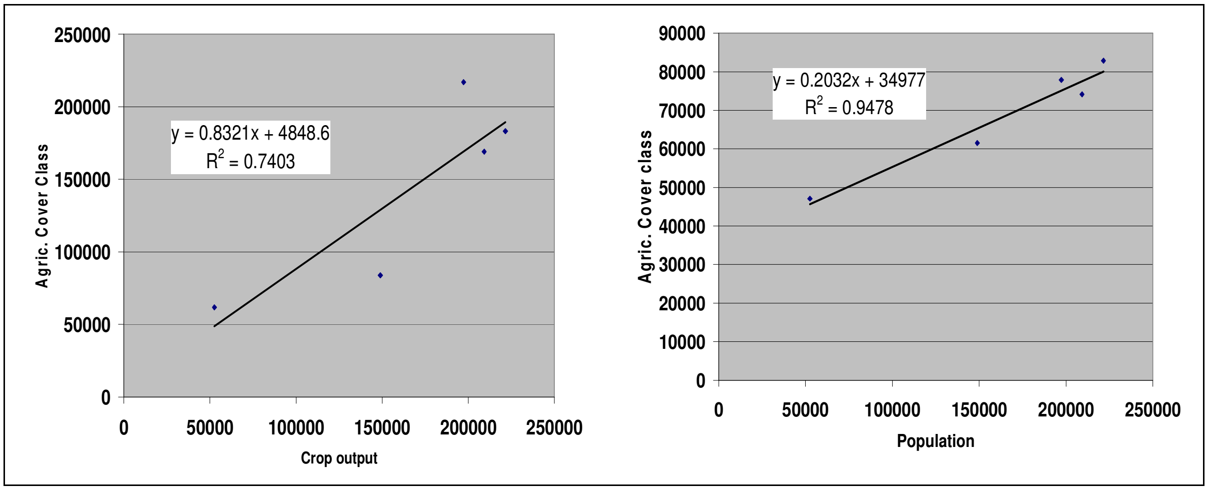

Figure 3: Relationship between Agric. Cover Class and Crop output & Population

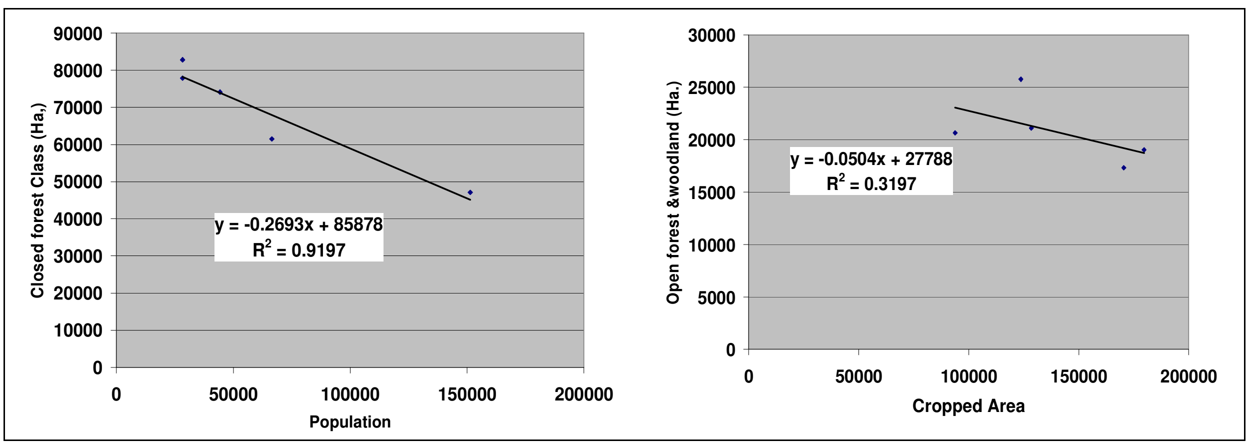

Figure 4: Relationship between Closed and Open forest with Population & Cropped area

Landscape Fragmentation at the Class Level

For the period under consideration (1975 - 2007), an interval of about 32 years, significant changes in the structure of the landscape occurred in the study area. The general pattern reveals a continuous change in the landscape structure, which is revealed by the changing landscape metrics. From Table 7, it can be observed that within the 15 year period between 1975 and 1990, the number of patches (NP) for all classes increased, with the Agriculture class increasing from 16,895 to 95,754, representing a change of about 82%. The number of patches for Closed forest and Open forest both increased by 85% for this period. The level of fragmentations for these two classes explains the phenomenon of forest conversion for the period. The year 2000 experienced a decline in the number of patches for Closed forest and Agriculture, while Open forest and the Bare classes witnessed very significant increases. The period from 2003 to 2007 also experienced a decline in the number of patches for all classes as a result of continuous agricultural expansion. This decline is attributable to the merging of patches into larger patches, which is seen in the increase in the Mean Patch Size (MPS) for all classes (Table 7).

The Patch Density (PD), which measures the NP per 100 hectares, is an index which measures the level of fragmentation within each class. The higher the PD, the higher the level of fragmentation within each class and vice versa. This increased for all classes from 1975 to 1990, but decreased for both Agriculture and Closed forest in the remaining years, reducing to 0.75 and 0.53 hectares, respectively, in 2007. Patch Density for Open forest & woodland and Bare increased tremendously in 2000 before reducing steadily to 0.69 and 0.84 hectares, respectively, in 2007. The Largest Patch Index (LPI) shows the dominance of a particular landuse / cover class. Except for the year 1975, the Agriculture class had the highest the LPI throughout the study period. It increased from 0.75% in 1975 to 13.9% in 2007, indicating the prevalence of agricultural activity in the study area compared to other landuse types (Table 7).

The Mean Patch Size (MPS), which is the average patch size per class has some correlation with the number of patches. In 1975, MPS was highest for Closed forest (22.46 ha), followed by Open forest, Agriculture and Bare classes, respectively. However, by the year 2007, Agriculture had the highest MPS of 41.84 ha, while Closed forest had declined to the lowest with, a MPS of 7.57 ha. The general trend in the MPS showed a decline for all classes from the initial year of 1975, but significant level of decrease occurred for Closed forest and Open forest between 1990 and 2000. In the later years (2003 to 2007,) significant increases in the Mean patch size occurred for both Agriculture and Bare classes.

Population, Agriculture and Drivers of Landcover Change

Population growth and migration to areas deemed favourable for agriculture are a concern in tropical regions worldwide because of the resultant rapid deforestation and ecosystem change (Baldyga *et al*., 2007). Population growth and pressure in the study area is as a result of increased migration of farmers and fisher folks from adjoining districts in the Volta region and other parts of the country. These movements are attributable to the declining soil fertility, decreased precipitation and poverty in the source districts and the perceived potential for agriculture in the destination (Wood *et al*., 2004).

Generally, there is low population density in the entire Volta basin, with about 36% of the population of Ghana (Codjoe, 2005a). Demographic change within the area has seen population rise from 47,111 in 1975 to 82,845 in 2007, and this has been accompanied by a proportionate rise in the number of households and population density. The population density for the district in the census year of 2000 (119 persons/km^2), was higher than the national and regional estimates of 79 and 109 persons/km^2, respectively. This population density was estimated to have risen to 130/ km^2 in 2007 and at such levels of increase, demand for farmlands is great. This level of change is commensurate with the level of change in the Agriculture class from the landcover maps for the period. Population size and density, therefore, have a very strong correlation of 0.97

with agriculture, and this explains the fact that increases in the level of agriculture is attributable to rapid population growth (Wood *et al*., 2004; Codjoe, 2005b).

Table 7: Fragmentation analysis of Landcover classes from 1975-2007

LANDSCAPE METRICS	CLASS	1975	1990	2000	2003	2007
NUMBER OF PATCHES (NP)	CLOSED FOREST	6,737	45,874	34,877	14,423	3,751
	AGRICULTURE	16,895	95,754	68,677	27,781	5,295
	OPEN FOREST & WOODLAND	9,091	66,583	115,282	41,463	4,886
	BARE	10,386	45,366	115,201	34,771	5,890
PATCH DENSITY (PD) (Patches per 100 ha.)	CLOSED FOREST	0.97	6.61	5.03	0.63	0.53
	AGRICULTURE	2.43	13.81	9.9	3.11	0.75
	OPEN FOREST & WOODLAND	1.31	9.60	16.63	2.64	0.69
	BARE	1.49	6.54	16.62	1.68	0.84
LARGEST PATCH INDEX (LPI ;%)	CLOSED FOREST	0.01	0.00	0.00	0.79	0.60
	AGRICULTURE	0.75	0.02	2.01	14.72	13.97
	OPEN FOREST & WOODLAND	2.65	1.64	1.87	2.19	2.90
	BARE	0.98	0.00	0.00	0.68	4.05
MEAN PATCH SIZE (MPS) Ha.	CLOSED FOREST	22.46	1.45	1.27	1.97	7.57
	AGRICULTURE	3.11	1.56	3.05	7.10	41.84
	OPEN FOREST & WOODLAND	18.75	2.70	1.11	2.98	19.20
	BARE	10.09	1.80	0.83	3.75	22.56

Landscape Fragmentation

The landscape analysis at the class level revealed significant trends of fragmentation evidenced by the high Number of Patches (NP), Largest Patch Index (LPI), Patch Density (PD) and the Mean Patch Size (MPS). These metrics have varied within and among classes and also varied from year to year. Demographic change and consequent agricultural expansion are the major driving forces for landuse/ landcover changes which have resulted in the nature of the fragmentation. Settlement growth has also contributed to the change in the variation in the pattern of the landscape (Negendra, 2004). There were both increases for all classes at the initial years and decreases in the number of patches for all cover classes in the period 2003-2007. This is explained by the level of increase of human activity such as agriculture and settlement expansion as a result of population increase explained earlier (Loza, 2004). The changes in Number of patches for all landuse classes followed the same trend of a sharp increase from 1975 to 2000 (especially for Open Forest and Woodland and Bare), followed by a sharp decrease from 2000 to 2007 below the NP recorded in 1975.

The reduction in the number of patches is explained by increased farming activity which has resulted in the merging of some patches for all classes. Consequently, the Mean Patch Size for Agriculture class increased from 3.11 hectares in 1975 to 41.84 hectares in 2007, corresponding with increase in agricultural yield and cultivable area (Table 5 and 6). The land tenure system also explains the extent of change in the landscape structure. This is so for the indigenous communities where land parcels bequeathed to a group of siblings are further redistributed among them causing further fragmentation. The changes in number of patches for all landuse classes followed the same trend of a sharp decrease from 1975 to 2000 (especially for Open forest & woodland and Bare), followed by a sharp decrease from 2000 to 2007 below the NPs recorded in 1975.

Largest Patch Index is a measure of the level of dominance of a particular class type (Turner, 1991). For the period under consideration, except the initial years of 1975 and 1990 where Open forest & woodland had the largest LPI, the Agricultural class had the highest LPI of 14.72 and 13.97 for the years 2003 and 2007, respectively. This was significantly higher than all the other classes put together. The highest LPI for this class showed not only the prevalence of this activity, but also its effect in the transformation of the landscape (Loza, 2004). The increase in the LPI also means that the class became more clumped as a consequence of gains from other classes, particularly, Closed Forest and Open forest and woodland (Nagendra, 2004). Patch Density for all the classes increased in the first initial years in parallel with increases in the Number of patches and then decreased in 2007. An increase in PD indicates that a particular landscape has increased in the number of uses (Southworth *et al*., 2002). There were substantial decreases in the proportion for both Closed and Open forest & woodland and increases for the non-forest vegetation (Agriculture) for the period. This change reflected in the increases in the PD for Agriculture which is indicative of rapid increase in plot sub-division, population growth and human-induced landscape change (Pan *et al*., 2004). For all the years under consideration, the Agricultural class had the highest PD. The PD for Agriculture increased from 2.43 per 100 hectares in 1975 to 9.9 per 100 hectares in 2000 before it dropped to 0.75 per 100 hectares. This is indicative of human alteration of the landscape, in the form of fragmentation of plots into separate non-adjacent patches (McGarigal *et al*., 1995), which is true for the Agricultural class where various crops are cultivated together with alternating pasture and fallow land.

Conclusion and Recommendations

The study has shown that agricultural expansion has been the most significant landcover change in the Volta gorge area. The observation of changes from time-series landcover maps revealed a trend in landcover conversions of various cover types. The construction of the Akosombo dam, which created the Volta Lake, resulted in a net increase in the population of the area. This has been as a result of the emerging potential for farming and fishing which 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 landcover change. Agricultural expansion measured in terms of yield, crop acreage and results from processed image data has increased over the period of consideration from 1975 to 2007. These data correlate strongly with population size and density, indicating how population has resulted in increased demand for farmlands as a source of livelihood. The following conclusions are drawn from the research questions proposed;

- High population size, population density and increased household number emanating from increased growth rate and migration and the development and expansion of settler communities are the factors driving agricultural expansion (Pearson product moment; $r = 0.97$). This is because high population increases demand for food and high food prices encourages expansion of farms into forest fringes. Agricultural expansion has been the major driver of landuse/ landcover change.
- Secondly, the prevailing land tenure system has combined with the population factor and impacted on landcover change. This is because the prevailing land tenure system of sharecropping and renting encourage leasing of land for the cultivation of annual crops only. This results in the conversion of forest patches into croplands and pasture.
- The evolving change in the landscape is seen in the changes in the landscape metrics. Throughout the period of study, the landscape metrics used have varied considerably from year to year and among the various classes. The increase in conversion of forest into cropland corresponds to the increase in the Number of Patches for the initial years and a decrease for the latter years which also meant an increase in the Mean Patch size. The high Landscape Patch Index for Agriculture shows the dominance of that class.

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