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Forest Land use and Cover Change in Ho Municipality of the Volta Region, Ghana

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I. Introduction

Deforestation is globally recognized as one of the world's leading environmental problems affecting productivity of the forest environment and loss of biodiversity (Brook et al., 2003; Sodhi et al., 2004). Global deforestation may occur at dramatic rates, involving changes in land use, vegetation cover change and species translocations (Sutherst, 2006). Tropical forest cover loss is estimated to be accelerating at a rate of 13 million hectares per year, (European Commission, 2013). Such deforestation rates could result in future substantive forest cover loss due to driving forces such as farming, animal grazing and logging (National Geographic Society, 2013). Furthermore, deforestation accounts for the loss of 70% to 90% of the world's genetic resources, tree species and 50 to 100 animal species (Myers, 1994). Human activities are central to the phenomenon of global deforestation, since population growth, land policy, cultural values, science and technology are key factors contributing to global deforestation (Seabrook, et al, 2006).

Deforestation is defined as a progressive phenomenon that results in the conversion of forest areas to pasture and degraded habitats (Panta, et al, 2008). Removal of trees in the forests per se does not constitute deforestation since removal of trees comprises part of normal forest management activities (Martin, 2008). Deforestation, however, takes place when trees are cleared, and neither natural succession nor replanting of the cut trees occurs (Rudel, 2005). Analysis of deforestation often focuses on the extent of forest loss, while less attention is paid to issues of fragmentation due to uncertainty concerning ecological effects of fragmentation on biodiversity (Kupfer, 2005). Forest fragmentation refers to the entire process of forest loss, isolation or change in the spatial configuration of forest remnants due to deforestation (Fahrig, 2003; Fahrig, 1997 and Kleinn, 2002).

In Ghana, deforestation has comprised a critical environmental issue since the 1930s due to diverse driving forces (Benneh, et al, 1990). The colonial forest policies of the past, for example, forcefully took forest lands from individual land owners and families. Those affected by such colonial land policies resorted to exploiting the forest cover indiscriminately, regardless of the negative effects on forest cover (Agbosu, 1983). During the 1960s and 1970s, cultivation of cocoa as an export commodity has further contributed to forest cover change (Dei, 1990). From 1981 to 1985, Ghana's annual deforestation rate was estimated at 1.3%. At this time, timber was the third largest export commodity contributing between 5% and 7% of Ghana's Gross Domestic Product (GDP), (International Institute for Environment and Development [IIED], 1987). Anthropogenic causes of deforestation contributed to a reduction of Ghana's forest cover from 8.2 million hectares to an estimated 0.836 million hectares of forest in 2000, indicating an annual deforestation rate of 2.8%

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(EPA, 2004). From 1990 to 2005 a quarter of Ghana's total forest cover was lost (Boafo, 2013). The loss in forest may result in complete disappearance of forests in 25 years due to lack of collaboration between stakeholders and policy makers to intervene to reduce deforestation (Boafo, 2013). In spite of the challenges mentioned, there was, however, a decline in the rate of deforestation in 2007, resulting in 60,000 hectares of forest gain due to re-planting of trees and tree protection in forest reserves by the Forestry Commission of Ghana. Despite the gain in forest cover, however, it is not likely that Ghana would be able to meet its 35% forest cover target set for 2015 by the Millennium Development Goal 7 (Ladson, 2010).

Accuracy in detecting and quantifying deforestation in Ghana has become more achievable with the application of remote sensing to forest change, effectively becoming available in the late 1980s. Prior to this, acquisition of accurate statistical data on vegetation cover change in Ghana was challenging, as such most deforestation reports were merely descriptive. During this period, foresters themselves served as a major source of quantitative data on forest cover change representing mainly the forest reserves. To bridge the data gap, remote sensing image analysis of forest cover is thus considered a useful complementary approach. Most studies in the areas used satellite multi-spectral data which is cost effective and reliable (Imbernon and Branthomme, 2004; Jones et al, 2008).

In view of the advantages of remote sensing to study change in forest cover, more studies have evolved over the years to estimate deforestation. For example, NDVI image analysis from 2000 to 2008 shows evidence of land degradation with particular reference to deforestation in Ghana (Centre for Remote Sensing and Geographic Information Services [CERSGIS], 2010). A participatory GIS and remote sensing study in Bolgatanga and Talensi- Nabdam districts of northern Ghana further revealed changes in vegetation health and cover from 1990s to 2004, accounting for 600km^2 of degraded land which negatively affected food crop production (Agyeman, 2007). As far as the Volta Region is concerned, however, few studies have been undertaken using remote sensing. In the Ho Municipality in particular, application of remote sensing to forest cover change is quite new. As a result, this study is aimed at providing reliable quantitative data for planning and policy making.

II. Study Area

The Ho Municipality is located approximately between latitude 6° 30' N and 6° 55' N and longitude 0° 30' E and 0° 12' E in the Volta Region (Figure 1). The Ho Municipality covers a total land area of 2,660 sq kms and shares boundaries with North Tongu in the south, Abutia in the west and Ketu district in the east. Two districts were recently carved out of the Municipality, hence the land area has since reduced. The population is approximately 235, 331 (Ghana Statistical Service, 2000), comprising 28.9% of the population in Volta Region. The population growth rate is 3% per annum (Ho District Assembly Profile). The mean monthly temperature ranges fall between 32°C and 22°C, and the annual maximum and minimum temperatures fall between 37.8°C and 16.5°C respectively. There are two periods of rainfall in the district which are from March to July and from mid August to October each year, and total annual rainfall ranges from 750 mm and 1020 mm (Ho District Assembly Profile).

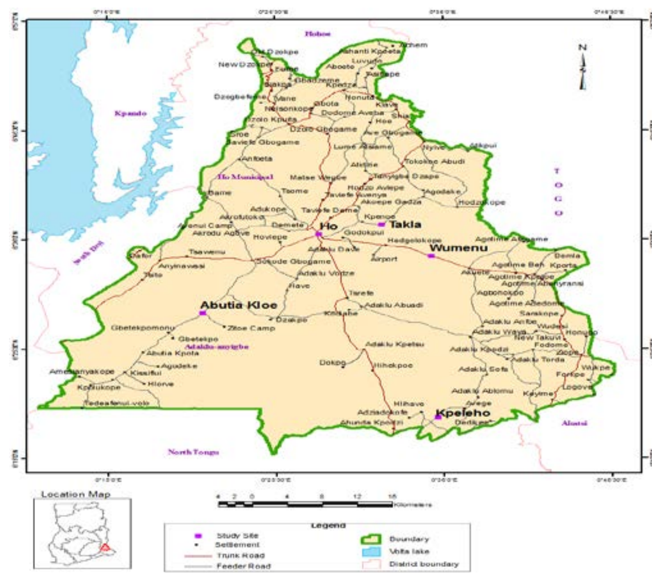

Figure 1 : Map of Study Area Ho Municipality.

III. Methodology

a) Data Sources and Classification Scheme

Landsat MSS 1975, Landsat TM 1991 and Landsat ETM$^+$ 2001 ortho-rectified imageries covering Takla, Wumenu, Abutia Kloe and Agbokofe were classified using Maximum likelihood supervised classification method to arrive at changes in land use and cover. The classification scheme used was the AFRICOVER scheme. AFRICOVER defines land cover as the observed physical cover, as seen from the ground or through remote sensing, such as the vegetation (natural or planted) and human constructions (buildings and roads) that cover the earth's surface (FAO, 1997). The AFRICOVER classification scheme recommended the use of classifiers that are hierarchically arranged, starting with a broad level class allowing for more detailed sub-classes as vegetated and non-vegetated areas (FAO, 1998). Questionnaire data was also analyzed to identify key drivers of deforestation in the Municipality.

b) *Accuracy Assessment*

Classified images are associated with errors. To reduce these errors, post classification refinements are done using an error matrix approach, to compare two thematic maps (such as the ground truth map and the automated image classification map) (Canadian Centre for Remote Sensing, www.ccrs.nrcan.gc.ca). The error matrix is computed as the total number of correct class predictions (sum of diagonal cells) divided by total number of cells (Verbyla, 1986). Accuracy assessment of classified images is undertaken to verify the extent to which classified imagery is accurate, by using different approaches. Other methods used include the producers and users accuracy that includes calculating percentage accuracies and validating accuracy results using Kappa statistics such as used in this study (Sexton et al., 2013). These assessments make it possible to correct conservative and optimistic biases in image classification due to misclassification of land cover classes.

For this study accuracy was assessed using the error matrix and the result validated using Kappa coefficient values. According to Congalton, (1996), Kappa coefficient values are categorized into 3 main groupings: a value greater than 0.80 (80%) represents strong agreement, values between 0.80 and 0.40 (80% to 40%) represent moderate agreement, and values below 0.40 (40%) represent poor agreement. The accuracy result for 1975 image was 92%, and a Kappa coefficient value of 0.8659 meeting the significant acceptable level. Assessment of accuracy for the 1991 classified image produced an overall accuracy of 89% and Kappa coefficient value of 0.8409 (again, indicating that the result is acceptable). Finally, accuracy for 2001 classified image was an overall accuracy of 86% and a Kappa coefficient value of 0.7794, which is within acceptable error margin.

c) *Detection of Change in Land Cover*

Change detection refers to monitoring land surface change over time using repetitive coverage and consistent data generated from satellite images as such image data sets are cost effective and reliable for estimating forest condition and broad scale land cover change (Jones et al, 2008; www.ciesin.Org/TG/RS/-chngdet.html). Land cover change detection can be done using different methods such as the tasseled cap method, principal component and regression analysis method (Healey, et al, 2005; Muchoney and Haack, 1994; Cohen, 2003). For this study, a change detection statistical method was used as it has the capability of clearly showing the distribution and extent of land covers types considered useful for the spatial assessment of the extent, nature and accurate quantification of the rate of land cover changes (Schneider et al, 2008). The spatial resolution of satellite images are important for the identification of objects and detecting changes in land cover types. It is for this reason that a mudium resolution Landsat images were used for the study (Swinne and Veroustraete, 2008; Julien and Sobrino, 2008, Yu et al., 2011).

IV. Results

a) *Analysis of Classified Imageries 1975, 1991 and 2001*

Analysis for Landsat MSS 1975, TM 1991 and ETM+ 2001 images show land cover classes for riparian forest, woody/grassland vegetation, settlements and bare areas (Figure 2). The analysis is based on pixel values and actual vegetation cover changes in hectares. Pixel values are the individual picture elements of objects classified as forest, woody/grassland vegetation, settlement and bare areas. An aggregation of these pixels provides a composite view of the cover types and further quantitative analysis of the pixels provide actual values of cover types in hectares to determine the extent of change. The forest cover in 1975 was quite extensive, coupled with dense woody/grassland vegetation, but the forest cover declined in 1991 and 2001 as shown by the classified images (Figure 2). Extensive grassland vegetation and bare areas classified depict deforestation and degradation caused by anthropogenic activities. For example; presence of fire scares in the 1991 imagery suggests the adverse effect of bushfires on the vegetation.

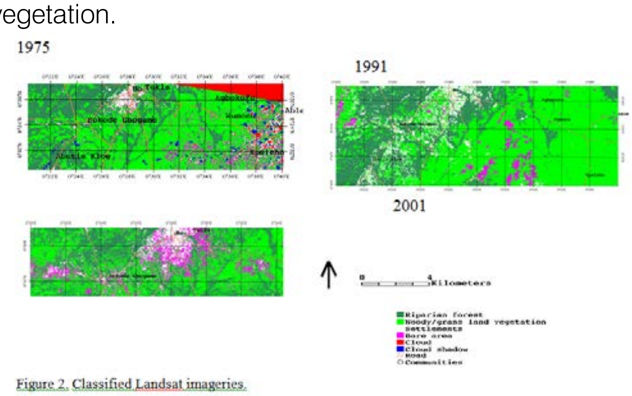

Figure 2 : Classified Landsat imageries.

i. *Detection of Change from 1975 to 1991*

The change detection statistical pixels report for 1975 and 1991 shows initial state classes (1975 classified image pixels) in columns and the final state classes (1991 classified image pixels) in rows (Table 1). Results show land cover types that remained static (riparian forest) and land cover classes that changed from one state to the other. Areas of change included 23294 pixels classified as riparian forest in the initial state but changed to woody /grassland vegetation in the final state image.

Table 1 : Change Detection Statistics Pixel Report from 1975 to 1991.

Classes	Riparian forest	Woody/grass vegetation	Settlements	Bare area	Row total	Class total
Riparian forest	8855	4623	124	221	13823	14388
Woody/grass land vegetation	23294	34950	1175	3236	62655	65488
Settlement	1371	1995	1058	600	5024	5564
Bare area	1068	9888	350	2877	14183	14730
Class total	34588	51456	2707	6934	0	0
Class change	25733	16506	1649	4057	0	0
Image difference	-20200	14032	2857	7796	0	0

As shown in the bottom row, the image difference for riparian forest cover is negative 20200, indicating a decrease in the class size for riparian forest cover compensating for the increase in woody/grassland vegetation by 14032 pixels. Positive image difference figures of 2857 and 7796 show increases in the class sizes for settlements and bare area pixels respectively. In terms of absolute values, riparian forest decreased by 6562 hectares, woody/grassland vegetation increased by 4558 hectares while 2532 and 928 hectares of increases were recorded for bare areas and settlements respectively (Figure 3).

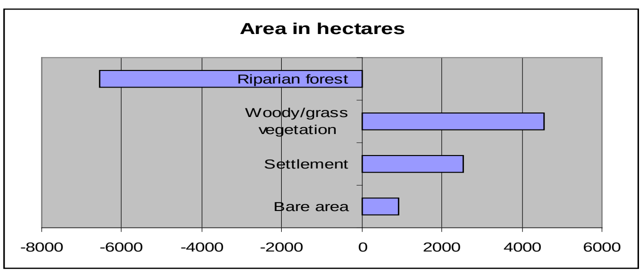

Figure 3 : Change Detection Image Difference Statistics Report from 1975 - 1991.

In terms of the rate of change in cover, 58% of riparian forest cover was lost. In the case of the woody/grassland vegetation, settlements and bare areas, 27.2%, 105.5% and 112.4% positive changes occurred, meaning an increase in the area of these respective land covers (Figure 4). The causes of deforestation investigated using questionnaires revealed multiple factors driving such change, including agriculture expansion, and commercial production of charcoal since the 1970s by Sissala migrant from

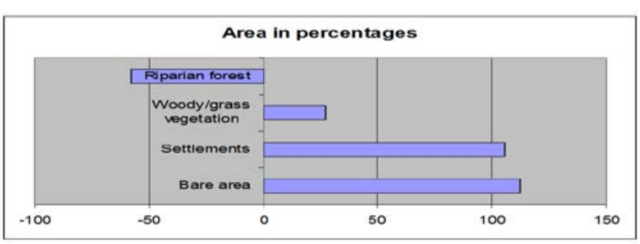

Figure 4 : Change Detection Image Difference Statistics in Percentages from 1975 – 1991.

Upper West Region to the Ho District. It was further evident that a major fire in 1983 resulted in significant vegetation loss. The burnt vegetation has, however, made it further possible for farmers to cultivate original forest and woody lands that could have regained their cover during the rainy season.

ii. *Change Detection Statistics Report For 1975 – 2001*

The change detection statistical report for the period 1975 to 2001 shows initial state classes (1975 image) in columns, while the final state classes (2001 image) are in rows (Table 2).

Table 2 : Change Detection Statistics Report 1975 – 2001.

Classes	Riparian forest	Woody/grass vegetation	Settlements	Bare area	Row total	Class total
Riparian forest	8726	12225	501	2467	23919	26613
Woody vegetation/grass land	18216	37615	1896	7360	65087	71032
Settlement	2452	3039	1487	1183	8161	9277
Bare area	6296	14276	1032	3036	24640	27268
Class total	35690	67155	4916	14046	-	-
Class change	26964	29540	3429	11010	-	-
Image difference	-9077	3877	4361	13222	-	-

The image difference pixels count for riparian forest is negative 9077, indicating a decrease in the riparian forest cover, accounting for the positive increase of woody/grassland vegetation by (3877). The analysis shows loss of 2949 hectares of forest in 26 years (Figure 5), which is in contrast to gains in woody/grassland vegetation by 1259 hectares, increases in settlement sizes, and bare areas by 1416 hectares and 4295 hectares respectively.

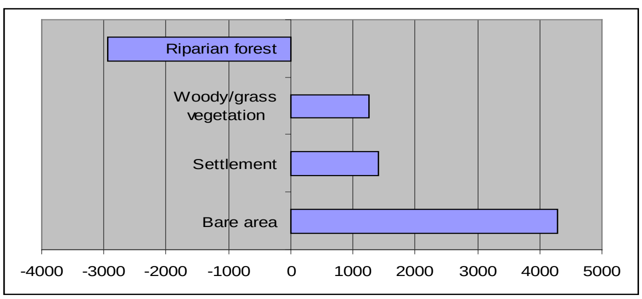

Figure 5 : Change Detection Image Difference Statistics Report from 1975 to 2001.

The rate of change in the land cover between 1975 and 2001 was 25% (Figure 6). In 26 years, it is clear that deforestation has been caused by rapid increases in the municipal population, increased woodfuel extraction, attitudes to lighting of bushfires, timber extraction and use of weed killers which terminated the growth of plants. These driving forces have resulted in dramatic deforestation rate of 50% from 1975 to 1991 compared to a less dramatic loss of 25% from 1975 to 2001. The less dramatic later loss of forest cover may have been due to an afforestation project embarked upon in the mid 1990s by FORUM. The FORUM project ensured that degraded forest reserves and off reserves were reforested and some grassland vegetation turned to woodlots to provide households with wood energy (thereby reducing.

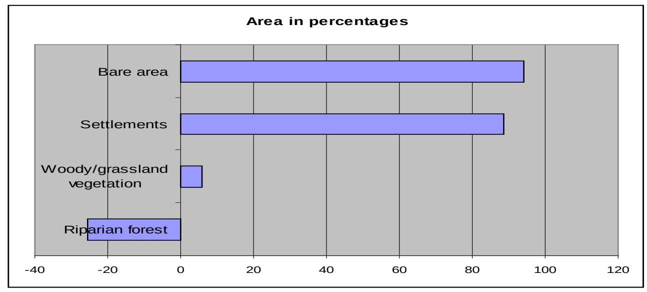

Figure 6 : Change Detection Image Difference Statistics from 1975 to 2001.

pressure on the forest cover). In terms of the woody/grass land vegetation cover, a 5.7% increase occurred, while 88.7% and 94.1% increases occurred for settlements and bare areas respectively. The increased percentage change for bare areas is likely due to bushfires that exposed the soil surface to wind erosion during the dry season and water erosion during the rainy season.

V. Discussion

Analysis of Landsat imagery revealed changes in the nature, extent and rate of deforestation, as well as other land cover classes from 1975 to 2001. The nature of land cover changes were varied. Accordingly, transition from forest to woody/grass vegetation, to settlement and bare areas occurred, while a loss of 6562 hectares of forest from 1975 to 1991, and 2949 hectares of forest loss from 1975 to 2001 was evident. It should be observed that an additional study in Adaklu Traditional area (a major charcoal and fire wood producing area in the Ho Municipality) indicated significant deforestation over 25 years (Adanu, 2009). The rate of deforestation is of concern estimated at 58% from 1975 to 1991, with a further more moderate loss of 25% from 1975 to 2001 due to multiple factors such as converting forests to farmlands, extensive exploitation of wood energy and effects of fire on forest lands. Apart from the decrease in forest cover, there were gains in woody/grass vegetation by 27.2%, settlements by 88.7% and bare areas by 84.1% from 1975 to 2001. A similar study at the Barekese catchment area in the Ashanti region of Ghana showed a 43% loss of open canopy forest, 32% increase of grasslands and 70% increase of open areas from 1973 and 2000 (Boakye *et al*., 2008). At the national level, an analysis of the vegetation cover in all ecological zones of Ghana using NDVI imagery from 2000 to 2008 produced results confirming loss of closed canopy forest by 12,607 square kilometers in 2000, and a further loss of 11,748 square kilometers in 2008 (CERSGIS, 2010).

Verification of the accuracy of classified image pixels showed overall accuracies of 92%, 89% and 86% for the 1975, 1991 and 2001 images respectively, an indication that the results are within an acceptable error margin.

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