Land Use Land Cover Change within Kakum Conservation Area in the Assin South District of Ghana, 1991-2015

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Abstract

Kakum Conservation Area is roughly 1187km^2, extending over large portions of forest reserves in the Assin South District of Ghana. The district hosts the remaining biodiversity hotspots within highly fragmented rainforest of West Africa. Although the conservation has been gazetted as protected area, it has since been impacted by illegal chainsaw logging, expanding agricultural land use and built construction to meet the housing needs of the rapidly growing population of the district. However, there is paucity of data on the magnitude, rate and types of land cover change occurring in the district. This study seeks to address these by examining the magnitude, the rate and direction of change in land cover between 1991 and 2015. The study objective was achieved using supervised classification and post classification change detection of remotely sensed Landsat satellite imagery of the district taken in 1991, 2001 and 2015. The results show that, within the study period, the population of the area increased by 2.9%, thick forest decreased by 8.2km^2, light forest increased by 5.3km^2 and built environment increased by 2.9km^2 per annum. These results are considered potential hindrance to sustainable development, including biodiversity conservation in the forest reserves and climate change mitigation in general. There is therefore need for measures to end deforestation and stimulate reforestation of the lost forest cover. The district needs to initiate an enquiry into the effectiveness of the current forest reserve management practices and sustainability of land use systems in the district.

Introduction

Land use land cover change (LULCC) is a major biophysical process altering the earth's land resources with enormous consequences on sustainable development and climate change mitigation (Coulter et al., 2016; IPCC, 1996; Stow et al., 2014). The rate of forest cover change (deforestation) and biodiversity loss to cropland and other land use systems (Käyhkö et al., 2011; Keenan, 2015) in pursuit of development is about 1,000 times faster than the ability of the forest to regenerate (Gross et al., 2017; Hudson et al., 2014; Pimm et al., 2014). Land use land cover change had links with overexploitation of natural forest resources during the last 50 years in Africa (Losch et al., 2012; Ntiamoah and Afrane, 2008; Ryan & Ntiamoa-Baidu, 2000). For instance, of the remaining forest cover in Ghana about 33.7% (1,254km^2) was lost between 1990 and 2010 (Food Agriculture Organization, 2010). The rate of forest cover decline was estimated to be about 2.24% per annum between 2005 and 2010 (Ministry of Environment Science Technology and Innovation (MESTI), 2015; National Development Planning Commission (NDPC), 2010). Currently, the national rate of deforestation is estimated at 2% per annum, representing 1,154km^2 (Forestry Commission, 2015; Oduro et al., 2015). These statistics are uninspiring in an era of green economy and heightened concerns for climate change and sustainable development.

The Food and Agricultural Organization (FAO) defines land as the earth's surface, which includes the earth's biophysical and geochemical natural resources (Briassoulis, 2000; FAO, 1996; Turner et al., 1995). Land cover is the biophysical state of land (Turner et al., 1995). According to the United States (US) Center for Geographic Information and Analysis (CGIA 1994), land simply refers to the "vegetative and non-vegetative characteristic of a portion of the earth surface". The use of land resources for human activities gave rise to the term land use (Briassoulis, 2000). In this study, land cover represents vegetative and built areas in the Assin South District while land use describes the human activities on the land. LULCC is the conversion of land cover "from one cover type to another" (Briassoulis, 2000). Two types of vegetative land use types were observed in this study, thick forest and light forests. Thick forest represents dense closed canopy forest vegetative cover, typical of tropical primary and secondary rainforests in reserves and outside reserves. Light forest represents tertiary and degraded forest canopy cover including agriculture farmlands around towns, in reserves or outside reserves. The magnitude of LULCC usually varies with time (Briassoulis, 2000; Turner et al., 1995). According to Turner et al., (1995) several factors account for LULCC; some of which include bio-physical and socio-economic drivers, environmental and politico-religious impacts, construction and urban development (CGIA, 1994).

Unsustainable LULCC causes perturbation in ecosystem functions and services directly on land surface, below it and above it (Alsterberg et al., 2017; Hulme et al., 2001; Newbold et al., 2015; Obeng and Aguilar, 2015; Pabi, 2007). It causes disturbance in ecosystem functions like biochemical cycles, energy balance and water balance. It also affects the delivery of ecosystem services such as biodiversity, wildlife, habitat, wild fruits, pollution control, climate regulation, etc. This study is concerned about the magnitude and direction of change in the biophysical state of land in the Assin South District of Ghana.

Kakum conservation area (KCA) which includes Kakum National Park (210km^2) and Assin Atandansu Resource Reserve (150km^2), covers the largest portions of five forest reserves in the Assin South District (1187km^2) of the Central Region (Wiafe, 2016). The district is a host to parts of the remaining biodiversity hotspots within highly fragmented rainforests of West Africa (Dudely et al., 1992; Doe, 2013). The KCA was gazetted as protected forest reserve 1992 (Wiafe, 2016). Although this rich land cover plays major role in conserving biodiversity (Dudley et al., 1992), carbon sequestration and climate change mitigation (Duguma et al., 2001; Wiafe, 2016), it is not spared from natural and artificial LULCC (Ghana Forestry Commission, 2010). According to the Ghana Forestry Commission, (2010), it is suffering from the impacts of illegal chainsaw logging, expanding frontiers of agricultural land use (50%) and built environment (10%) to serve the rapid population growth around protected forest reserves. Within the last three decades, vegetative forest cover, just like other parts of land, has latently experienced potential dangers of unsustainable land use and management (Asase et al., 2010; Doe, 2013; Kusimi, 2008; Wiafe, 2016). These activities associated with population growth (2.9%) (Ghana Statistical Service (GSS), 2014; NDPC, 2010; Wiafe, 2016 MESTI, 2015; Coulter et al., 2016; Doe, 2013; Stow et al., 2014) are known for causing deforestation and environmental degradation (Benhin and Barbier, 2004; FAO, 2010; Greco et al., 2012) in the KCA (Doe, 2013; Ghana Forestry Commission, 2010; Wiafe, 2016).

Ecological community and succession theories (Gleason, 1926; Odum, 1992; Palmer et al., 1997) have become relevant in forest cover loss restoration practice (Stanturf et al., 2014). For example, the sustainable principle of renewable natural resource use, requires that the rate of resource use should not exceed the successional ability of the resource to regenerate itself (Barr, 2008; Chapin et al., 2009; Doe, 2013; Yiran et al., 2012; Gross et al., 2017; Hudson et al., 2014; Pimm et al., 2014). The use of ecological theories in land use land cover (LULC) management and restoration, requires knowledge and data about the biophysical state of the resource (land) being used (Hobbs & Harris, 2001; Palmer et al., 1997; Stanturf et al., 2014) .

However, a careful review of existing literature (Attua and Fisher, 2011; Coulter et al., 2016; Stow et al., 2014) shows knowledge about the direction and rate of LULCC in the Assin South District are rare. In other words, there is paucity of knowledge about the direction and rate of LULCC in the district. These gaps in literature are what the current study seeks to fill. The focus of the study was to examine the direction (decrease or increase), the magnitude (km2) of change and the rate of vegetative and built LULCC in the Assin South District from 1991 to 2015.

Temporal analysis, of the direction, magnitude and rate of LULCC is essential for planning, managing, and monitoring sustainable development (Kusimi, 2008; Stow et al., 2014; Yiran et al., 2012). With increasing human population and two billion hungry (Conway & Wilson, 2012), overexploitation of natural resources is adverse to sustainability of environment, agriculture and development (Giller et al., 2006; Barr, 2008; Barrow, 2006; Goosen, 2012; Scoones, 1998). The findings of the study would inform land and agriculture resource management, forest restoration, development planning and policy formulation in the Assin South District.

Study area

This study was conducted at the Assin South District in Central Region of Ghana. Figure 1 shows the study area.

With Nsuaem-Kyekyewere as its administrative capital, the Assin South District is located within latitude 5°30''N and longitude 1°2''W, covering a total land area of about 1187km^2 (Assin South District Assembly (ASDA), 2014). The population of the area was about 104,244 in 2010 and it was estimated to be growing at an average rate of 2.9%, which is above the national growth rate of 2.5% (GSS, 2014). Figure 2 shows the trend of population from 1991 to 2015. As shown in Figure 2, the

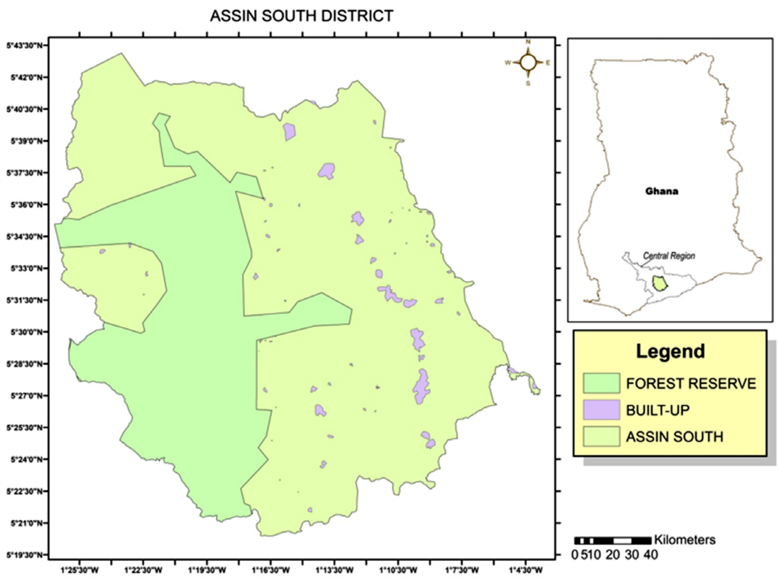


Figure 1 Map of study area: Assin South District
Source: Authors' construct 2018

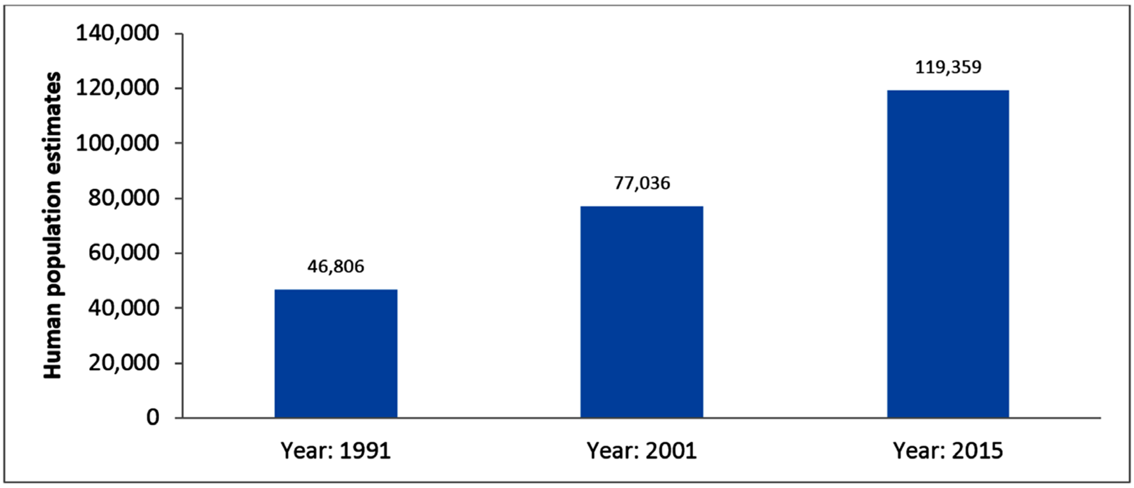


Figure 2 Population increase in the Assin South District from 1991 to 2015.
Source: Authors' computation based on 2010 Population and Housing Census, GSS

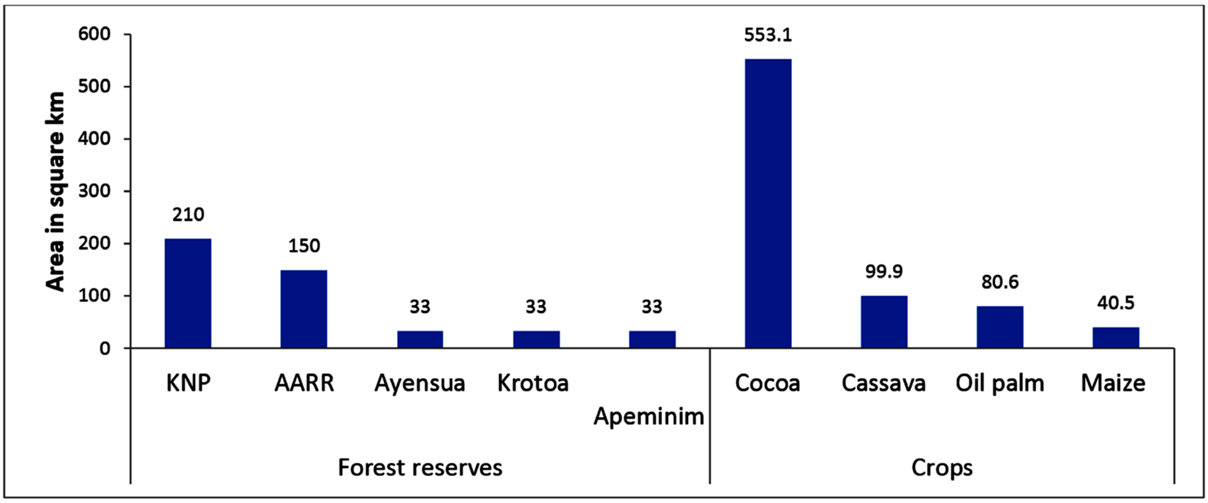


Figure 3 Vegetative land use in the Assin South District
Source: Assin South District Ministry of Food and Agriculture MoFA, 2010

population of the area was about 46,806 in 1991. This increased to 77,036 in 2001 and to 119,359 in 2015.

The climatic conditions of the area are suitable for forest and agriculture land use. The average annual rainfall is about 1700mm-2000mm with a relative humidity of 60%-70%. The average annual temperature ranges between 20^{o}C and 30^{o}C. The area has a bi-modal raining seasons with major and minor rainfall seasons in April-July and September-November respectively. The topography is undulating in nature and is drained by major streams such as Kakum, Ochi, Wanko, Kyina and many other minor streams and swamps. The vegetation is mainly thick evergreen and semi-deciduous forests and home to trees like Wawa, Odum, Mahogany, bamboo, raffia palms etc. Most revered endangered wildlife species such as African forest elephants, Diana monkeys, yellow-back duikers, giant bongo antelopes, birds and butterflies are found in the reserves (Dudley et al., 1992;Doe, 2013). As shown in Figure 3, five forest reserves make up the KCA. These include the Kakum National Park (KNP), the Assin Atendansu Resource Reserve (AARR), Ayensua, Krotoa and Apeminim forest reserves. The KNP and AARR were gazetted as wildlife reserve with Legislative Instrument (L.I.) 1525 in

TABLE 1
Properties of data downloaded from United State Geological Survey

Satellite	Sensor ID	Date acquired*	Sun elevation	Spatial resolution	Spectral band
Landsat 4 Level 1T	TM	1st Sept, 1991	44.68572457	30 x 30 m^2	Blue, Green, Red
Landsat 7 Level 1T	ETM	2nd Oct, 2001	60.66222386	30 x 30 m^2	Blue, Green, Red
Landsat 8 Level 1T	OLI_TIRS	28th Nov, 2015	51.11618792	30 x 30 m^2	Blue, Green, Red

*WRS Path: 194, WRS Row: 56

1992 but portions of the area remain under concessionaires since 1948 (Wiafe, 2016).

Human settlements estimate was over 1500 settlements, mainly along major road networks such as the Cape Coast-Kumasi road (GSS, 2014) and on forest fringes (Doe, 2013). As shown in Figure 3, the main livelihoods of the people are natural resource based activities like cocoa, citrus, oil palm, maize cultivation (Doe, 2013; MOFA (Ministry of Food and Agriculture, Assin South, 2010). Illegal chain saw timber logging and wildlife poaching are often reported (Dudley et al., 1992). Figure 3 also shows land area covered by each of the five (5) reserves and land area covered by four (4) livelihood activities of the area.

Materials and methods

Data processing and analysis

The study objective was achieved using supervised classification and post classification change detection of remotely sensed Landsat satellite imagery of Assin South District as of 1991, 2001 and 2015. Table 1 provides details about the satellite data used in the study. Pre-processing and classification activities were done using ENVI 5.3 software and the embedded algorithms.

These images (Landsat data) were selected after review of several others. Attempt was made to avoid images that were impaired by cloud and haze. Preference was given to images which had same date (month/season) of acquisition and sun position. The path (194) and row (56) of the selected images were the same but they were acquired during different months, September 1991, October 2001 and November 2015. These images were then calibrated individually for radiometric correction. Due to the small size of the ground resolution, there was no need to perform geometric correction for the level 1T data which masked off clouds and cloud shadows (Stow et al., 2014). After sub-setting the region of interest (ROI), the three LULC types were classified using supervised classification. This was done using maximum likelihood (ML) algorithm in ENVI 5.3 software, guided by observed stable training sites (Lillesand et al., 1999; Lillesand et al., 2004; Parivallal, 2014; Stow et al., 2014). The ML classifier assumes Gaussian normal distribution for class pixel statistics of each band. It estimates "the probability that a given pixel belongs to a specific" LULC type (Parivallal, 2014). Equation one (1) shows mathematical expression of the ML classifier, following Parivallal, (2014):

$$y_k(b) = 1np(w_k) - \tfrac{1}{2}1b|\textstyle\sum_k| - \tfrac{1}{2}(b - m_k)^T \ \textstyle\sum_k^{-1}(b - m_k) \quad \text{[Equation 1]}$$

Where, $y_k^{(b)}$ is the probability of b belonging to k class of LULC type, b is image data of n-deminensions of n bands, $p(w_k)$ is the probability that LULC type w_k occurs in the image and is assumed same for all LULC types, $|\sum_k|$ is the determinant of covarience matrix ($\sum_k$) for data in LULC type w_k, $\sum_k^{-1}$) is the inverse of $\sum_k$ and m_k is the mean of k^{th} class vector.

The software produced a total of 1,968,373 pixels and the percentage of pixels in each LULC type. As shown in equation two (2) and three (3), each pixel is equivalent to 0.0009km^2 and thus provides input for estimating the LULC size in km^2:

$$One\ 30m^2\ pixel = \frac{30m \times 30m}{1000m \times 1000m} = 0.0009km^2 \quad \text{[Equation 2]}$$

$$Area\ of\ LULC = number\ of\ pixels\ per\ class \times 0.0009km^2 \quad \text{[Equation 3]}$$

In absence of ground truth data, using pixel counts to estimate LULC area (km^2) often leads to over estimation due to overlapping pixels (Pretorius and Pretorius, 2015). Therefore, the pixels for each of the observed LULC type were converted to km^2 using the following equation four (4):

$$Area\ of\ LULC\ in\ km^2 = proportion\ of\ pixels\ counts \times 1187km^2 \quad \text{[Equation 4]}$$

Where, 1187km^2 is the total land cover size of the study area. Change in LULC was then calculated using equation five (5) and the rate of change was computed using equations six (6) and seven (7):

$$Change\ in\ LULC(km^2) = \left[\frac{LULC_{current\ year} - LULC_{past\ year}}{LULC_{past\ year}}\right] \quad \text{[Equation 5]}$$

$$Percentage(\%)\ change\ in\ LULC(km^2) = \left[\frac{LULC_{current\ year} - LULC_{past\ year}}{LULC_{past\ year}}\right] \times 100 \quad \text{[Equation 6]}$$

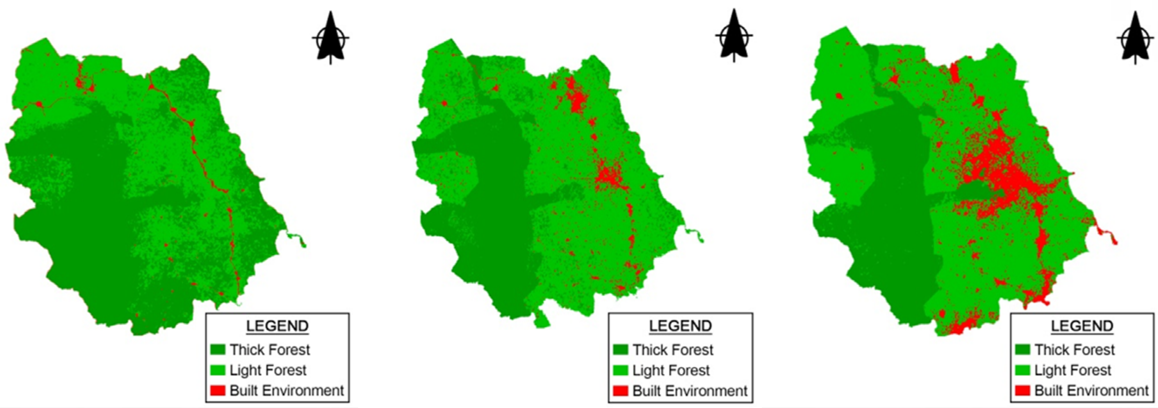
$$Rate\ of\ change\ in\ LULC\ per\ year = Percentage\ change\ in\ LULC \div 25\ years \quad \text{[Equation 7]}$$

Results

Figure 4 shows the pre-processed subset Landsat satellite images of the district before

Year 1991 Year 2001 Year 2015

Figure 4 the subset Landsat images of Assin South District before classification
Source: Authors' construct, 2018



Year 1991 Year 2001 Year 2015

Figure 5 Classified land use land cover in Assin South District
Source: Authors' construct, 2018

classification was done. Figure 5 shows the same images after the LULC classification was carried out.

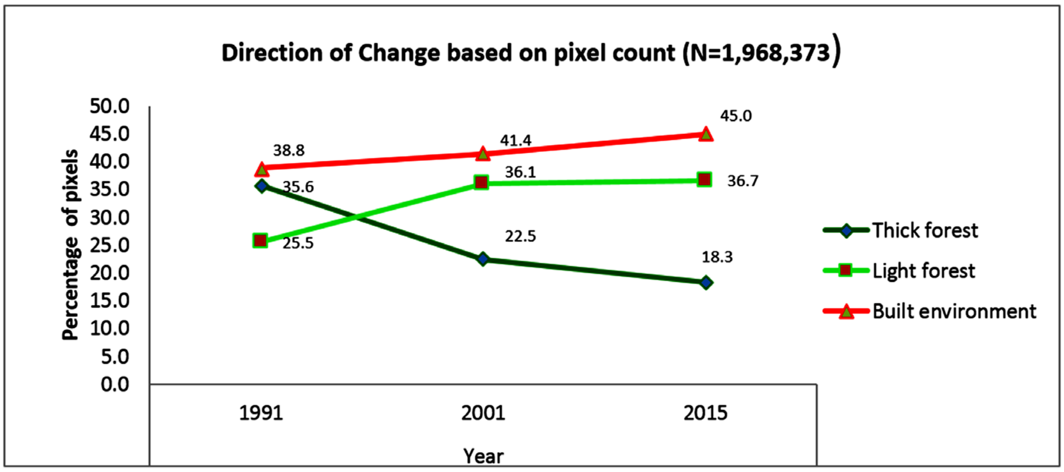


Figure 6 Change in land use land cover based on pixel counts
Source: Authors' computation, 2018

Figure 6 shows the direction of LULCC based on the percentage of number of pixels. In 1991, 35.6% of the total land size (1187km^2) in Assin South District could be associated with thick (dense) forest cover, this land use type declined to 18.3% by 2015. In contrast, light vegetative cover increased from 25.5% to 36.7% during the same period (1991-2015). Similarly, built environment increased from 38.8% to 45.0%. Figure 7 shows the direction of LULCC in terms of land area (km2) for each LULC type observed.

Table 2 presents the change in LULC and the rate of change during the study period. In terms of LULC size (km^2) as shown in Figure

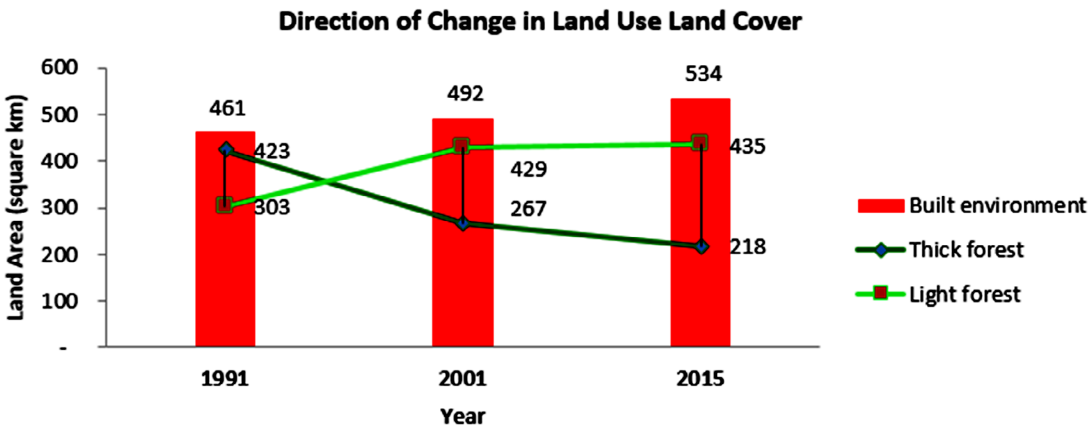


Figure 7 Magnitude of Land use land cover change in km^2
Source: Authors' computation, 2018

TABLE 2
Change and rate of change in land use land cover in the district from 1991 and 2015

Classified LULC	Rate of Change in Land Use Land Cover		
	Magnitude of change (km^2)	Rate of change/year	Magnitude of change (km^2)/year
Thick forest (1991-2015)	-205	-2%	-8.2
Light forest (1991-2015)	132	2%	5.3
Built environment (1991-2015)	73	1%	2.9

Source: Authors' computation, 2018

7 and the rate of change as shown in Table 2, it was observed that, the proportion of thick forest vegetative cover reduced from 423km^2 to 218km^2 (decrease of 205km^2). In contrast, light forest vegetative cover, increased from 303km^2 to 435km^2 (increase of 132km^2). The frontiers of built environment expanded from 461km^2 to 534km^2 at the rate of 1% (2.9km^2) per annum.

Discussion

The results showed a downward trend of thick forest cover loss of 205km^2 at the rate of 2% (8.2km^2) per annum. As per the operating definition of the current study, this loss does not include light or tertiary forest cover. The quality of the thick forest cover loss is richer in primary and secondary forest cover than the national loss rate estimate. Although, the observed rate (2%) compares quite well with the Ghana national forest cover loss estimate (2%) (Forestry Commission, 2015; Oduro et al,, 2015), the national rate includes tertiary forest cover. Therefore, the result implies that, the Assin South District, especially the KCA is losing its primary and secondary forest cover. On the other hand, the FAO global forest resources assessment report stated that Ghana as a whole has gained forest cover during 1990 and 2015 (Keenan, 2015). The statistics of this study show weakness in the climate change mitigation potential (Barrow, 2006; Hulme et al., 2001; IPCC, 1996) of protected forest reserves in the Assin South District. The effectiveness of the KCA management was previously questioned in the report of Cobbinah et al., (2015), who revealed poor engagement of local communities and traditional authorities in the reserves management. Secondly, although, Coulter et al., (2016) reported a declining trend of secondary forest cover loss of 45km^2 for the entire southern Ghana during 2000-2010, this current report shows that the situation is more (205km^2) precarious in the Assin South District.

Whereas forest loss could be attributed to natural phenomena (Kennedy et al., 2009), the study shows that, in contrast to declining dense (thick) forest cover, frontiers of less dense (light) forest and agriculture land use cover have expanded by 132km^2, at 5.3km^2 per annum. This direction of change (increase) is consistent with the report of Coulter et al., (2016), who associated 62% forest conversion to agriculture farmlands from secondary forests.

In addition, the district is reported to have experienced a more than average national population growth of 2.9% (Ghana Statistical Service, 2013). Coupled with a general rise in non-agriculture unemployment (Attua and Fisher, 2011; Cobbinah et al., 2015; Kusimi, 2008) in forest fringe communities, the observed expansion in agriculture land use is not surprising. However, the sustainability of livelihoods in such land use systems is of essence (Giller et al., 2006; Losch et al., 2012; Scoones, 2009; Yiran et al, 2012; Doe, 2013;Dobermann & Nelson, 2013).

The study results also revealed another reason for loss in the observed thick forest cover. This was indicated by the observed expansion in built environment, 73km^2, at the rate of 1% (2.9km^2) per annum. This finding corroborates previous reports by Anglaaere et al., (2011), Coulter et al., (2016), Wiafe, (2016), Yiran et al., (2012), Stow et al., 2014 and Yaro et al., (2016) which showed pressure of growing human demographics on natural resources (Ghana Forestry Commission, 2010). Since the Assin South District serves as a growth pole and growth centre for macroeconomic development (Anaman et al., 2007), expansion in built environment, including residential and commercial buildings, markets, bare lands and roads is inevitable. Therefore, the observed rate and magnitude of lateral expansion of built environment in the district is unfriendly to climate change mitigation and sustainable development.

Conclusions and Recommendations

The primary/secondary forest vegetative cover in the Assin South District is reducing rapidly than expected. This is a potential hindrance at the same time, an opportunity for sustainable development, especially, for sustainable agriculture intensification (SDG2), forest restoration, reforestation, biodiversity conservation (SDG 15) and climate change mitigation (SDG 13).

There is need for further enquiry into the effectiveness of current forest reserve management and sustainability of agricultural land use systems in the district. This would provide further justification to start an extensive restoration and reforestation of the lost thick forest cover in the district and intensification of sustainable cocoa agroforestry, tree planting and other forest conservation and restoration programmes in the study area.

With increasing human population and expansion in built environments in the district, developing distinctive indicators for sustainable cities and communities in line with sustainable development goal (SDG) eleven (11) is required. This would be useful for built environment planning and monitoring to minimize deforestation caused by expansion in built land cover. As more of such built environment expansions are expected in the future, there is urgency for sustainable built land use planning of the district. The Assin South District needs to promote vertical buildings, conserve green spaces and reduce the current trend of horizontal expansion that is exploiting green spaces.

Acknowledgement

We thank staff of the Department of Geography and Resource Development, University of Ghana, especially Dr. G.A.B Yiran and Dr. George Owusu who assisted in the acquisition of data for the study.

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