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Deforestation in forest-savannah transition zone of Ghana: Boabeng-Fiema monkey sanctuary

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A B S T R A C T

Forests provide many resources, ecosystem services and absorb carbon dioxide, which helps in climate regulation. In spite of the enormous benefits of forests, the issue of deforestation is still ongoing. There has been a continuous decline in forests globally and the forest area of Boabeng Fiema Monkey Sanctuary (BFMS) in Ghana is facing a similar threat. The aim of the study is to determine the different forest cover types and changes in the forest of BFMS. Satellite images for the years 1992, 1998, 2004, 2010, 2016 and 2018 were downloaded. Unsupervised and supervised classification were performed to determine the different forest cover types and remote sensing software was used to detect the changes in the forest cover. The forest cover was classified into six classes; closed forest, open forest, savannah woodland, savannah, farmlands and built-up area. Available data suggests that between 1992 and 2018, closed forest decreased by 242.19ha, open forest increased by 122.85 ha, savannah woodland increased by 7.47ha, savannah increased by 6.48 ha, farmland increased by 39.39ha and built-up area increased by 65.7ha. The changes in closed forest, open forest, farmland and built-up were all significant. Decreasing forest cover of BFMS is a threat to sustainable ecotourism since the forest serves as a habitat and food source to the monkeys. This research serves as guide to other researches aiming at determining forest cover changes in forest-savannah transition zones. In addition, the results have produced an inventory of the forest, which will help forest resource managers sustainably manage the forest.

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1. Introduction

Forests cover one third of the world's land surface and provides many resources (Chao, 2012). These resources includes food, timber, fibre amongst others (Millennium Ecosystem Assessment (Program) and Millennium Ecosystem Assessment, 2005). In addition, the forest provides other services. These services are; ecological, economic, sociocultural, scenic and landscape services (Lindberg et al., 1997). The United Nations in 2014 emphasized on carbon storage, nutrient cycling, water and air purification, and maintenance of wildlife habitat as ecological functions of the forest (Lindberg et al., 1997; FAO, 2007; Harris et al., 2012).

Forests absorb carbon dioxide and this helps in the regulation of the climate. However, when these forests are cleared as a result of deforestation and forest degradation, the carbon is converted to carbon dioxide into the atmosphere (Chave et al., 2005). Deforestation and forest degradation of the tropical forest account for about 15–25% annual global greenhouse gas emission (Gibbs et al., 2007). There have been many conferences worldwide aimed at finding lasting measures to mitigate the effects of climate change and put an end to the processes leading to it under the United Nations Framework Convention on Climate Change (UNFCCC) (Miles and Dickson, 2010). Amongst which was the Reduce Emissions from Deforestation and Forest Degradation, and Foster Conservation of Forest Carbon Stock, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks(REDD+) project in 2005 (UNFCCC, 2011).

The REDD + gave the same precedence as deforestation and forest degradation to prevention of carbon discharge from preservation of forest carbon stocks, sustainable management of forests and the enhancement of forest carbon stocks (Minang and Murphy, 2010). Monitoring and detecting changes in forest cover and mapping of forests are giant steps toward climate change mitigation (Vastaranta, 2012). However, doing all these manually can be inefficient, costly and time consuming if not nearly impossible (Du et al., 2014). There is therefore the need to integrate a method which is appropriate and cost effective. Remote sensing (RS) and geographic information system (GIS) are well known in the measurements of forest and are becoming increasingly important in this era of deforestation and its contribution to climate change and global warming (Foody, 2002; Gibbs et al., 2007). Maps produced from satellite images are used for monitoring changes and prediction of future changes of the forest. This is significant in monitoring studies, resource management and planning activities (Foody, 2002).

There are 196 parties under the UNFCCC and these parties have been grouped into Annex 1 parties (developed countries) and non-Annex 1 parties (developing countries). Canada, Australia, Denmark, Germany and United States of America are all Annex 1 parties whilst Ghana, Angola, Cambodia, Benin, and Chile are all non-Annex 1 parties (UN-REDD Programme, 2016). The REDD + agreement included the mobilization of funds from developed countries to assist the development of results-based activities by developing countries (Streck and Costenbader, 2012). Since Ghana is participating in REDD + there is the need to update the country's forest maps and changes in forest cover over the years which on the contrary are few. (Donkor et al., 2016). Maps of forest cover provides a static depiction of the land and produces an accurate information from forest resources for forest managers (Kumar, 2011; Vastaranta, 2012).

The Boabeng-Fiema Monkey Sanctuary (BFMS) in the Bono East Region of Ghana is characterized by forest and savannah woodland vegetation (Fargey, 1991; Saj et al., 2006). The forest–savannah transition is the most widespread ecotone in tropical areas and sensitive to changes in climate and other driving causes (Oliveras and Malhi, 2016). Many botanists and foresters in Ghana believe the area covered by savannah today would have been forested if it had been left undisturbed and these changes can be attributed to anthropogenic activities (Swaine et al.,1976; Afikorah-Danquah, 1997). The BFMS also serves as a home to two species of primates (the ursine black and white colobus and the Campbell's monkey) and the only place in Africa where the two different species of monkeys exist in large numbers and co-exist harmoniously with humans (Saj et al., 2006; Eshun and Tonto, 2014). In addition, it is a sacred grove, an important example of how traditional values in Ghana have helped in wildlife conservation (Fargey, 1992; Dudley et al., 2013).

Though the monkeys are protected the forest does not receive the same level of protection (Fargey, 1992; Wong and Sicotte, 2006). There have been decrease in the closed forest and habitat of the monkeys in BFMS and this can be attributed to anthropogenic activities in the forest (Kankam, 2010). Deforestation leads to alteration of the structure and composition of the forest, affects the ability of the forest to sequester carbon from the atmosphere, release of CO_2 into the atmosphere, loss of biodiversity and exposes the area to changes in climate (Oliveras and Malhi, 2016). In addition, there is a positive relationship between the closed forest cover and the presence of one species of the primate (*C. vellerosus* monkey) (Kankam, 2010). Decreasing closed forest cover indicates a decrease in the habitat of the monkeys as well as the monkeys.

This research was based on the integration of RS, GIS and field data. In addition, satellite imagery was acquired to produce a forest cover map of the vegetation of the BFMS forest. GIS is a useful instrument in forest management because it helps answer questions about the location of the forest, its condition, trends in the forest, patterns of the forest, amongst a lot (SH, 2016). RS has added useful instrument for forestry applications. The spectral resolution of sensors, repeated coverage and digital nature of data allows detection of forest conditions which cannot be recognized by human eye (Ethirajan and Mariappan, 2013). Moreover, forest cover map serves as a useful component in environmental assessments and provides data for change detection (Jones, 2006).

Most research works done in the BFMS focused on the primates and not on the forest. The aim of the research is to determine the forest cover types of BFMS and the changes in the forest cover from 1992 to 2018.

2. Materials and method

2.1. Study area

The study area is in the Nkoranza North District and lies within the transitional zone between the savannah woodland of Northern Ghana and the forest belt of the South (Ghana Statistical Service, 2014). The study area falls within longitudes 1°41″10′ West to 1°42″15′ West and latitudes 7°41″30′ North to 7°43″33′ North (Fig. 1). Communities surrounding the study area are; Busunya, Kokrompe, Senya, Bomini, Boaman, Odumase, Domeabra and Yefra. The study area is a sacred grove, an important example of how traditional values in Ghana have resulted in wildlife conservation (Fargey, 1992; Dudley et al., 2013). The monkeys are protected though nonetheless the forest does not receive the same level of protection (Fargey, 1992; Wong and Sicotte, 2006).

The vegetation of the study area is dry semi-deciduous. The study site serves as an ecotourism site and in 2003 won the 6th National Tourism Tourist Attraction (Eshun and Tonto, 2014). It recorded the highest number of visitors and generator of revenue. The Nkoranza North District is dominated by agriculture and its related activities.

2.2. Satellite imagery

Multispectral images of Landsat 5 TM were obtained for the years 1992, 1998 and 2004. Landsat 7 ETM was acquired for the years 2010, 2016 and 2018. The images were obtained from the US Geological Survey (USGS) Centre for Earth Resources Observation and Science (EROS). Data collected were within the same season of the years, the spatial resolution of the images were 30 m. The various bands were stacked together. Remote sensing software was used to correct scan lines for the years 2004, 2010, 2016 and 2018. The study area was clipped from the images and radiometric correction (haze reduction) was performed on the images.

Classification of forest cover types was done using unsupervised and supervised classification method. Unsupervised classification was performed for image segmentation and to have a fair idea about the image. Supervised classification on the other hand, was done to select training data samples and generate signature file for classification. Global Positioning System (GPS) was used to pick coordinates in the study area for supervised classification. Accuracy assessment was performed using GPS points (150 referenced points) obtained from field survey of the study area. A post-classification method was used for change detection, as this study's primary objective was to detect and analyse the spatio-temporal forest change. Land Cover Modeler (LCM) was used in analysing the forest cover changes that have occurred between the various land cover classes in the periods 1992–1998, 1998–2004, 2004–2010, 2010–2016, 2016–2018 and 1992–2018. The results generated six change

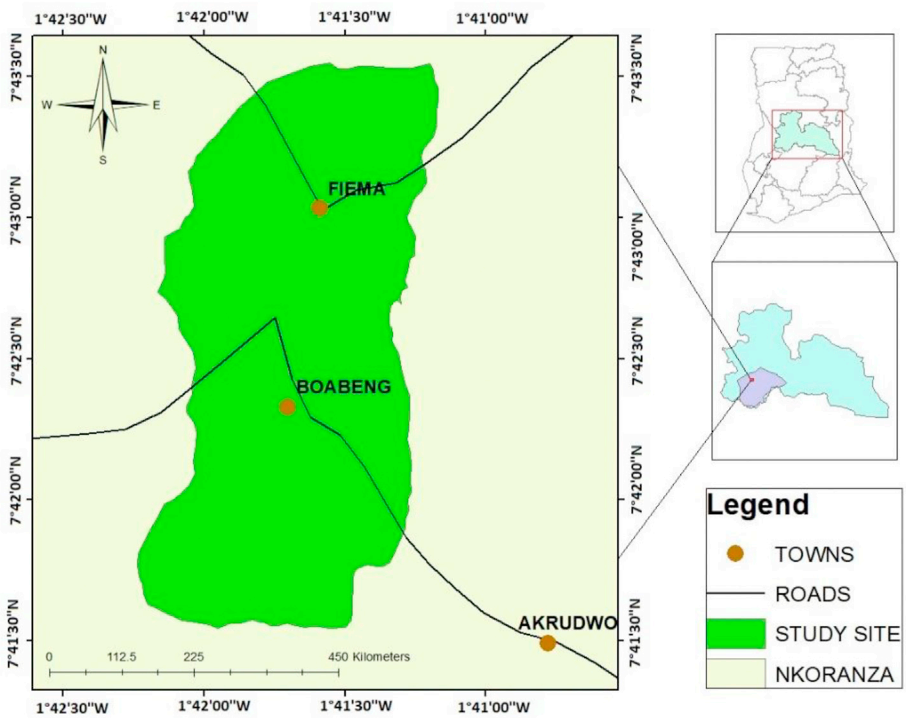

Fig. 1. Study area.

maps to address the spatial distribution of change patterns within the given time interval. This study adopted Markov Chain analysis and Cellular Automata (CA) as modelling techniques in predicting forest cover change in the future. A Markov chain analysis (MARKOV) was used to estimate the transition matrix between the two past and documented dates (1992 and 2018). The forest was classified into six classes (Fig. 2). That is, closed forest (multiple trees species in the various storeys that have a continuous canopy obstructing sunlight from reaching the floor), open forest (discontinuous tree layer allowing sunlight to reach the floor), savannah woodland (scattered trees or shrubs with layer of grass), savannah (continuous layer of grass with negligible number of trees/shrubs), farmland and built-up.

3. Results and discussion

3.1. Forest cover types

Fig. 2 shows the different forest cover types which are closed forest, open forest, savannah woodland, savannah, farmland and built-up of BFMS. The total forest area of the study is 535.68 ha as of 2019. Classification of the different forest cover was challenging because of the spatial resolution of the satellite image, which is 30 m. Satellite image of a higher resolution can improve classification.

3.2. Forest cover change

The closed forest cover is declining whilst on the other hand; open forest cover, built-up and farmland are increasing (Table 1). Predicting for future changes in forest cover is important to prepare and mitigate adverse effects of changes in the forest. This will assist in sustainable management of the forest.

Fig. 3 shows the different forest cover types between circa 1992 and 2018. From Fig. 3, the spatial extent of the closed forest cover is reducing whilst the spatial extent of open forest cover, built-up and farmlands are increasing.

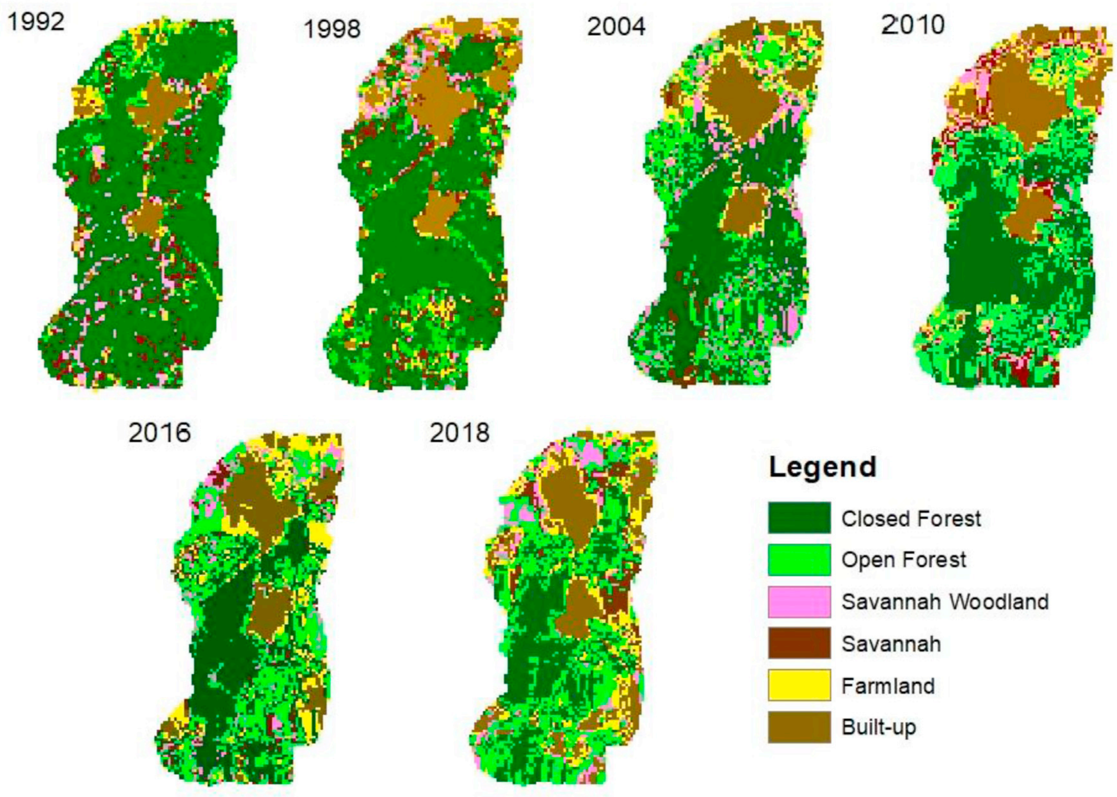

Fig. 2. Classified forest cover distribution in six different stages: 1992, 1998,2004,2010, 2016 and 2018.

Table 1
Spatial extent and changes in the different types of forest cover with respect to years in hectares (ha).

Given year	Closed Forest	Open Forest	Savannah Woodland	Savannah	Farmlands	Built-up
1992	369.72	30.78	26.19	40.50	28.17	40.32
1998	281.52	66.69	23.13	58.05	35.32	70.97
2004	225.63	104.68	50.13	21.69	46.90	87.48
2010	205.02	133.38	26.82	32.58	46.28	91.60
2016	162.99	142.65	30.15	35.91	64.98	99
2018	127.53	153.63	33.66	46.98	67.86	106.02
Change 1992–1998	−88.2	35.91	−3.06	17.55	7.15	30.65
Change 1998–2004	−55.89	37.99	27.18	−36.36	11.58	16.51
Change 2004–2010	−20.61	28.7	−23.49	10.89	−0.62	4.12
Change 2010–2016	−42.03	9.27	3.33	3.33	18.7	7.4
Change 2016–2018	−35.46	10.98	3.51	11.07	2.88	7.02
Change 1992–2018	−242.19	122.85	7.47	6.48	39.39	65.7

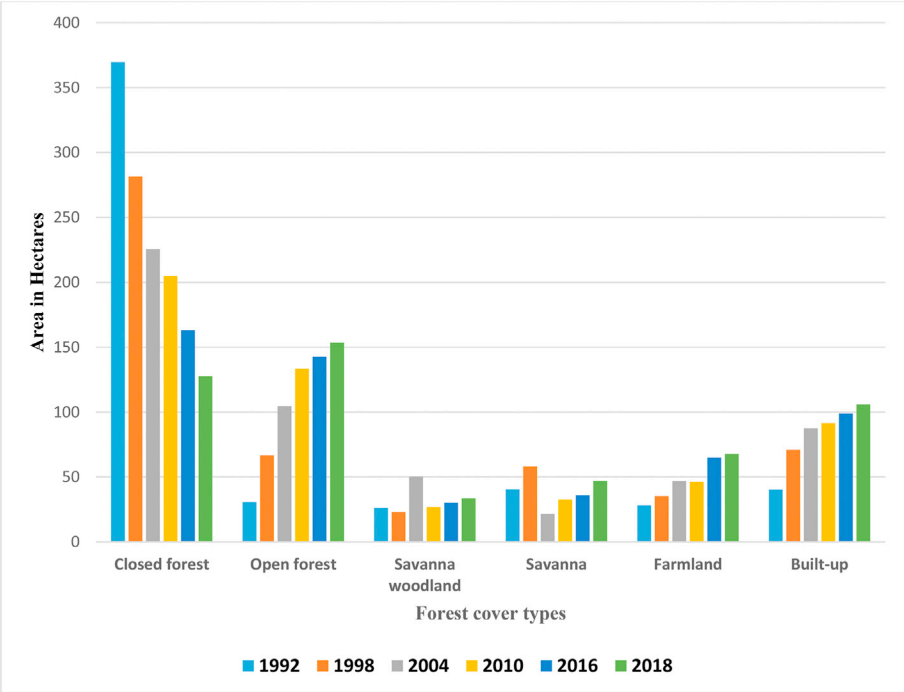

Fig. 3. A bar graph of the spatial extent of various forest cover types with respect to years.

3.3. Changes in closed forest cover and open forest cover

3.3.1. Changes in closed forest cover

From the year 1992 to 2018, there was an overall decrease of the closed forest by 242.19 ha (Table 1). From 1992 to 1998, the closed forest recorded its highest decrease which is 88.2 ha. This significant decrease of closed forest from 1992 to 1998 is in agreement with a research work done by National REDD+ Secretariat (2017). The author stated that from 1950 to 2000, Ghana lost 2.7 million hectares of forest. In addition, from 1984 to 2000, Ghana experienced a rapid rise in population by 6.6 million (Population, 2006). Rapid population increase in the study area resulted in the demand for more land for farming and infrastructural development. In addition, logging and accidental fires are well known in the area resulting in the conversion of the closed forest to open forest as also observed by Awotwi et al. (2018). Fig. 4 shows the changes in closed forest over the years.

There was another rapid decrease in the closed forest within a period of two years. From 2016 to 2018, the closed forest decreased by 35.46 ha (6.62 %). This is a cause for alarm because the decrease in closed forest from the year 2016–2018 is almost a half of the highest recorded decrease of the closed forest, which is a period of six years (1992–1998). The National REDD+ Secretariat (2017) reported an increase in the deforestation rate of Ghana, and from the year 2013 the rate was 794,214 ha/year, and the study period falls within this range. There has been an increase in anthropogenic activities of the

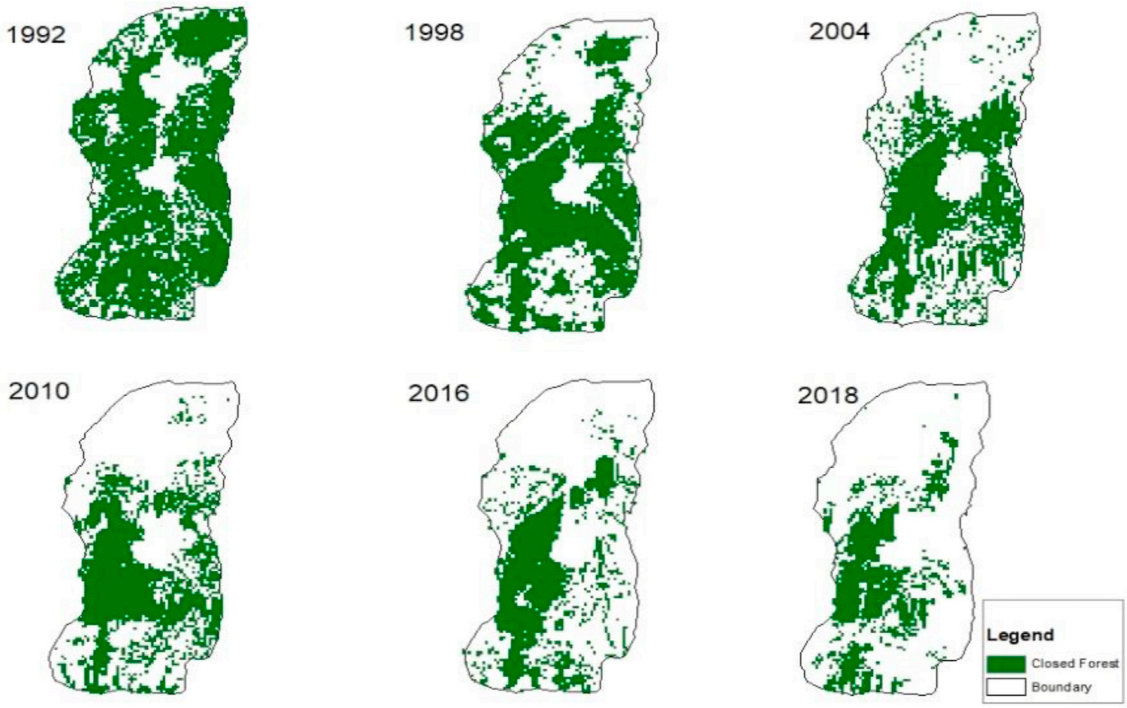

Fig. 4. Change map of Closed Forest.

study area due to rising population growth over the past few years with farming and charcoal burning on the rise. Fuelwood is the mostly used energy for domestic activities by the inhabitants of the study area. The fuelwood is obtained from the forest.

Closed forest cover could positively predict the presence of *C. vellerosus* monkeys which is listed as critically endangered species in the International Union for Conservation of Nature (IUCN) Red list (Kankam et al., 2013). In 2003, the 6th National Tourism Tourist Attraction was won by BFMS and it recorded the leading numbers of visitors and revenue generated (Eshun and Tonto, 2014). By field observation, the number of monkeys decreases as one moves away from the closed forest cover. Closed forest have matured trees with interlocking canopies which takes years to form (Vickers and Palmer, 2000). Therefore, closed forest may take years to be restored when destroyed (Cao et al., 2017).

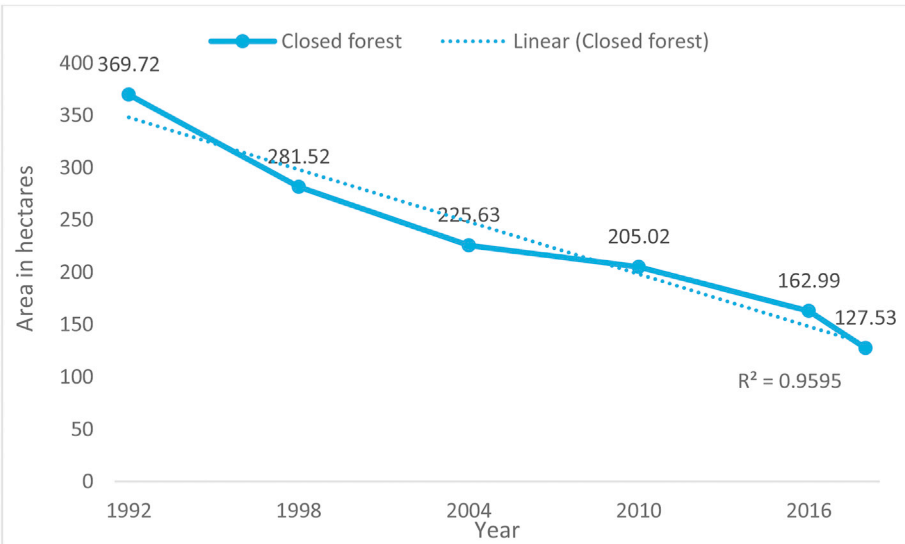

Fig. 5. Regression analysis of changes in closed forest cover for 1992, 1998, 2004, 2010, 2016 and 2018.

A regression analysis (Fig. 5) showed a significant decrease in the closed forest since the R^2 (Coefficient of determination) is 0.9595 at 95% confidence interval. From the trend, there is an average loss of 8 ha of the closed forest cover every year.

3.3.2. Changes in open forest cover

There was an overall increase in the open forest cover from 1992 to 2018 by 122.85ha (Table 1). The open forest recorded its highest increase between the period of 1998–2004 (37.99 ha) and second highest increase between 1992 and 1998 (35.59 ha). Fig. 6 shows the changes in open forest over the years.

The increase in the open forest is due to cutting down of trees for charcoal burning and farming activities. A research work done by Kankam and Sicotte (2010) in the BFMS agreed that there has been an increase in the open forest circa the period the closed forest had its highest decrease. The authors revealed that the threats to the forest were bush fires, cutting of trees, farming, charcoal burning and urbanization, which are currently ongoing in the study area. Similarly, Chiteculo et al. (2018) confirmed that intensive charcoal and firewood production and agriculture have led to the decrease of the forest in Angola with the main driver being agriculture. In addition, Panta (2003) attributed the key factors of forest loss in Nepal to expansion of agricultural lands and infrastructural development.

A regression analysis (Fig. 7) showed a significant increase in the open forest since the R^2 is 0.9671 at 95% confidence interval. From the trend, there is an average annual increase of 5 ha of the open forest cover.

The open forest consist of a single canopy layer as a result of shrinking closed forest canopy and creation of gaps in the closed forest (Duncan, 2002). Large gaps in forests affect the composition and structure of mature forests (Duncan, 2002). Panta (2003) acknowledged that forest canopies are opened by the fall of trees or big branches, which creates gaps in the forest cover.

3.4. Effects of changes in closed forest cover and open forest cover

Decreasing closed forest cover and increasing open forest in BFMS has resulted in the net loss of trees. The forest of BFMS serves as a habitat and a source of food for the monkeys and thus a decrease in the number of trees in the forest is a threat to sustainable ecotourism of the study area in particular and Ghana in general. Reduction in forest cover (deforestation) leads to the conversion of carbon stored in trees to carbon dioxide which is released into the atmosphere and reduction in carbon stock of the forests contributing to climate change and global warming (Chave et al., 2005; Friedlingstein et al., 2006; Nogueira et al., 2018). Deforestation and forest degradation of the tropical forest account for about 15–25% annual global greenhouse gas emission (Gibbs et al., 2007). In addition, deforestation leads to loss of biodiversity of the forest (Anyanwu

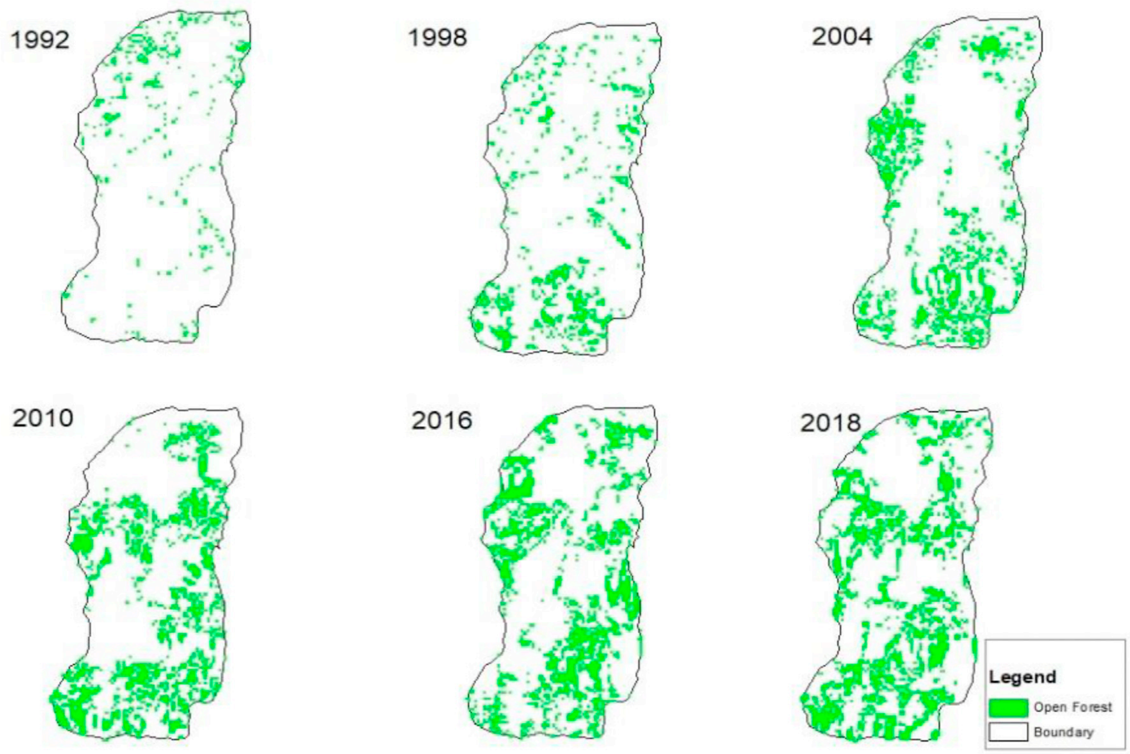

Fig. 6. Change map of Open forest.

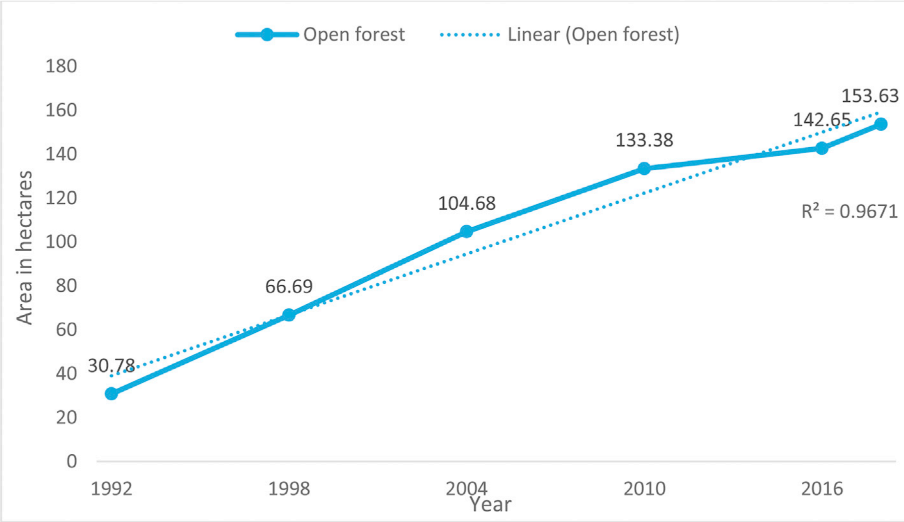

Fig. 7. Regression analysis of changes in open forest cover for 1992, 1998, 2004, 2010, 2016 and 2018.

et al., 2016). Chiteculo et al. (2018) mentioned that reduction of trees threatens the stability of a forest and has serious adverse effect on the environment. Therefore decreasing closed forest and increasing open forest in BFMS points to an alteration of the structure and composition of the forest, loss of biodiversity of forest, reduction in carbon stock of the forest and emission of carbon from the forest into the atmosphere.

3.5. Changes in savannah woodland

Fig. 8 shows the changes in savannah woodland over the years. There were scattered trees on the savannah woodland, which is as result of trees being felled from open forest. Ratnam et al. (2011) established savannahs are defined based on their

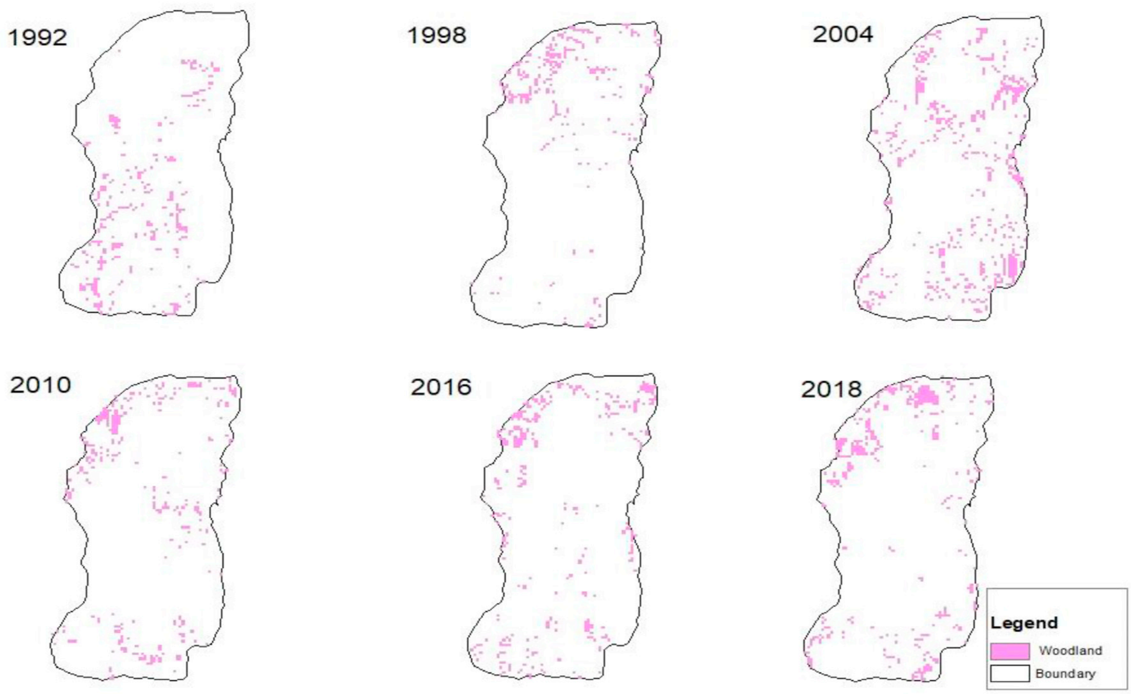

Fig. 8. Change map of Savannah woodland.

vegetation structure and the main idea is discontinuous tree cover in a continuous grass understorey. The authors confirmed that where there are more numbers of trees than grass in a savannah biome it can be attributed to degradation of open forests.

From 1998 to 2004 savannah woodland had a rapid increase of 27.18 ha (Table 1). On the other hand, open forest had its highest increase within the same period due to cutting down of trees for charcoal burning and farming activities. These anthropogenic activities in the open forest have led to its degradation and hence increase in savannah woodland. Moreover, Atsri et al. (2018) added that savannah woodlands are associated with a greater number of trees and increase in savannah woodlands can be attributed to decrease in closed forest cover and degradation of open forest cover.

A regression analysis (Fig. 9) showed the change in savannah woodland was not significant since the R^2 is 0.0374 at 95% confidence interval.

3.6. Changes in savannah

Fig. 10 shows the changes in savannah over the years. From 1998 to 2004 the savannah biome experienced a rapid decrease of 36.36 ha (Table 1).

From 1998 to 2004, the savannah site experienced its highest decrease of 36.36 ha (Table 1). It was around the same period that Ghana had a rapid rise in population (Population, 2006). Increasing population leads to increase in anthropogenic activities like hunting which can increase the chances of fire in the savannah biome (Murphy and Bowman, 2012). Also, from 1960 to 2008, Ghana experienced a decreasing trend in rainfall with an average decrease of 2.3 mm per month (Nkrumah et al., 2014). Fire and water supply are the main determinants of the structure of the savannah biome (Sjögren, 2000). There have been incidences of fire in the savannah cover of the study area. The savannah biome is vulnerable to changes in the climate and been affected by the way people are using it. Moreover, there is a regular bush fires incidence in the savannah biome (Ratnam et al., 2011; Staver et al., 2011). Many botanist and foresters in Ghana believe changes in the savannah biome can be attributed to anthropogenic activities (Swaine et al.,1976; Afikorah-Danquah, 1997).

A regression analysis (Fig. 11) showed the changes in savannah was not significant since the R^2 is 0.0246 at 95% confidence interval.

3.7. Changes in farmlands

There was an overall increase of 39.39 ha in the farmlands from 1992 to 2018 (Table 1). The increasing area of farmlands in the forest of BFMS which falls within the forest-savannah transition zone of Ghana is in accordance with assertion that agriculture in a lot of sub-Saharan African countries occur in the savannah areas (Staver et al., 2011; Ghana Statistical Service, 2014). Kankam and Sicotte (2010) recognized farming to be the second highest threat affecting the forest of BFMS. Fig. 12 shows the changes in farmland over the years.

Increase in population in the study area has contributed to the creation of more farmlands in the forest. Households consume produce from farmlands and sell the remaining produce to generate income for the family. Cultivation of yam and groundnut were the commonest in the study area. According to MoFA (2016), 84.2% of rural household of the then Brong Ahafo Region are engaged in agriculture and the study area is within this region. Farmland recorded its highest increase

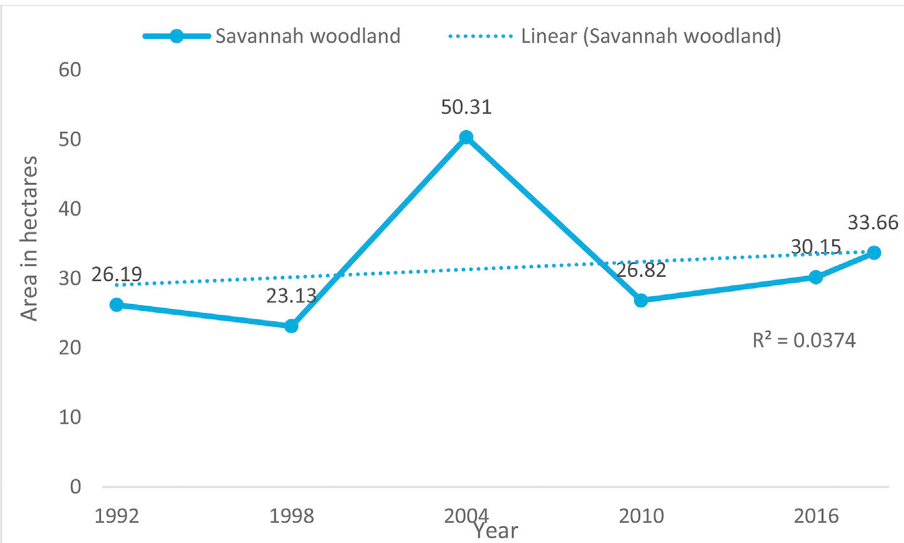

Fig. 9. Regression analysis of changes in savannah woodland for 1992, 1998, 2004, 2010, 2016 and 2018.

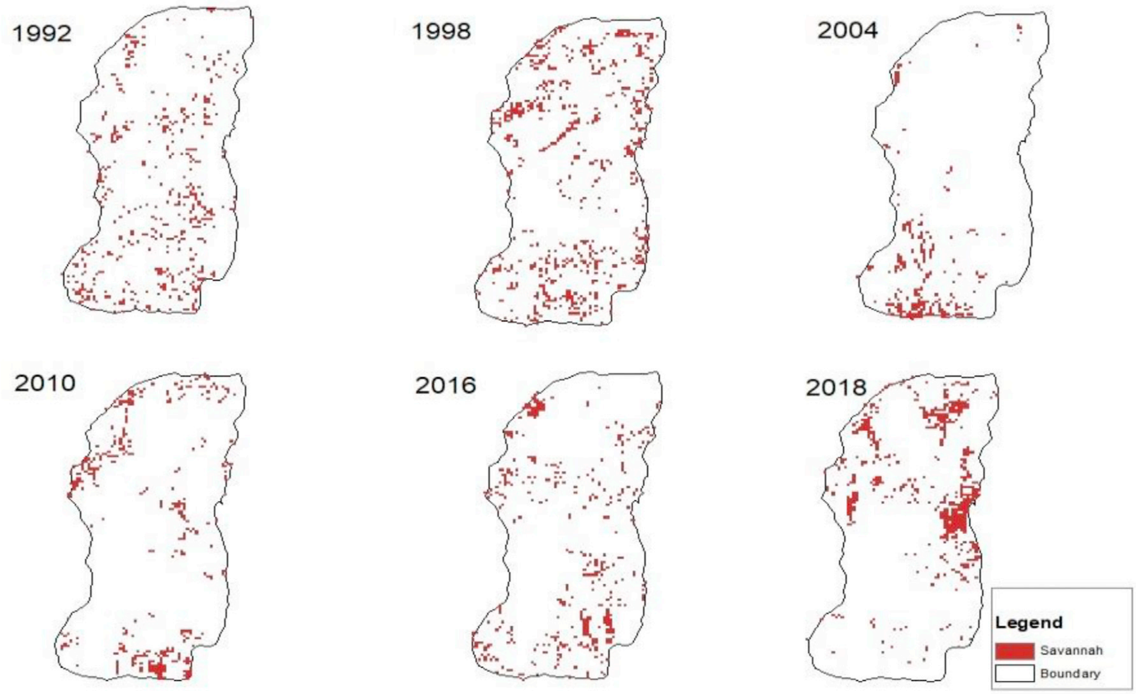

Fig. 10. Change map of Savannah.

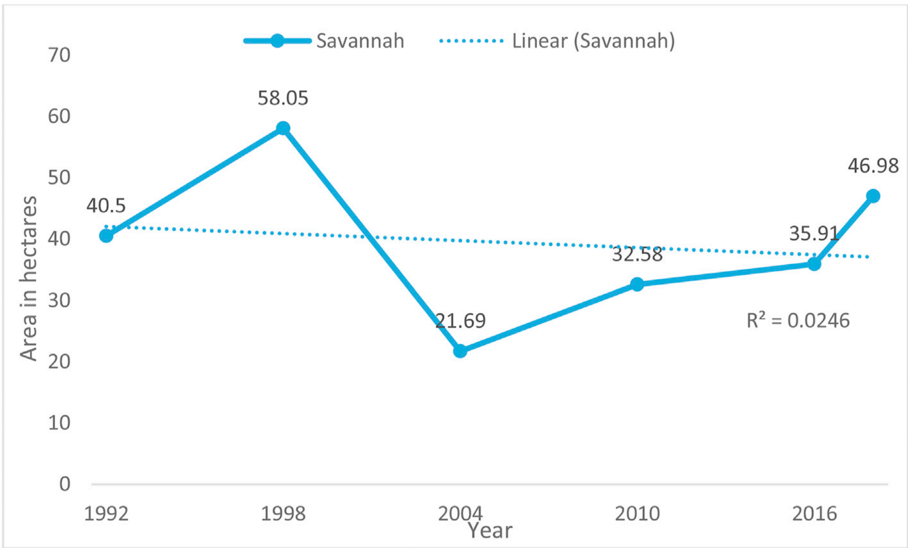

Fig. 11. Regression analysis of changes in savannah for 1992, 1998, 2004, 2010, 2016 and 2018.

(18.7 ha) from 2010 to 2016. Within the aforementioned period, the then Brong Ahafo topped the five maize and yam producing regions of Ghana (MoFA, 2016).

A regression analysis (Fig. 13) showed a significant increase in farmland since the R^2 is 0.9419 at 95% confidence interval. From the trend, there is an average annual increase of 1.5 ha of the farmland cover.cover every year.

Although an increase of farmlands means an increase in food production of the region, farmers in the study area practise slash and burn agriculture, which depletes the soil when continuously done within a short period and is detrimental to the environment. Most of the trees on the farmlands were burnt, indicating clearance of the forest for farming purposes. Farmers in the study area complained of reduced farm produce and loss of soil fertility. Agriculture and its related activities not done

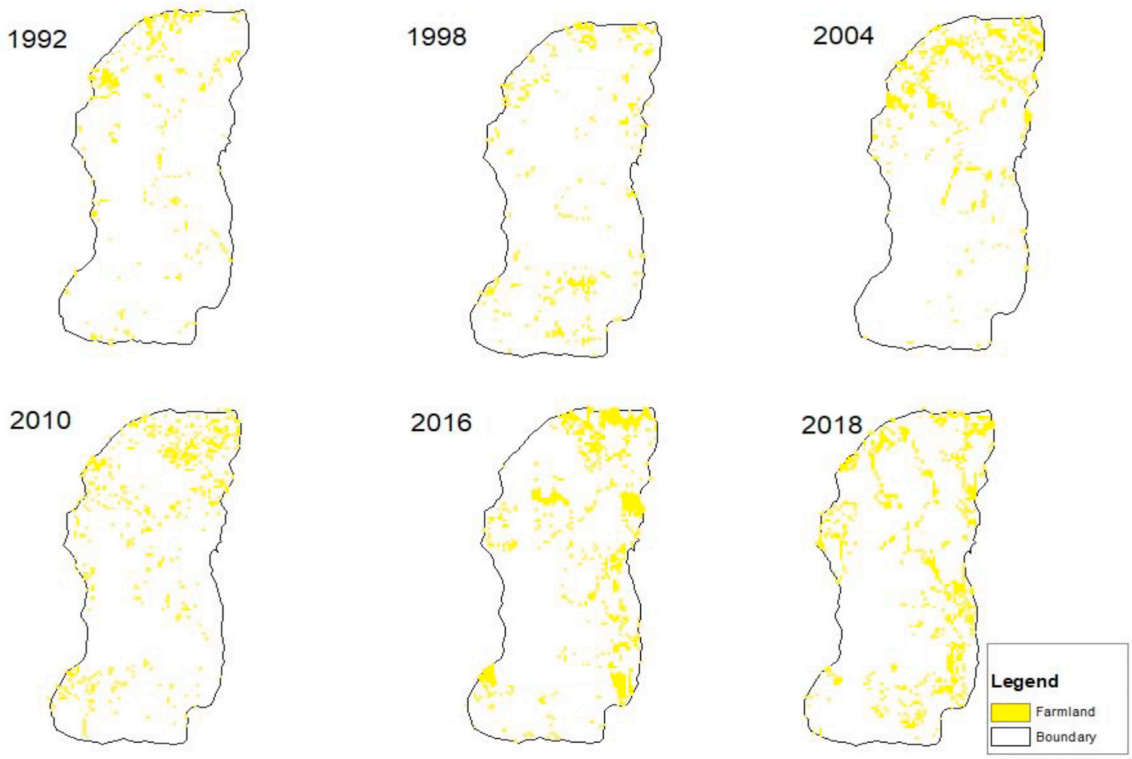

Fig. 12. Change map of Farmland.

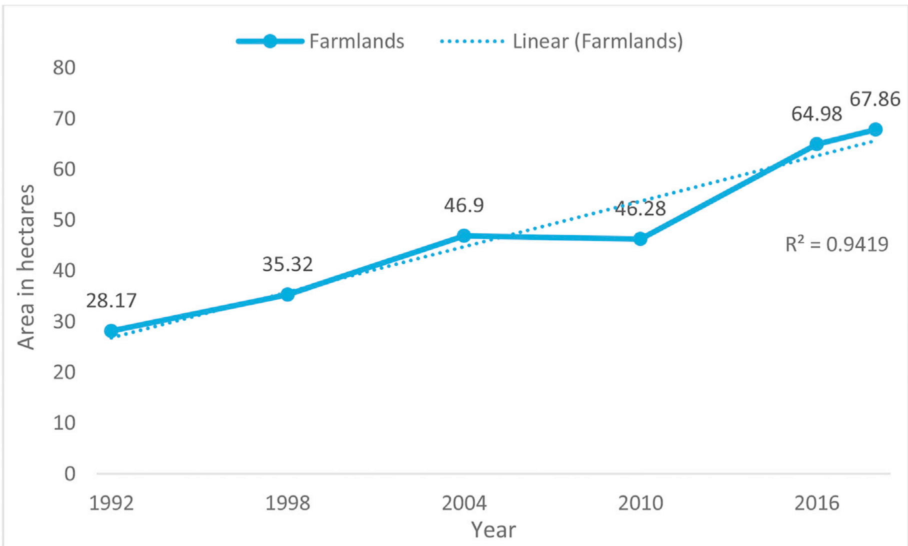

Fig. 13. Regression analysis of farmlands for 1992, 1998, 2004, 2010, 2016 and 2018.

properly leads to loss of soil nutrients and fertility and reduction in agricultural produce (Henao and Baanante, 1999; Lal, 2004).

3.8. Changes in built-up

There was an overall increase (Table 1) in the built-up areas from 1992 to 2018 by 65.7 ha (12.26%). From 1992 to 1998, built-up areas had its highest increase by 30.65 ha. Within the same period, closed forest recorded its highest decrease, which is 88.2 ha. Most of the forest cover within the said period was converted to physical structures because of growing population. In addition, most of the houses are built horizontally which occupies more land as compared to vertical buildings. The increment of built-ups agrees with a research done by Kankam and Sicotte (2010) which ranked establishment of physical structures as the fifth overall threat to the forest of BFMS. Fig. 14 shows changes in built-up areas.

Increase in built-ups is mainly as a result of growing population which puts pressure on lands and forest (Basnyat, 2009). Kankam (2010) confirmed an increase in the population of Boabeng-Fiema and predicted a further increase in the subsequent years. In addition, from 1984 to 2000, Ghana experienced a rapid rise in population by 6.6 million (Population, 2006). DeFries et al. (2010) stated that demographic factors like population growth and urbanization are major drivers of deforestation. In addition, Sejati et al. (2018) stated that the higher the level of urbanization, the higher the conversion of forests and the extent of forest degradation.

A regression analysis (Fig. 15) showed a significant increase in the built-up areas since the R^2 is 0.898 at 95% confidence interval. From the trend, there is an average annual increase of 2 ha of the built-up cover.

4. Conclusions and recommendations

This research is important because it addresses Sustainable Development Goal (SDGs) 15 (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss).

The forest cover of BFMS was classified into 6 classes; closed forest, open forest, savannah woodland, savannah, farmland, built-up. There were changes in the forest cover of BFMS from 1992 to 2018; closed forest decreased by 242.19ha, open forest increased by 122.85ha, savannah woodland increased by 7.47ha, savannah increased by 6.48 ha, farmlands increased by 39.39 ha and built-up increased by 65.7 ha. The changes in closed forest, open forest, farmland and built-up were all significant. Population growth and anthropogenic activities like charcoal burning and farming have contributed to these changes in the forest cover. Predicting for future changes in forest cover is important to prepare and mitigate adverse effects of changes in the forest. This will assist in sustainable management of the forest. Understanding how the variations in the land cover might affect the environment will aid natural resource managers and supporters attain sustainable management by connecting LULC change to ecological safeguard. It is then important for the rules and regulations of forest sustainability to be integrated into planning and management to mitigate forest loss for protection of natural resources.

A satellite image of higher spatial resolution should be used for classification of the forest cover. Furthermore, Forestry Commission should intensify monitoring activities in the forest of BFMS to curb the menace of illegal activities (illegal felling

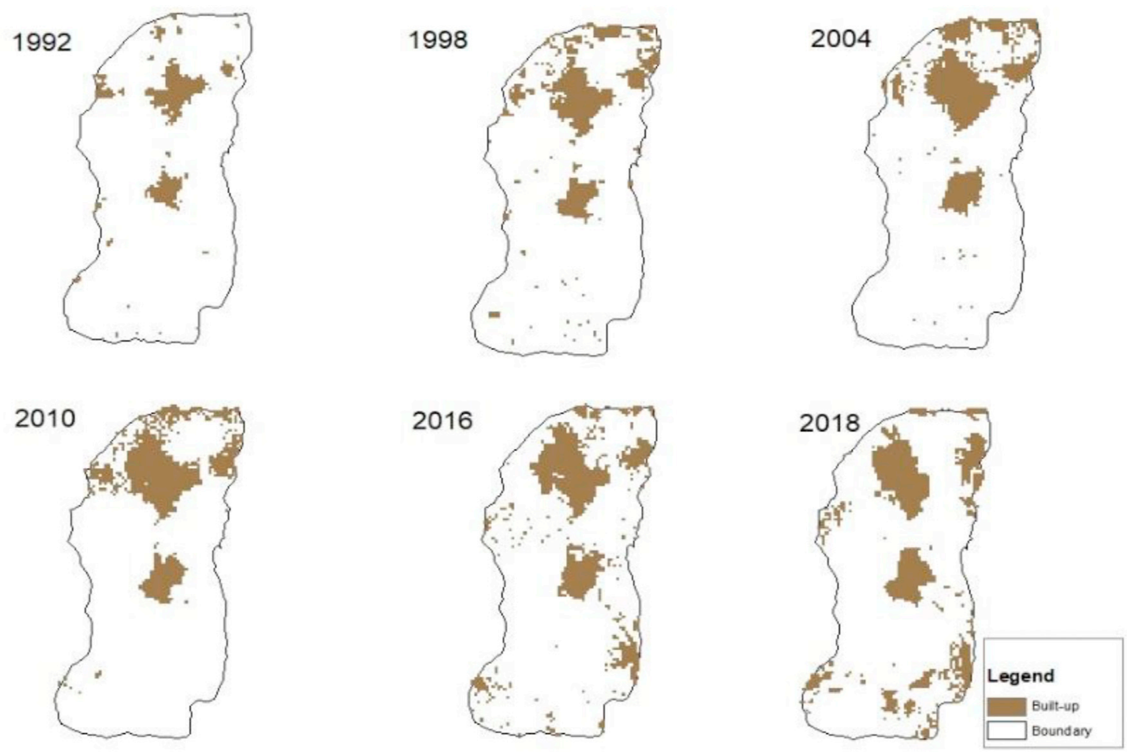

Fig. 14. Change map of Built-up.

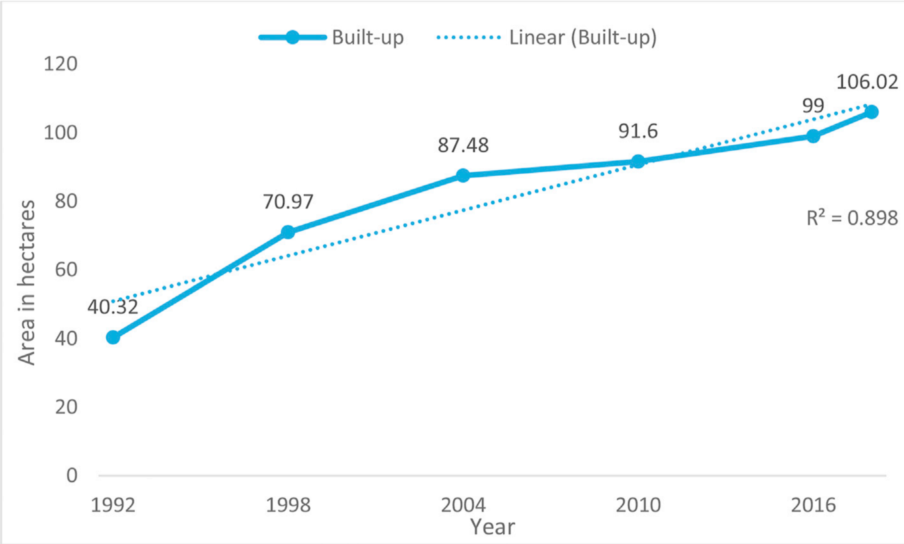

Fig. 15. Regression analysis of changes in built-up for 1992, 1998, 2004, 2010, 2016 and 2018.

of trees, charcoal burning, etc.). There is the need to predict future changes in forest cover to prepare and mitigate adverse effects of changes in the forest. This will assist in sustainable management of the forest. In addition, there should be sensitization of the inhabitants through educative programs by Forestry Commission and Wildlife Department about the dangers of deforestation and forest degradation. Likewise, an alternative source of energy like establishment of woodlots should be done. Additionally, farmers should be encouraged to adopt Agroforestry practices like multipurpose trees on croplands and should be supplied with tree seedlings to plant on their farms. In addition, there should be engagement of stakeholders and clearly defined tree tenure system. Just as important, there should be reafforestation of the forest of BFMS by Forestry Commission.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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