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Research Application Summary

Using GIS and remote sensing to assess the past trends in land use/cover change in Ahafo Ano north district, Ghana

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Abstract

An attempt was made to evaluate land use/cover change trajectory in Ahafo Ano North District for a period of thirty-three years (33) using remote sensing (RS) and GIS. The study used multi-spectral satellite data obtained from Landsat-5, Landsat-7 and Landsat-8. Supervised classification through maximum classification algorithm was used for image classification. Post-classification algorithm was employed to detect changes. The 33-year study reveals that substantial change has occurred in the study watershed. Between 1986 to 2002, farm land changed to built-up, forest and shrub by 802.2-ha, 2174.9-ha and 1431.6-ha, respectively. Forest changed to built-up, farm land and shrub land by 471.4-ha, 4697.4-ha and 8220.7-ha respectively. Shrub land changed to built-up, farm land and forest by 218.6-ha, 4523.6-ha and 16608.2-ha, respectively. While at the same time, built-up changed to farm land, forest and shrub land by 32.0-ha, 10.5-ha and 49.3-ha, respectively. Between 2002 to 2019, it appeared that farm land changed to built-up, forest and shrub land by 1176.9-ha, 145.7-ha and 3906.9-ha, respectively. Built-up changed to farm land, forest and shrub land by 507.5-ha, 76.9-ha and 192.3-ha respectively. Shrub land changed to built-up, farm land and forest by 306.3-ha, 4388.9-ha and 9822.9-ha respectively. Between the same period, forest changed to built-up, farm land, and shrub land by 376.2-ha, 4924.1-ha and 12976.7-ha, respectively. The changes from-and-to that occurred in the land classes indicate the dynamic state in the study area, and it is strongly recommended that sustainable land utilization measures are established to avert future changes and associated landscape damage amid different land use systems. The study strongly suggests further study in future potential areas for farm land expansion in the study area.

Key words: Ghana, GIS, land use/cover, Remote sensing

Résumé

Une tentative a été faite pour évaluer la trajectoire de changement d'utilisation/couverture des terres dans le district nord d'Ahafo Ano pendant une période de trente-trois ans (33) en utilisant la télédétection et le SIG. L'étude a utilisé des données satellitaires multispectrales obtenues de Landsat-5, Landsat-7 et Landsat-8. Une classification supervisée par un algorithme de classification maximale a été utilisée pour la classification des images. Un algorithme de post-classification a été utilisé pour détecter les changements. L'étude de 33 ans révèle que des changements substantiels

se sont produits dans le bassin versant de l'étude. Entre 1986 et 2002, les terres agricoles sont devenues bâties, forestières et arbustives de 802,2 ha, 2174,9 ha et 1431,6 ha, respectivement. La forêt s'est transformée en terres bâties, terres agricoles et terres arbustives de 471,4 ha, 4 697,4 ha et 8 220,7 ha respectivement. Les terres arbustives sont devenues des terres bâties, des terres agricoles et des forêts de 218,6 ha, 4 523,6 ha et 16 608,2 ha, respectivement. Dans le même temps, le bâti s'est transformé en terres agricoles, en forêts et en terres arbustives de 32,0 ha, 10,5 ha et 49,3 ha, respectivement. Entre 2002 et 2019, il est apparu que les terres agricoles se sont transformées en terres bâties, forestières et arbustives de 1176,9 ha, 145,7 ha et 3906,9 ha, respectivement. Le bâti s'est transformé en terres agricoles, forêts et terres arbustives de 507,5 ha, 76,9 ha et 192,3 ha respectivement. Les terres arbustives sont devenues bâties, terres agricoles et forêts de 306,3 ha, 4388,9 ha et 9822,9 ha respectivement. Entre la même période, la forêt s'est transformée en terres bâties, terres agricoles et terres arbustives de 376,2 ha, 4924,1 ha et 12976,7 ha, respectivement. Les changements de et vers qui se sont produits dans les classes de terres indiquent l'état dynamique dans la zone d'étude, et il est fortement recommandé que des mesures d'utilisation durable des terres soient établies pour éviter les changements futurs et les dommages associés au paysage parmi les différents systèmes d'utilisation des terres. L'étude suggère fortement une étude plus approfondie des futures zones potentielles d'expansion des terres agricoles dans la zone d'étude.

Mots clés : Ghana, SIG, utilisation/couverture des terres, télédétection

Introduction

It is recognized that the world environmental problems are the function of human attachment to land resources. This is through conversion and modification of land resources in particular forest (Watson and Zakri 2003). Study by Ellis and Pontius (2007) pointed out that land use/cover change is a general term used to describe human modification of Earth terrestrial surface. This state of affairs has given rise to human induced changes over the globe. Studies have shown that changes in land use/cover result from population growth, burgeoning cities, agriculture growth and climate change effect that is partly induced by humans (Bai *et al*. 2008; Hooke *et al*., 2012).

Over the years, it is known that agriculture is the main cause of land use/cover change. For instance, FAO (2006) reported that the dominant cause of land use/cover transition is the conversion of forest to agricultural systems with continuously high rates of 13 million ha being deforested per year in the world. In their study, Lambin *et al*. (2003) indicated that land has been used by human chiefly by bringing more land into production at the expense of native vegetation. It has been estimated that 50% of the forest that once covered Earth now is gone (Bryant *et al*., 1997). And, between the years 1980 and 2000, about 83% of all new agricultural land in the tropics came from either intact forests (55%) or disturbed forest (28%) (Gibbs *et al.,* 2010). Agriculture expansion through increase in area under cultivation is the main cause of tropical deforestation and this may continue to expand into wetlands and rainforests (Gibbs *et al*., 2010; Angelsen and Kaimowitz, 2001; FAO, 2003). The share of tropical deforestation related to agricultural expansion had been estimated at 70% in the 1990's (UNEP, 2003).

In assessing the spatial patterns and trends in land use/cover changes, remote sensing (RS) and geographic information systems (GIS) serves as adequate tools are the most widely used method

for detecting changes in land use/cover (Turner *et al*., 2007). A study by Kusimi (2008) used RS and GIS to reveal changes in forest cover and urban expansion in Wassa District of Ghana. In obtaining information from remotely sensed data, image classification is the most widely used method. Image classification through supervised classification technique allows using common identities to represent particular land use/cover. This system of classification is mainly controlled by the analyst as the analyst select common identities that are representative of the desire land cover (But *et al*., 2015).

Through human activities the physical features covering Ghana's Earth surface have changed. For example, in the last century it has been estimated that 8.2 million hectares of forest that was once covered had decreased to 1.7 million hectares in the mid-1980's, and now decreased to about 1 million hectares by the mid-1990's (Forest Services Division, 1996). Ghana is experiencing high changes in forest cover despite efforts to conserve forest, and this is driven by slash and burn agriculture, arable land expansion, new settlements, timber harvest, road development, climate change, and mining (Kuudaar, 2015).

The aim of this study was to assess the past trends in land use/cover change in Ahafo Ano North District to provide information on the current land use/cover so as to inform decision making. This was achieved by examining the trajectory of land use/cover change in Ahafo Ano North District for the past thirty-three years.

Research Methodology

Ahafo Ano North District was chosen as a case study for this research because information on the extent of land use/cover change was not available. Also, this District is endowed with many natural resources, and just like in other districts in Ghana, the District land resources are greatly affected by dynamic human activities such as built-up expansion, cropland expansion, mining activities, among others. Therefore, attention was given to monitor changes in the land use/cover to provide a basis for decision making to improve resources management.

Ahafo Ano North District is located in the Ashanti Region of Ghana, with a land size of 593 km^2. The district lies between latitudes 6 47'N and 7 02'N, and longitudes 2 26'W and 2 04'W. The district is influenced by wet semi equatorial double maxima rainfall in June and October. This bi-modal rainfall pattern provides conducive condition for major and minor cropping seasons. The vegetation of the district is mostly classified as moist deciduous forest type. The district has three main soil types, i.e., Adjaso Hwidiem Association, Susan Simple Association and Biri Chichiwere Association which are generally fertile and support the cultivation of cash crop, food and vegetable crops (Brammer 1962).

This study used satellite remote sensing data obtained from United State Geological Survey (USGS) (http://usgs.glovis.gov and http://EarthExplorer.usgs.gov). Multi-spectral Landsat images from 1986 to 2019 covering thirty-three years (33) were considered for this study. Several studies on LULC transition have been made possible using Landsat images (see Siva and Srikanth, 2015; Shi *et al*., 2018). Specifically, the time series satellite datasets were collected from three different intervals of 1986, 2002 and 2019. These intervals were selected based on availability of cloud-free data. Table Iprovides multi-spectral satellite images considered in this study.

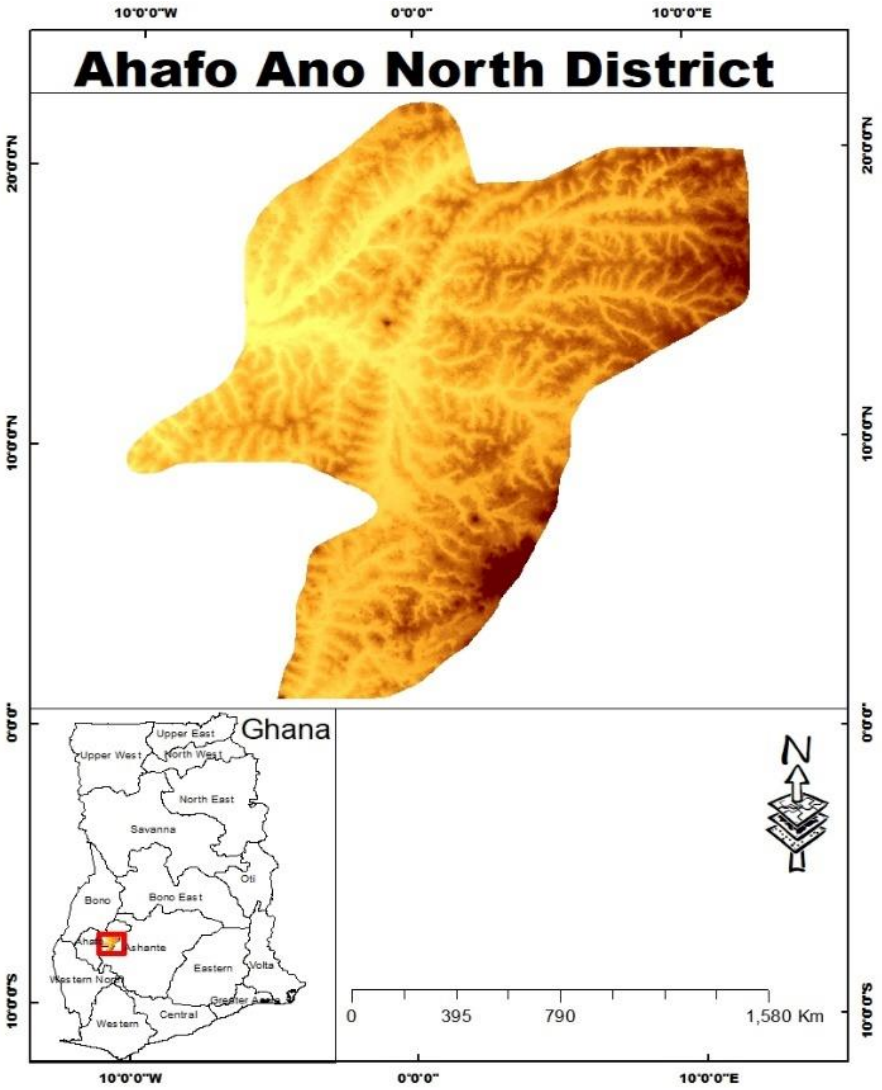


Figure I. Location of the research study in Ghana

Data processing. The time series Landsat imagery acquired for this study were geometrically corrected and enhanced. Ortho rectified Landsat imageries Thematic Mapper (TM) and Enhanced Thematic Mapper plus (ETM+) bands for each year 1986, 2002 and 2019 were combined into single images using Composite Band tool in the Data management tool. The resultant composite images were subsided to administrative boundary of Ahafo Ano North District using Extract by Mask tool in Spatial Analysis tool within ArcToolbox. The composite images were finally reprojected onto Ghana datum based on Universal Traverse Mercator Projection zone 30N.

Table 1. Satellite remote sensing data

Data	Data of acquisition	Resolution
Landsat-5 TM	22/12/1986	30m
Landsat-7 TM	20/12/2002	30m
Landsat-8 ETM+	22/12/2019	30m

Land use/cover classification. A classification scheme of four (4) LULC were developed based on physiographical knowledge, visual interpretation using historical function of Google Earth, researcher's prior knowledge and ancillary data. The classification scheme were based on Anderson *et al*. (1976) level 1. The following LULC classes were distinguished:

(i) Forest: This covers mixed woody vegetation, native forest with higher density of trees above the threshold of Forest Land category situated in the district.
(ii) Shrub: An area with mixed short woody vegetation, grassland, pasture, fallow land.
(iii) Farm land: This designate crop land including cereal field, vegetable field and plantation where vegetation structure falls below Forest Land category thresholds.
(iv) Built up: This portrays all developed land, including roads, built-up areas, and any form of human settlements.

Image classification. In this study, supervised classification technique was employed to extract thematic information from images. The study used supervised classification to select common identities which were used to represent particular land use/land cover on the remotely sensed data. Maximum likelihood classification (MLC) algorithm was then employed after signature creation to perform class assignment and used to calculate the probability that a given pixel belongs to a specific class. The MLC algorithm is one of the well-known parametric classifier for supervised classification (Otukei and Blaschke, 2010) and is widely applied in literature (Lillesand *et al*., 2008).

Change detection. Many change detection techniques have been developed such as mono-temporal change delineation, delta or post classification comparisons, multi-dimensional temporal feature space analysis, composite analysis, multi temporal linear data transformation, change vector analysis and multi temporal biomass index (Nori *et al*., 2005; Lunetta and Elvidge, 2008). In this study, post-classification change detection technique was employed to find which land use/cover changes to which land use/cover. The study adopted this technique because it has been widely used and proved accurate and is the most commonly used quantitative method of change detection (Chen, 2002). Post-classification technique requires at least two thematic maps of different dates to detect changes. Post-classification techniques provide 'from-to' change information and makes it easy to calculate and map the types of landscape transitions that have occurred (Bauer *et al*., 2005). The Food and Agriculture Organization of the United Nations (1990) applied post-classification technique in a survey of forest cover and change process, and the result was successful. Interception tool in Geoprocessing tab was then used in analyzing the land use/cover changes that have occurred between the periods 1986 – 2002 and 2002 – 2019. Graphs of gains and losses, net change, and change maps were generated to address the spatial distribution of change patterns within the given time interval (Eastman, 2006). Subsequently, area in kilometer square was calculated to ascertain the amount of land cover change (Figure 3).

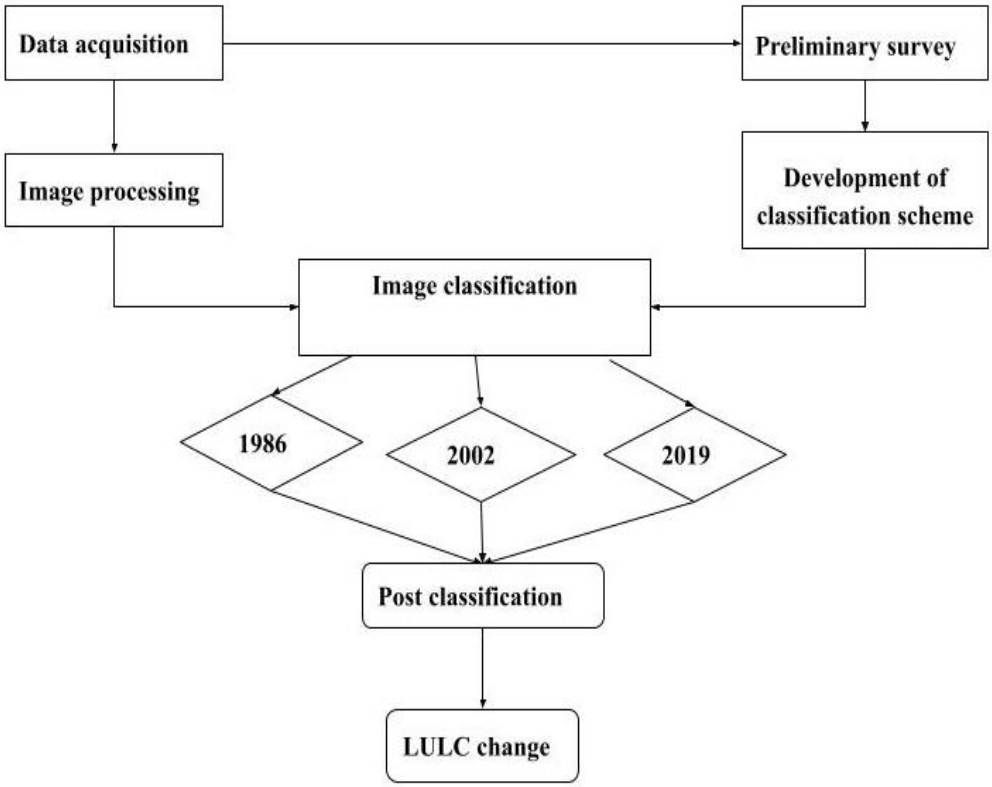


Figure 2. Flow Chart to detect changes over 33-years

Result and Discussion

Land use/cover classification and accuracy assessment. Three different land cover maps were obtained and the main land use/cover types derived include forest cover, shrub land, farm land and built-up (Figs. 3-5).

Critical examination of land use/cover classes for the 33 years study revealed shrub cover as the dominant land cover type occupying 39381.8 ha (1986), 27733 ha (2002) and 30281.9 ha (2019) of the total classified pixels, representing 54.02%, 38.04% and 41.55% of total area respectively. Forest cover is made up of areas with mixed woody vegetation, native forest with higher density of trees above the threshold of Forest Land category and covered 23261 ha (1986), 28664.1 ha (2002) and 21733 ha (2019), representing 31.9%, 39.32% and 29.82% land cover, respectively. Farmland is made up of areas under cultivation appeared the third land use/cover after forest during the period of the study. This land cover occupied 9806.5 ha (1986), 14655.3 ha (2002) and 179261 ha (2019), and thus formed 13.45% in 1986, 20.1% in 2002 and 24.60% in 2019 of the total land areas in the classified pixels. Built-up is made up of settlements, roads and industries is the fourth land cover/use after farm land representing 0.62% (1986), 2.54% (2002) and 4.03% (2019) of the total land area in the classified pixels. Table 2 shows the extent of the area of individual land use/cover classes in hectares (ha) with associated percentage they occupied. Figures 3,4, and 5 depict land cover maps for 1986, 2002 and 2019, while Figure 6 shows the distribution of individual land use/cover.

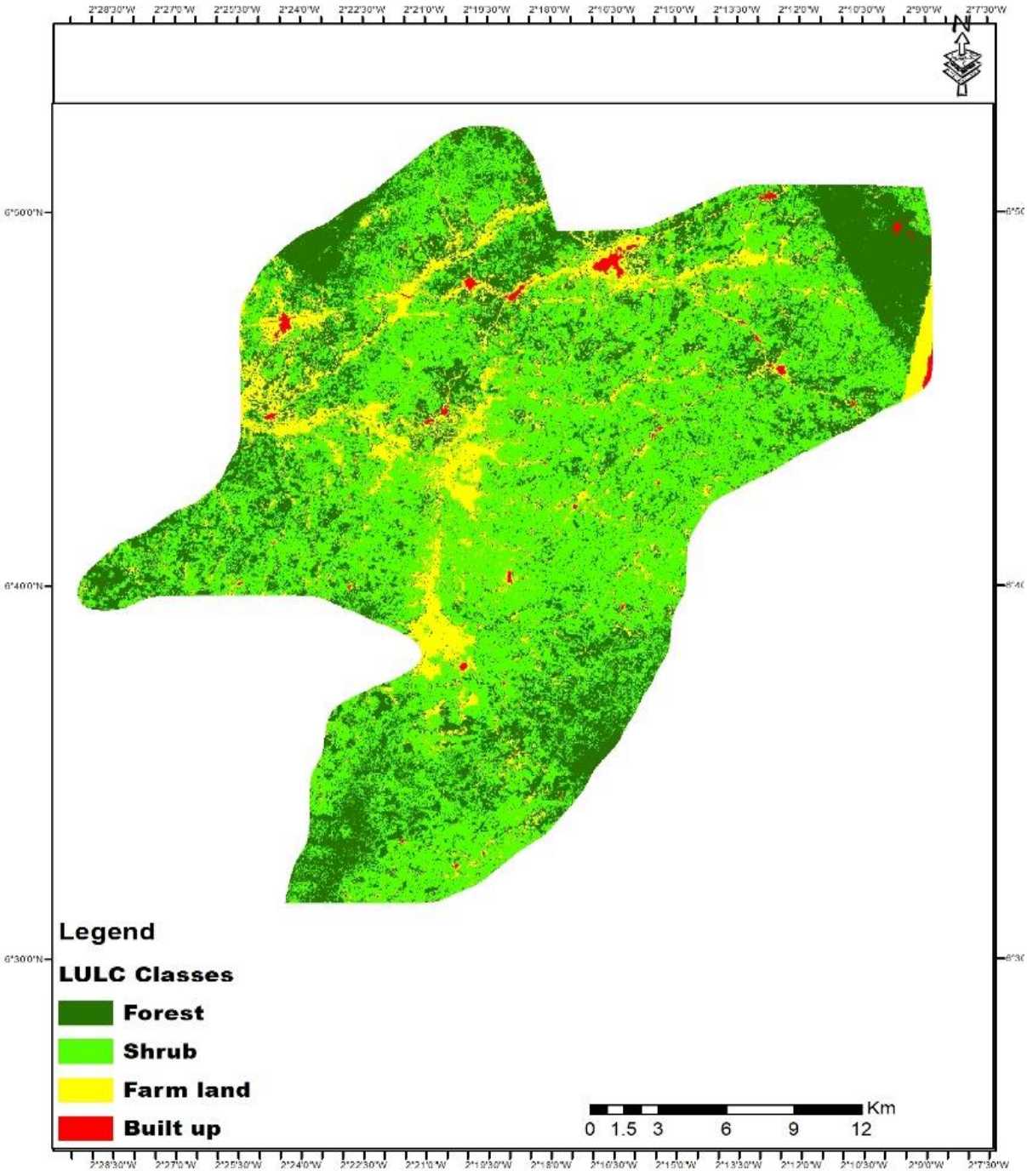


Figure 3. Land use/land cover classes for the year 1986

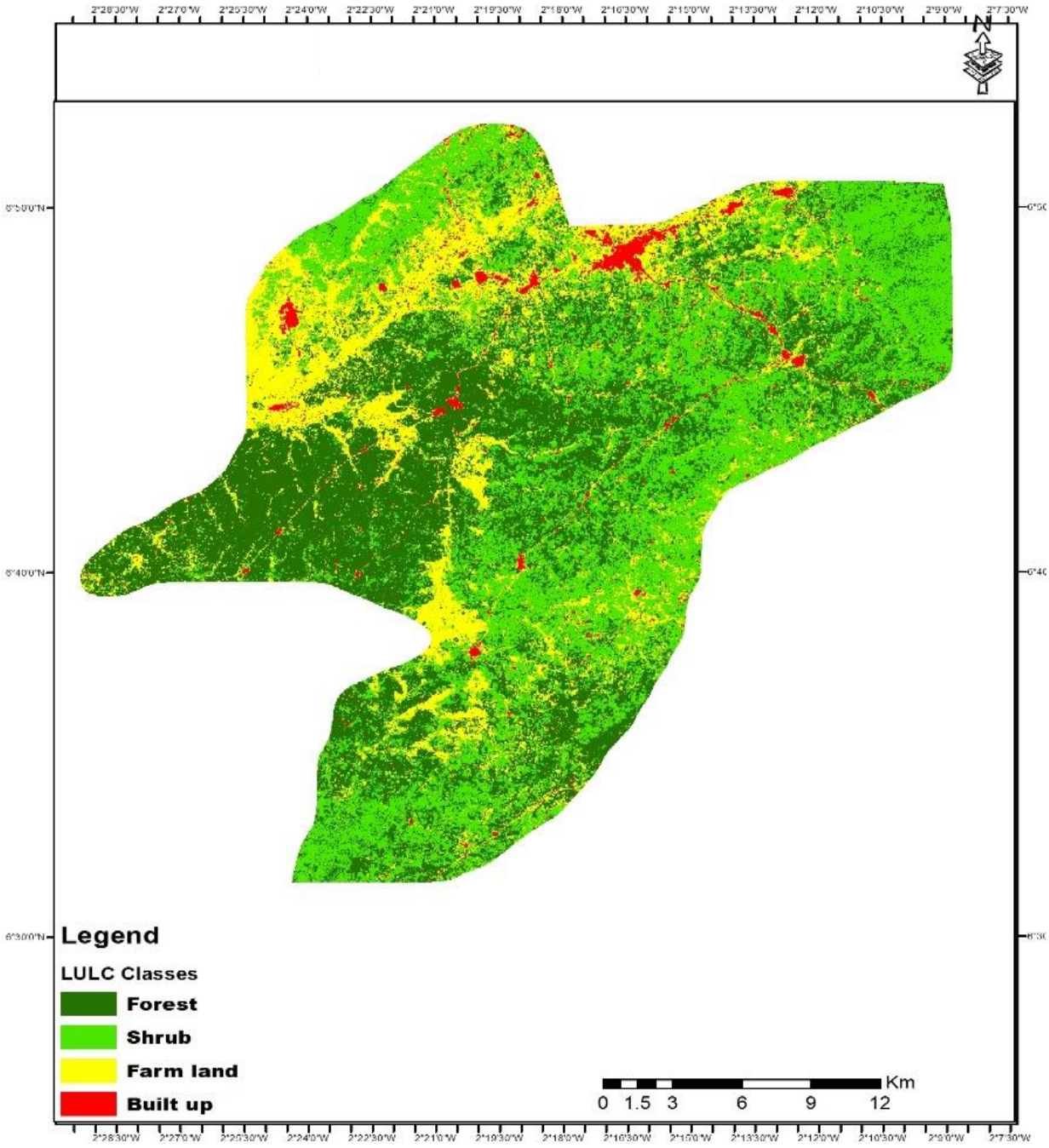


Figure 4. Land use/land cover classes for the year 2002

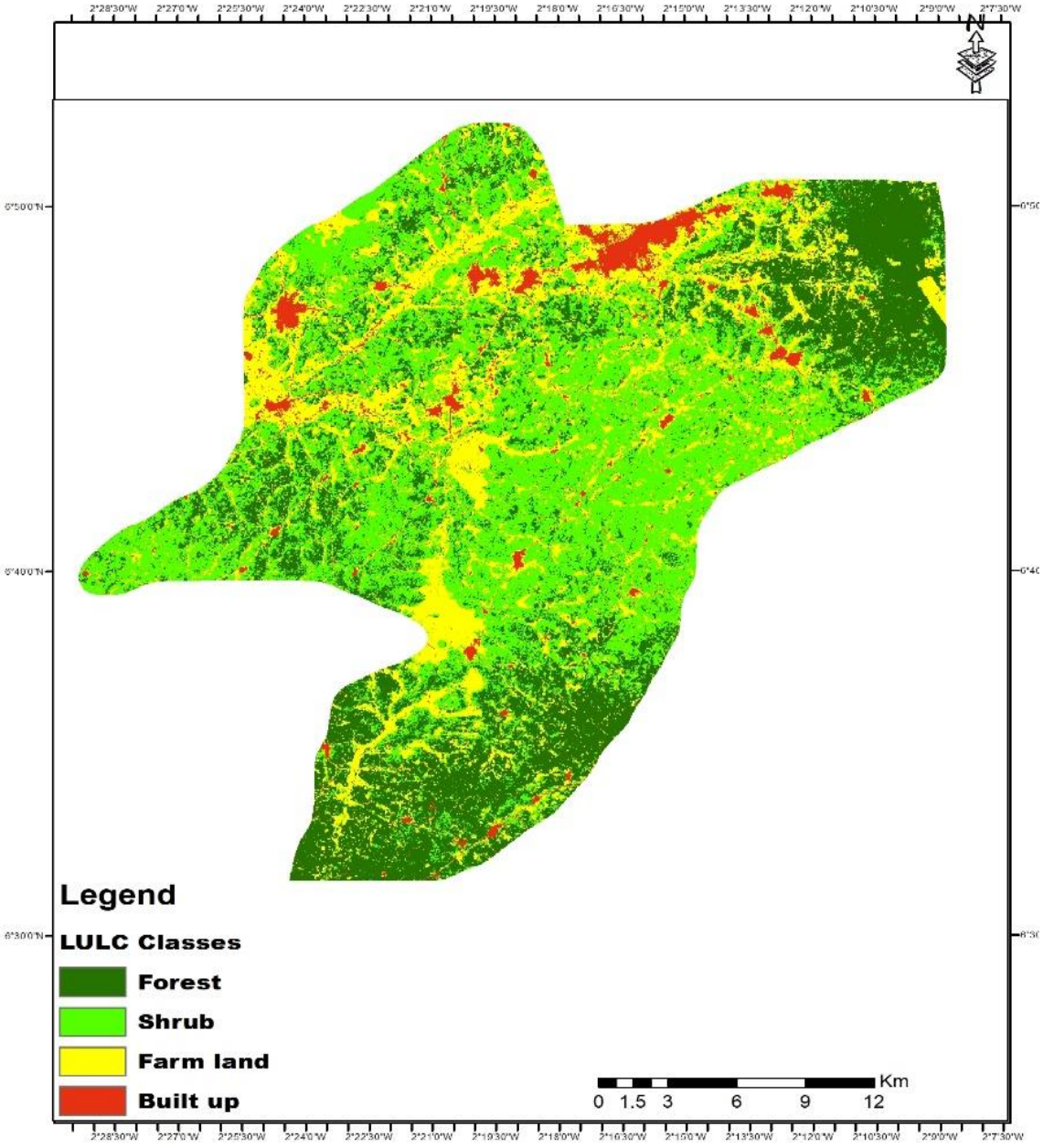
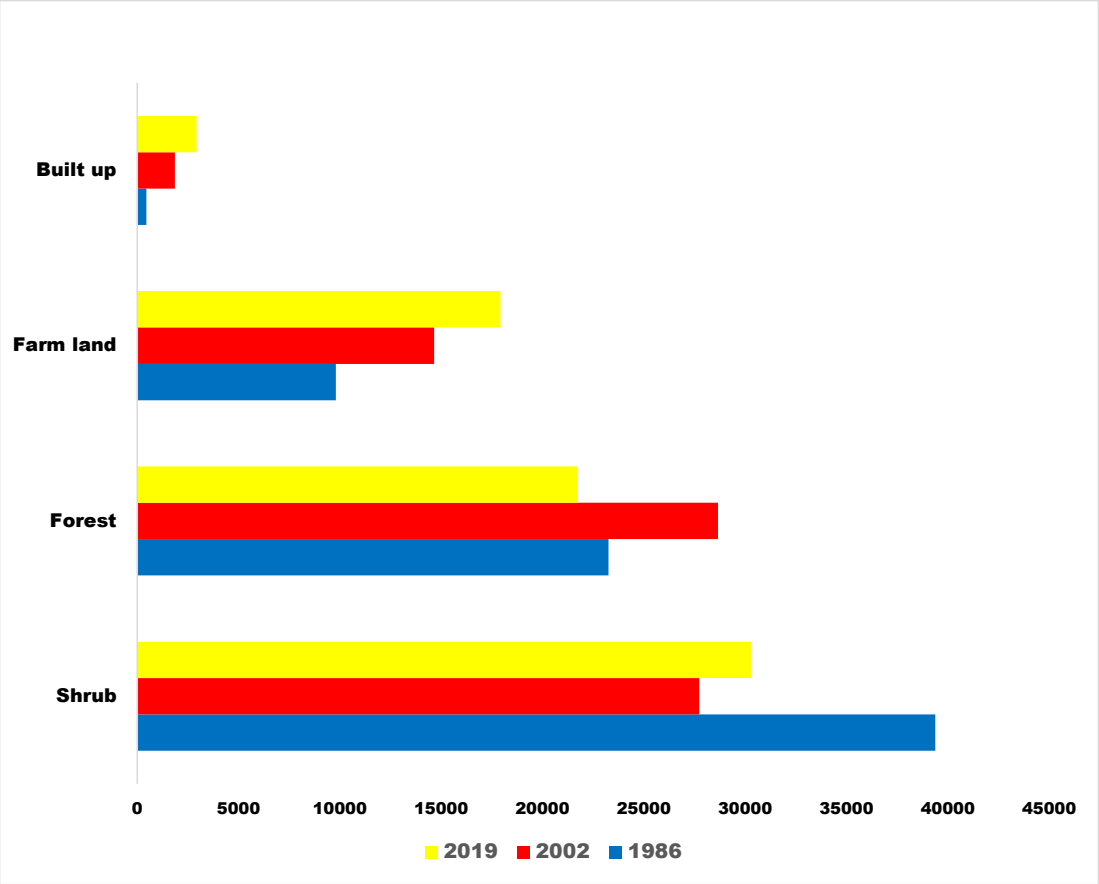


Figure 5. Land use/land cover for the year 2019

Table 2. Area covered by land use/cover classes

LULC Categories	1986	Area	2002	Area	2019	Area
Shrub	39381.8	54.02%	27733.0	38.04%	30281.9	41.55%
Forest	23261.0	31.91%	28664.1	39.32%	21733.1	29.82%
Farm land	9806.5	13.45%	14655.3	20.10%	17926.1	24.60%
Built up	451.1	0.62%	1852.1	2.54%	2933.9	4.03%



Land use/cover change detection. Post classification technique adopted for this study revealed the dynamics state in the study watershed. All the land cover classes considered in this study experienced some form of change. This means that over the 33 year study period the land use/cover in Ahafo Ano North has undergone change. The result of post-classification technique employed to detect changes are shown in Figures 7 and 8. while Table 3 shows the degree of changes. The data in Table 3 show that changes from forest land and shrub land to farm land and built up were significant. For instance, area changes from forest to farm land between 1986 to 2002 was 4,697.4

ha of land, representing 6.45%, while from farm land to forest was 2,174.9 ha of area changed, representing 2.98%. Changes in area coverage from shrub land to farm land between the same period (1986 to 2002) was 4,523.6 ha, representing 6.21%, while at the same time, only 1,431.6 ha of farm land were converted to shrub land representing 1.96% change. From1986 to 2002, forest land changed to build up by 471.4 ha, representing 0.65% area changed, while only 10.5 ha of built-up land were converted to forest land, representing 0.01% of area changed. Shrub land was also converted to build up by 306.3 ha, representing 0.30% of total area changed, while only 218.6 ha, representing 0.07% of total area changed.

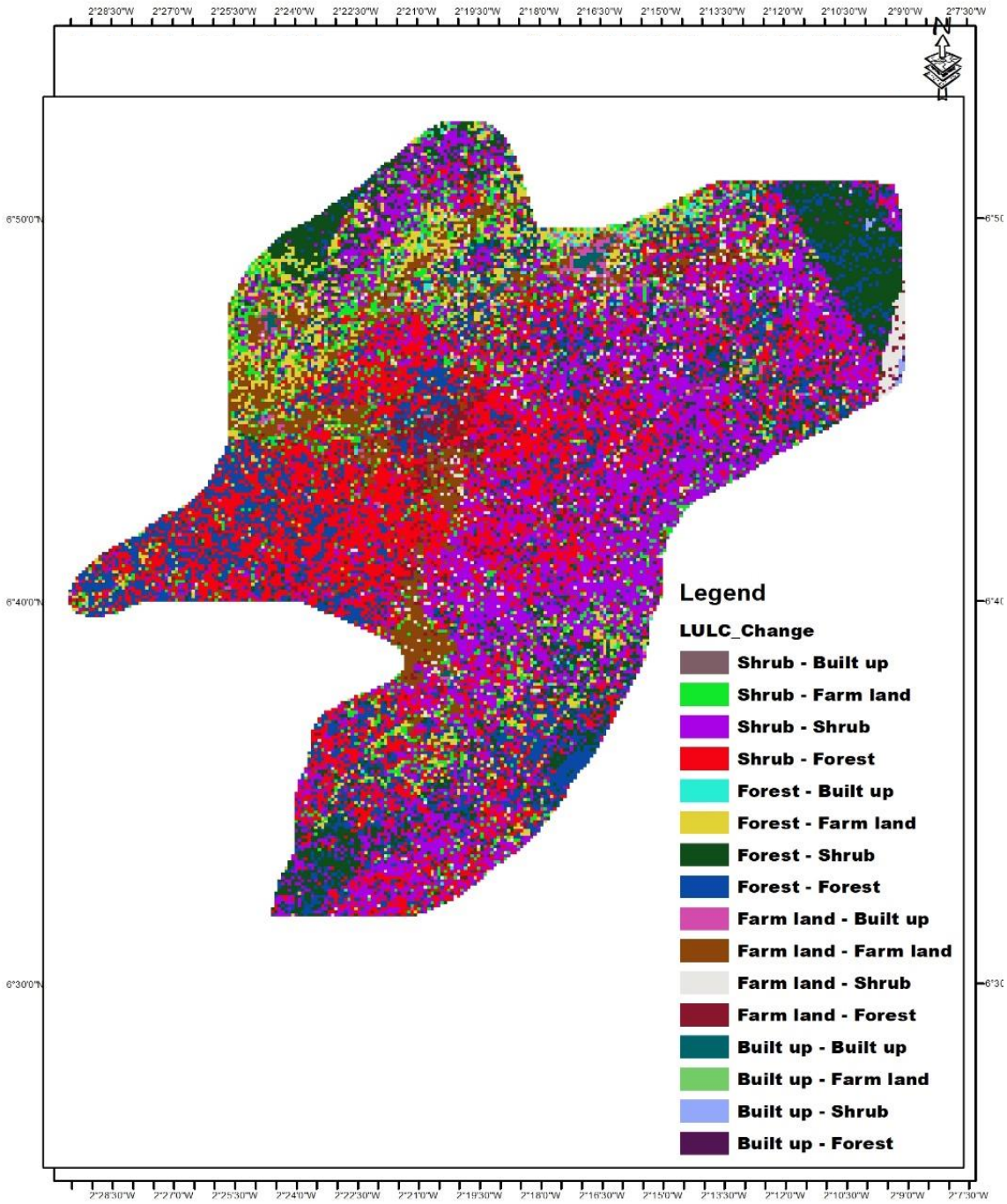


Figure 7. Land use and land cover change from 1986 to 2002

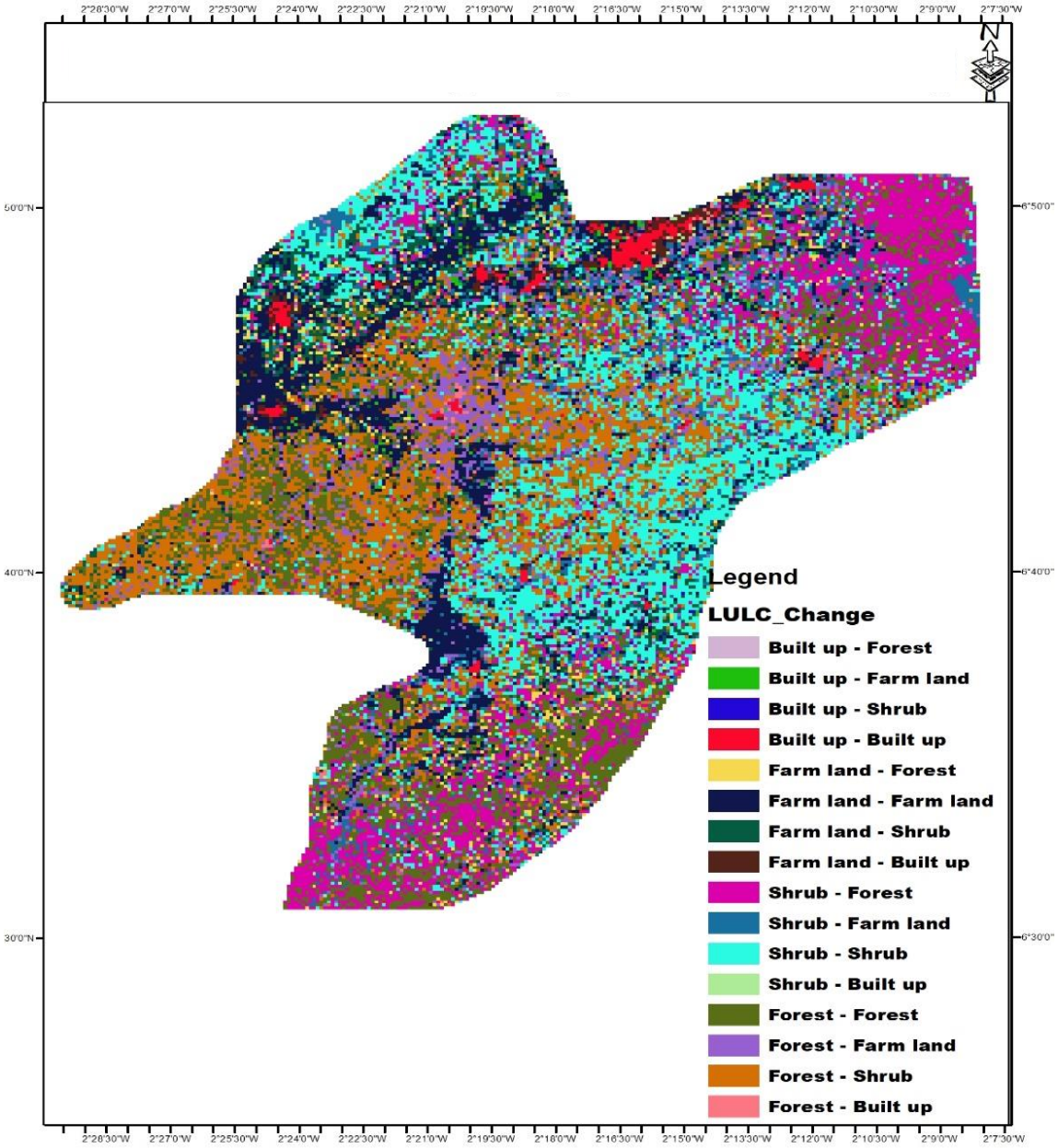


Figure 8. Land use and land cover change from 2002 to 2019

It appeared that between 2002 to 2019, changes from forest land and shrub land to farm land and built up also experienced high changes. Forest land changed to farm land by 4,924.1 ha, representing 6.76% area changed, while at the same time, only 1,456.7 ha of farm land changed to forest, representing 2.0% changed. From the same period, shrub land was converted to farm land by 4,388.9 ha, representing 6.02% of area changed. At the same period, only 3,9069 ha of farm land changed to shrub land representing 5.36% of area changed. Over the period, forest land changed to build up by 376.2 ha, representing 0.52% of area changed. At the same period,

only 76.9 ha of buildup land were converted to forest land, and it represent 0.11% of total area changed. Area covered by shrubs also converted to build up between the same period by 306.3 ha, representing 0.42% of area changed. At the same time, build up area also converted to shrubs by 1,92.3 ha, representing 0.26% of area changed. This means that for the entire study period forest land and shrub land have converted to farm land and built up (see Figures 3, 4 and 5).

Over the study period, forest and shrub covers have changed to farm land and built up. This is due to expansion in farm land and built up in the district, and is evidence throughout the study period. This trend is consistent with that reported by Kusimi (2008) in Wassa District in Ghana, and Batar *et al*. (2017) study in Garhwal Himalayan Region in India. These studies revealed that forest coverage decreased due to cropland and built-up expansions. In the current 33 year study period remarkable gains in farm land and built-up covers have occured in Ano North district. The general pattern of area coverages increased between the observed classes are at the cost of forest cover and shrub land. Similarly, the study by Biro and others (2013) in the Gadaif State in Eastern Sudan revealed that forest cover changed drastically to crop land over their study period. Likewise, the study by Tahir *et al*. (2013) revealed that built-up area increased at the expense of forest in Mekelle City, Ethiopia. It is clear that as farm land and built-up increased over the study period, forest cover and shrub lands decreased. This has been also witnessed in Ethiopia highlands by Braimoh and Vlek (2008).

Table 3. Table showing area changed from 1986 to 2002

LULC Change	Built up	Farm land	Forest	Shrub
Built up - Built up	358.9			
Built up - Farm land	32.0			
Built up - Forest	10.5			
Built up - Shrub	49.3			
Farm land - Built up		802.2		
Farm land - Farm land		5393.9		
Farm land - Forest		2174.9		
Farm land - Shrub		1431.6		
Forest - Built up			471.4	
Forest - Farm land			4697.4	
Forest - Forest			9860.1	
Forest - Shrub			8220.7	
Shrub - Built up				218.6
Shrub - Farm land				4523.6
Shrub - Forest				16608.2
Shrub - Shrub				18020.6

Table 4. Table showing area changed from 2002 to 2019

LULC Change	Built up	Farm land	Forest	Shrub
Built up - Built up	1074.0			
Built up - Farm land	507.5			
Built up - Forest	76.9			
Built up - Shrub	192.3			
Farm land - Built up		1176.9		
Farm land - Farm land		8102.2		
Farm land - Forest		1456.7		
Farm land - Shrub		3906.9		
Forest - Built up			376.2	
Forest - Farm land			4924.1	
Forest - Forest			10371.1	
Forest - Shrub			12976.7	
Shrub - Built up				306.3
Shrub - Farm land				4388.9
Shrub - Forest				9822.9
Shrub - Shrub				13199.8

Table 5. Table showing the area changed and percentage changed over the 33-year period

	1986 to 2002		2002 to 2019		
LULC Changed	Area Changed	% Area Changed	LULC Changed	Area Changed%	Area Changed
Built up - Built up	358.9	0.49%	Built up - Built up	1074.0	1.47%
Built up - Farm land	32.0	0.04%	Built up - Farm land	507.5	0.70%
Built up - Forest	10.5	0.01%	Built up - Forest	76.9	0.11%
Built up - Shrub	49.3	0.07%	Built up - Shrub	192.3	0.26%
Farm land - Built up	802.2	1.10%	Farm land - Built up	1176.9	1.62%
Farm land - Farm land	5393.9	7.40%	Farm land - Farm land	8102.2	11.12%
Farm land - Forest	2174.9	2.98%	Farm land - Forest	1456.7	2.00%
Farm land - Shrub	1431.6	1.96%	Farm land - Shrub	3906.9	5.36%
Forest - Built up	471.4	0.65%	Forest - Built up	376.2	0.52%
Forest - Farm land	4697.4	6.45%	Forest - Farm land	4924.1	6.76%
Forest - Forest	9860.1	13.53%	Forest - Forest	10371.1	14.23%
Forest - Shrub	8220.7	11.28%	Forest - Shrub	12976.7	17.81%
Shrub - Built up	218.6	0.30%	Shrub - Built up	306.3	0.42%
Shrub - Farm land	4523.6	6.21%	Shrub - Farm land	4388.9	6.02%
Shrub - Forest	16608.2	22.79%	Shrub - Forest	9822.9	13.48%
Shrub - Shrub	18020.6	24.73%	Shrub - Shrub	13199.8	18.12%

Conclusion and Recommendation

An attempt was made to establish the land use/cover change trajectory in Ahafo Ano North District for 33 years using remote sensing and GIS. This study has established that Ahafo Ano North District has undergone phenomenal change in land use/cover from 1986 to 2019. These changes are attributed to human land use.

This study revealed that forest cover and shrub land are diminishing, while farm lands and built-up areas are increasing. The farm land and built-up expansion have caused reduction in forest and shrub lands over the study period. The continued changes in land use/cover in the district will have strong socio-economic and environmental consequence. At the same time future changes in forest and shrub covers are anticipated. As such remedial strategies need to be put in place.

Establishing the rate of land use/cover changes is essential to monitor changes over time and is key for managing resources. In the study area, the dynamics in land classes in particular forest cover and shrub land indicate deforestation and this will lead to land degradation. The study recommends that emphasis be given to engage all the users and interest groups regarding land utilization in particular forest and agriculture to ensure sustainable uses. Appropriate measures should be taken by land managers to promote farm practices that minimizes farm land expansion. As future changes are inevitable, effort should be made to look for potential suitable areas for expansion of farm land. This should be backed by policies which should be enforced by the Ministry of Food and Agriculture (MoFA), Environmental Protection Agency of Ghana (EPA) and Forestry Commission of Ghana.

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