# Assessing Food Security in the Southern Part of Ghana Using Normalised Difference Vegetation Index*

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Baffoe, P. E. and Kingsley, A. F. (2019), "Assessing Food Security in the Southern Part of Ghana Using Normalised Difference Vegetation Index", *Ghana Journal of Technology,* Vol. 4, No. 1, pp. 31 - 39.

## Abstract

Food security plays a very important role in urban planning and development. It has become a problem in the developing world due to population growth and infrastructural development. There is decrease in the natural conditions supporting vegetation growth such as rainfall, good weather conditions and others. In this study, the food security of an urban area in the southern part Ghana was assessed using Landsat images of 1991, 2003 and 2017. The lowest and the highest Normalised Difference Vegetation Index (NDVI) values of the years of study were determined. The four land cover classes in the classification scheme identified were built-up areas, farmlands, thin forest and thick forests. It was observed that the farmlands increased from 9% in 1991 to 23% in 2003 and to 28% in 2017. This revealed that, there has been an improvement in food production. However, it was observed that, there was a decrease in the forest reserves and also the components that supported vegetation growth such as rainfall and favourable weather conditions decreased by 4% and 14% in 2003 and 2017 respectively compared to 1991 of 1%. Although the security of food is quite stable currently, it was concluded that, if nothing is done about the rate at which the forest is depleting, there could be food insufficiency in the future. It was recommended that measures should be put in place to reduce the rate at which the various forest covers are being destroyed and reafforestation should be embarked upon.

**Keywords**: Food Insecurity, Normalised Difference Vegetation Index, Forest**,** Landsat, Security

## 1 Introduction

Food is a basic necessity for human survival. Until recent times there had been abundant land resources to produce enough food to sustain the relatively small population. However, with the explosion in the population coupled with the remarkable growth rate of infrastructural development activities such as construction of building, road, deforestation and many other anthropogenic activities, there has been a significant reduction in the available agricultural land (Zubair, 2006). Moreover, due to the continuous use of the limited available farmlands year in year out, there has been a significant reduction in their potency as to how they support plant growth.

Vegetation cover around the world has undergone various changes due to the direct effects of natural causes such as fire outbreaks, global warming and dryness, and these changes have been increasing in the last decades (Elmendorf *et al.*, 2012). Land use and land cover changes have become a central component in current strategies for monitoring natural resources and also environmental changes for major urban planning and developments. The advancement in the concept of vegetation mapping has greatly increased research on land use and land cover changes, thus providing an accurate evaluation of the extent and health of the world's forest, grassland and agricultural resources which have become an important priority (Zubair, 2006). For these reasons there is the need to systematically and scientifically monitor the limited agricultural land to enable the land managers the ability to know how their lands are doing with regards to support plant growth and develop more appropriate land management practices (Pradhan, 2009).

To study the rate at which the various land cover changes are occurring, as a means to ensuring food security, a proper design was put in place for monitoring food security at Akuapem South District of Ghana, an area noted for its distinct agricultural activities. The time series method of Normalised Difference Vegetation Index (NDVI) was used to monitor the vegetation changes (Gross, 2005).

## 2 Resources and Methods Used

### 2.1 Study Area

The Akuapem South District is located at the south eastern part of the Eastern Region of Ghana between latitudes 05° 48' 00" N and longitude 00° 21' 00" W and 06° 05' 00" N and longitude 00° 05' 00" E. It covers a land area of about 440 km$^2$. It is bordered to the west by the Nsawam-Adoagyiri Municipality, to the south-east by the Kpone Katamanso District, to the south by Ga East District and to the North-East by the Akuapem North Municipality (Anon, 2017a).
The weather conditions in the District are generally cold with annual average temperature of 24°C

**Manuscript received June 20, 2019*
*Revised version accepted September 19, 2019*

recorded between March and April, the lowest temperature of 20° C in August. The District lies within the semi-equatorial climatic region and experiences two rainfall seasons in a year, with an average rainfall between 125 cm and 200 cm (Anon, 2017b).

The forest covers about 90% of the District (Anon., 2017a). Soil types are generally sandy loam with clays found in the valley bottoms. The Akuapem South District is characteristically agricultural based with 60% of its population engaged in subsistence and commercial farming (Anon, 2017b). The study area is shown in Fig. 1.

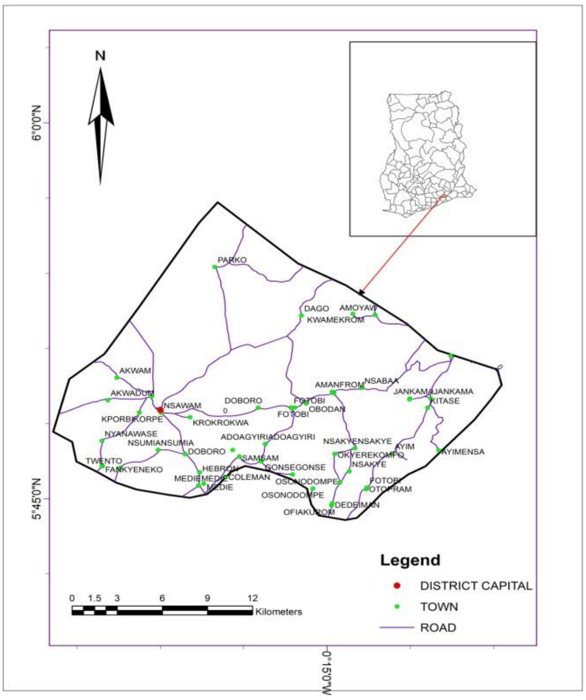


**Fig. 1 Map of Study Area**

## 2.2 Land Use and Land Cover Changes

Land use and land cover change dynamics are accelerating being driven by human activities but also producing changes that affect humans. These dynamics alter the availability of different biophysical resources including soil, vegetation, water, animal feed and others. Consequently, land use and cover changes could lead to a decreased availability of different products and services for human, livestock, agricultural production and damage to the environment as well (Oumar, 2009).

It is estimated that undisturbed (or wilderness) areas represent 46% of the earth's land surface. Forests covered about 50% of the earth's land area 8 000 years ago, as opposed to 30% today. Agriculture has expanded into forests, savannas, and there have been measures in all parts of the world to meet the demand for food and fiber (Lambin *et al.*, 2003). Based on data from diverse sources, the Global Forest Resources Assessment for the year 2000 estimated that the world's natural forests decreased by 16.1 million hectares per year on average during the 1990s, which is a loss of 4.2% of the natural forest that existed in 1990 (Lambin *et al.*, 2003). Land use in West Africa has changed swiftly over the last half-century: expansion of mixed crop-livestock systems into former grazing land and other natural areas and intensification of agriculture are the two largest changes that have been detected (Lambin, *et al.*, 2003).

Land change studies attempt to explain the areas where change is occurring, what land cover types are changing, the types of transformation occurring, the rate at which the land is changing, the driving forces and the proximate cause of change. The ultimate reasons for studying these change characteristics are to understand land change trends, evaluate and manage the consequences of these changes and define future scenarios of change (Anon, 2017c). The impacts of change in land cover may be positive or negative spatially or temporally but mostly negative in the tropical forest areas. In the long term, these negative changes reduce the ability of the earth to produce foods and nutrients on which human survive (Dale *et al*., 2000).

The ability to forecast land cover change and to predict the consequences of the change will depend on the ability to understand the past, current and the future drivers of land cover change (Anon, 2017d). The patterns of land cover change are shaped by the interaction of the economic, social, environmental and technological forces. The drivers of the change are mostly as a result of human activities other than naturally occurring. Some natural causes include landslides, storm and fire (Asubonteng, 2007).

Rapid urban development, agricultural activities, mining as well as quarrying are the notable human activities that also influence the land cover changes (Asubonteng, 2007). Increase in population which normally brings about various developmental projects is also a major factor.

An important aspect of change detection is to determine what is actually changing and to what extent i.e. which land use class is changing to the other. This information will reveal the desirable and undesirable changes and classes that are "relatively" stable over time. This information will also serve as a vital tool in management decisions. This process involves a pixel to pixel comparison of the study year images through overlay.

## 2.3 Food

Food is any substance consumed to provide nutritional support for the body. It is usually of plant or animal origin, and contains essential nutrients such as carbohydrates, fats, proteins, vitamins, or minerals (Anon, 2017d).

Food security is considered differently depending on whether the focus is at the macro or the micro level. At the macro level, food security means that enough food has to be available to cover the whole population's nutritional requirements. At the micro level, for households and individuals, three conditions need to be considered: sufficient food at the macro level, stability in supply and a regular access to food for all households and their members (Wanghamrong, 2010).

The World Food Summit of 1996 defined food security as existing "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life". Commonly, the concept of food security is defined as including both physical and economic access to food that meet people's dietary needs as well as their food preferences. In many countries, health problems related to dietary excess are an ever increasing threat. In fact, malnutrition and foodborne diarrhea have become double burden.

Food security is built on two pillars:

(i) Food availability: sufficient quantities of food available on a consistent basis; and

(ii) Food use: appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation.

Food security is a complex sustainable development issue, linked to health through malnutrition, but also to sustainable economic development, environment, and trade (Anon, 2017d).

## 2.4 Normalised Difference Vegetation Index

The NDVI is a simple graphical indicator that can be used to analyse remote sensing measurements and assess whether the target being observed contains live green vegetation or not.
The NDVI is the ratio of NIR (near-infrared radiation) and red bands. This is illustrated in Equation (1).

$$NDVI = (NIR - Red) / (NIR + Red) \quad (1)$$

The NDVI is employed in numerous studies to estimate vegetation biomass, greenness, primary production and dominant species, leaf area index (LAI), fraction of absorbed photosynthetically active radiation (Senay and Elliot, 2000).

NDVI is calculated from the visible and the near-infrared light reflected by vegetation. Healthy vegetation absorbs most of the visible light that incidents on it and reflects a substantial amount of the near-infrared radiations. Unhealthy or spares vegetation reflect more visible light and less near-infrared light. Bare soil on the other hand reflects moderately in both the visible and the infrared portion of the electromagnetic spectrum (Holmes *et al.*, 1987). Being aware of how plants behave across the electromagnetic spectrum, NDVI information could be derived by laying emphasis on the satellite bands that is the most sensitive to the vegetation information.

Calculation for NDVI for a given pixel always result in a number that ranges from (-1) to (+1), however no green leaf gives a value close to zero. A zero means no vegetation and close to (+1), i.e. (0.8-0.9) indicate the highest possible density of green leafs (Anon, 2017d). There are different vegetation indices, however those that rely on NIR and red reflectance as their principal input will typically yield the same information as the NDVI. One of the reasons for the popularity of the NDVI is that many sensors (from handheld to satellite) provide measurements in the NIR and red portion of the spectrum.

## 2.5 Materials

The data used for the study (see Table 1) include:
(i) Boundary Shapefile of the study area; and
(ii) Landsat images.

**Table 1 Data Used**

| Type of Data | Path and Row | Acquisition Year | Spatial Resolution |
|---|---|---|---|
| Landsat 4-5 TM | 193/056 | 1991 | 30 m |
| Landsat 7 ETM+ | 193/056 | 2003 | 30 m |
| Landsat 7 ETM+ | 193/056 | 2017 | 30 m |

## 2.6 Methods Used

The methods used (see Fig. 2) were:
(i) Field data collection/Ground Truthing;
(ii) Data Processing;
(iii) NDVI Calculation;
(iv) Supervised Classification; and
(v) Accuracy assessment.

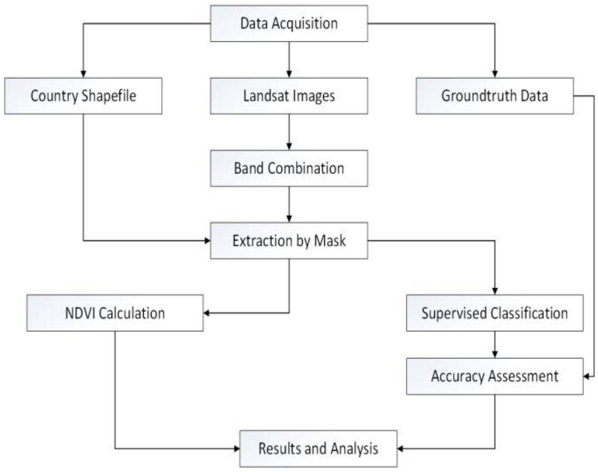


**Fig. 2 Flow Chart of the Methods Used**

2.6.1 Field Data Collection and Ground Truthing

The purpose of the field survey was to observe how the different image characteristics look like in reality. On the field, points were picked with GPS receiver on the different vegetation cover that exist in the area of study, to be able to understand the satellite images better for interpretation. The classes of interest such as thick forest, thin forest, farmlands and built-up areas were recorded.

2.6.2 Image Processing

The satellite images were processed using ArcGIS software. The satellite image processes include layer stacking and radiometric correction. The application of atmospheric correction is very essential for the current study for two reasons. Firstly, the study compares the relationship between field-based data and spectral information. Secondly, the images that are being used were acquired on dates with varying atmospheric conditions and also collected by different types of sensors via different platforms.

Removing atmospheric effects involve calibration and atmospheric correction. Calibration adjusts the image by converting raw radiance values of each pixel to atmospheric absolute (radiance) or relative (reflectance) values. Atmospheric corrections then adjust these values to ground radiance or reflectance at each pixel based on sun-ground-sensor geometry and atmospheric composition.

2.6.3 Image Enhancement

Enhancement makes important features of raw remotely-sensed image more interpretable to the human eye. The graphical model algorithms in ArcGIS were employed to perform the enhancement of the images. Radiometric enhancement for haze was done to correct for any irregular brightness in the picture due to the sensor irregularities and unwanted sensor. This correction was done so as to accurately represent the true reflectance of the image.

2.6.4 Interpretation of Satellite Images

After the printing of satellite images, they are inspected to aid in the preparation of the legend. The legend was established in terms of the image characteristics after which the interpretation was done. Homogenous areas were identified and defined in terms of the image characteristics. These are the colour, pattern, texture, shape, size and location (Bakker *et al*., 2004). A number was assigned to each homogenous area.

2.6.5 NDVI Calculation

The NDVI of the images of the different years of study were calculated. The different bands of the landsat images were separated. The NDVI was calculated from the reflectance measurements in the red and near infrared portions (NIR) portions of the spectrum as shown in Equation (1).

2.6.6 Classification

Image classification is based on the different spectral characteristics of the different materials on the earth's surface (Bakker *et al*., 2004). It is a process that operates in feature space. The process of the image classification involved these four steps:

(i) Selection and preparation of the image data;
(ii) Definition of the clusters in the feature space;
(iii) Selection of the classification algorithm; and
(iv) Running the actual classification.

Various land cover types from the image were determined and classified. This was done using the field knowledge, the positions of the GPS points taken from the field and their positions on the image (Lillesand and Kiefer, 1994).

The various land cover groupings and their descriptions used for the classification are shown in Table 2.

**Table 2 Data Used and their Sources**

| Land Cover Type | Description |
| --- | --- |
| Built-Up Areas | This include residential and commercial facilities |
| Farmlands | A land suitable or reserved for the cultivation of crops |
| Thin Forest | Consist of trees with no overhead canopy |
| Thick Forest | Consists of trees with canopy that can block sunlight from reaching the floor |

2.6.7 Accuracy Assessment

Accuracy assessment is an important part of any classification project. It compares the classified to another data source that is considered to be accurate or ground truth data. Ground truth coordinates were collected on the field. The most common way to assess the accuracy of a classified map is to create a set of random points from the ground truth data and compare that to the classified data.

# 3 Results and Discussion

## 3.1 Results

3.1.1 NDVI Maps

The NDVI maps are presented in Figs. 3, 4 and 5 for 1991, 2003 and 2017, respectively.

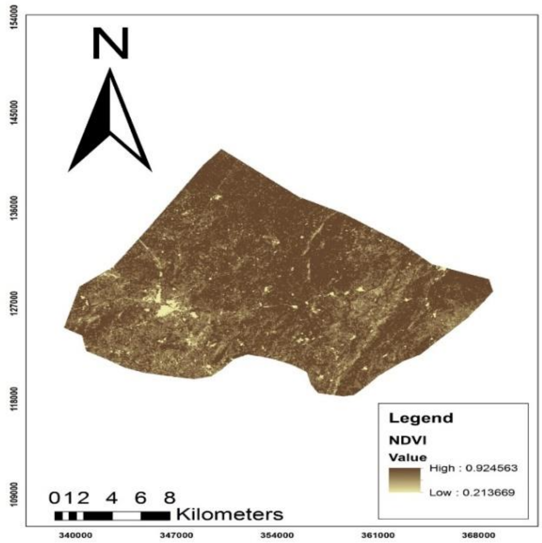


**Fig. 3 A 1991 NDVI Map of the District**

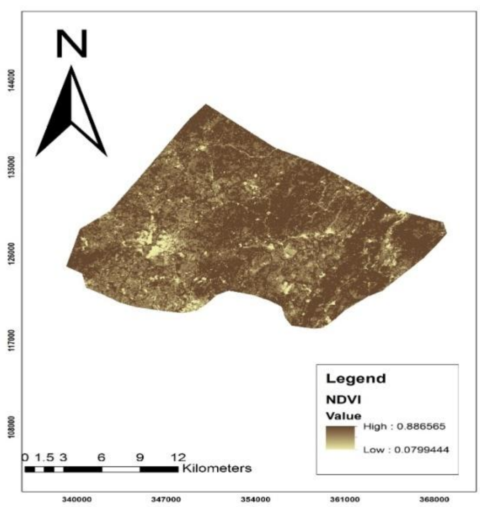


**Fig. 4 A 2003 NDVI Map of the District**

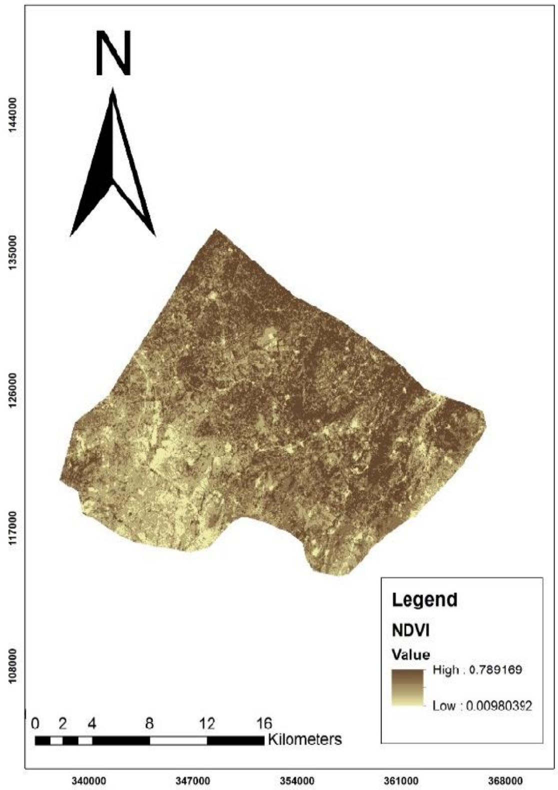


**Fig. 5 A 2017 NDVI Map of the District**

3.1.2 Classification of Maps

From the supervised classification, using maximum likelihood, three land cover maps (see Figs. 6 to 8) for 1991, 2003 and 2017 were produced. In this condition, four land cover classes were delineated. The classes identified in the study were built-areas, farmlands, thin and thick forests.

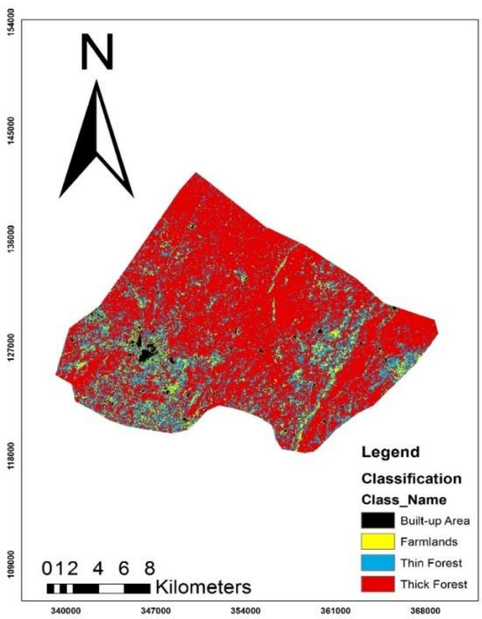


**Fig. 6 A 1991 Classified Map of the District**

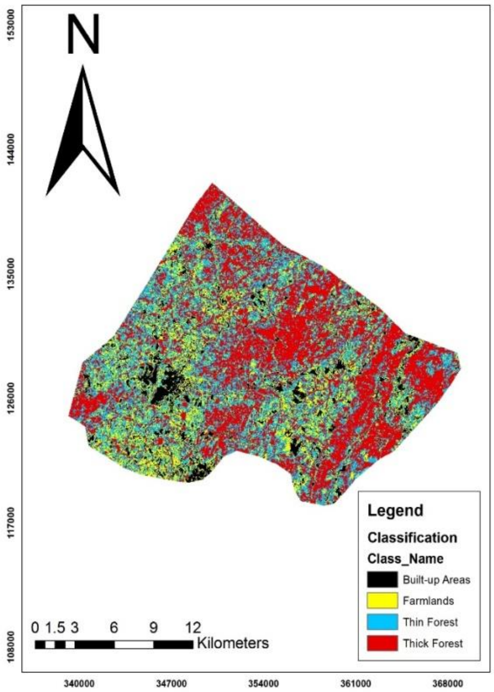


**Fig. 7 A 2003 Classified Map of the District**

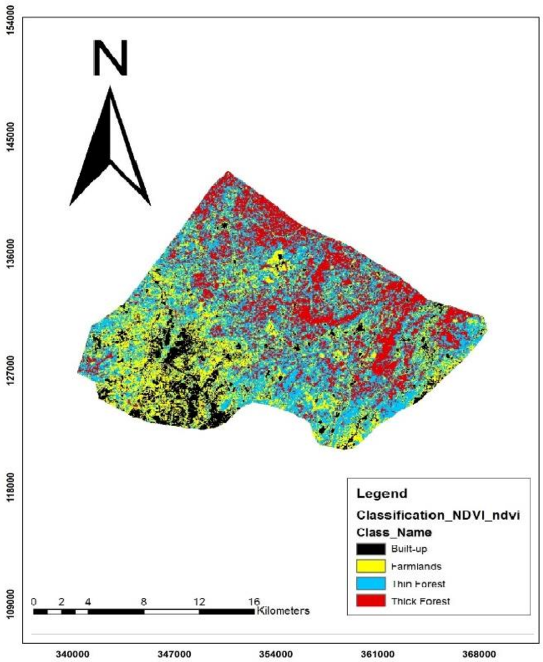


**Fig. 8 A 2017 Classified Map of the District**

Pie charts illustration of land use/cover distribution maps for 1991, 2003 and 2017 are presented in Figs. 9, 10 and 11. Table 3 illustrates the land cover changes.

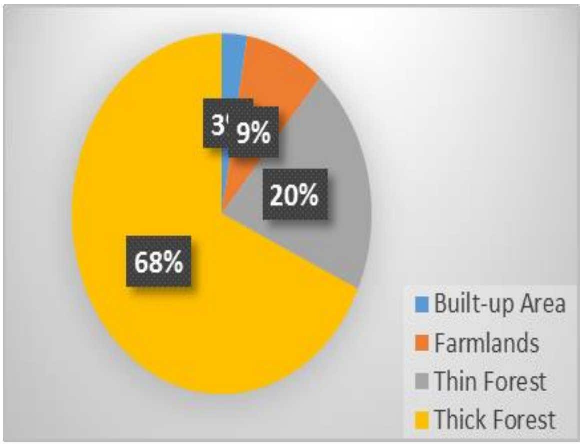


**Fig. 9 Pie Chart of 1991 Land Cover Map**

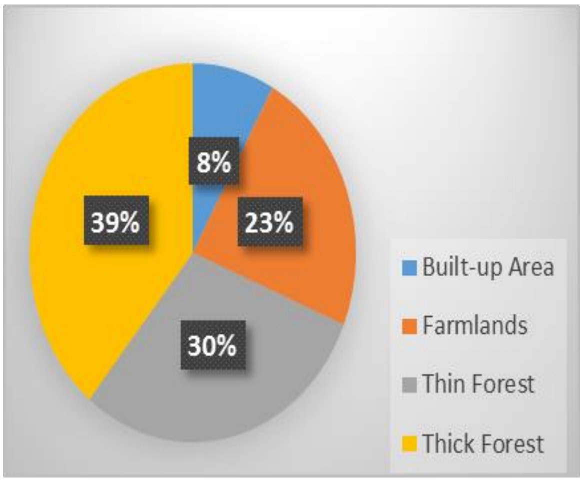


**Fig. 10 Pie Chart of 2003 Land Cover Map**

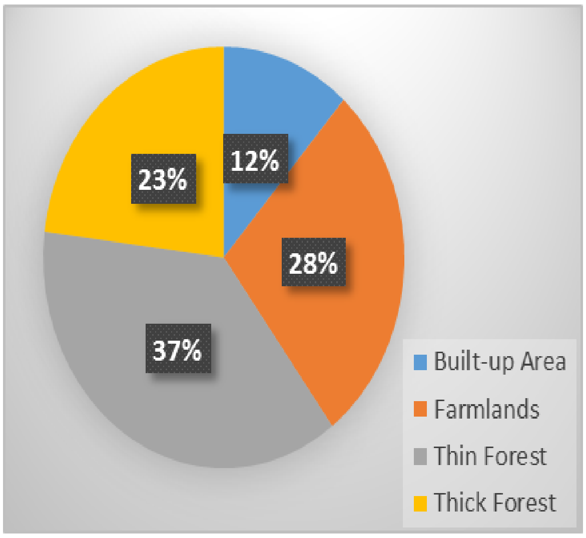


**Fig. 11 Pie Chart of 2017 Land Cover Map**

The bar chart of the land cover classes of the years 1991, 2003 and 2017 were created and presented in Fig. 12. The actual extent of the changes in land cover is presented in Table 4**.**

**Table 3 Land Cover Changes**

| Land Cover Classes | 1991 | % | 2003 | % | 2017 | % |
|---|---|---|---|---|---|---|
| Built-up Area | 18.008 | 4.093 | 35.811 | 8.139 | 50.797 | 11.545 |
| Farmlands | 38.173 | 8.676 | 101.482 | 23.064 | 122.095 | 27.749 |
| Thin Forest | 90.022 | 20.460 | 130.862 | 29.741 | 159.748 | 36.306 |
| Thick Forest | 293.797 | 66.772 | 171.845 | 39.056 | 107.360 | 24.400 |

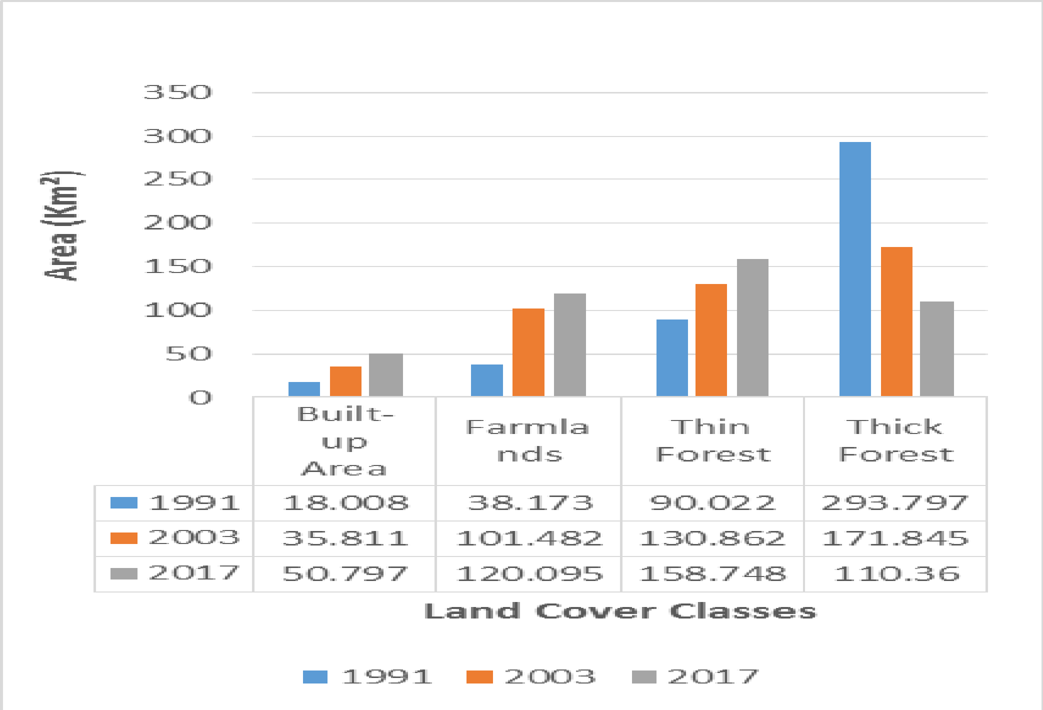


**Fig. 12 Bar Chart of the Land Cover Classes**

**Table 4 Actual Extent and Rates of Changes (km$^2$)**

| Class | 1991-2003 | | 2003-2017 | | 1991-2017 | | Annual Change | |
|---|---|---|---|---|---|---|---|---|
| | **Change** | **Rate (%)** | **Change** | **Rate (%)** | **Change** | **Rate (%)** | **change** | **Rate (%)** |
| Built-up | 23.803 | 4.046 | 14.986 | 3.406 | 38.789 | 7.452 | 1.492 | 0.287 |
| Farmlands | 63.309 | 14.388 | 22.613 | 5.139 | 85.922 | 19.528 | 3.305 | 0.751 |
| Thin Forest | 40.84 | 9.282 | 32.886 | 7.474 | 73.726 | 16.756 | 2.836 | 0.644 |
| Thick Forest | -127.952 | -29.08 | -70.485 | -16.019 | -198.437 | -45.099 | -7.632 | -1.735 |

### 3.1.3 Accuracy Assessment

To assess the accuracy of the three classified images, the ground truth points were overlaid on the 1991, 2003 and 2017 classified images. Forty eight transformed ground control points were used and the accuracies obtained are 77%, 81.3% and 87.5% for the years 1991, 2003 and 2017 respectively.

The accuracies increased from 1991 to 2003 through to 2017. This is because the more current the image, the more accurately it represent modern state of the area. The accuracy assessment for 1991, 2003 and 2017 are presented in Tables 5, 6 and 7 respectively.

**Table 5 Accuracy Assessment of 1991**

| Land Cover Class | Reference Totals | Number Correct | Individual Accuracy (%) |
|---|---|---|---|
| Built-Up Area | 16 | 14 | 87.5 |
| Farmlands | 14 | 12 | 85.7 |
| Thin Forest | 10 | 7 | 70 |
| Thick Forest | 8 | 6 | 75 |
| Total | 48 | 39 | |
| Overall Accuracy | 81.3% | | |

**Table 6 Accuracy Assessment for 2003**

| Land Cover Class | Reference Totals | Number Correct | Individual Accuracy (%) |
|---|---|---|---|
| Built-Up Area | 16 | 13 | 81.25 |
| Farmlands | 14 | 11 | 78.6 |
| Thin Forest | 10 | 7 | 70 |
| Thick Forest | 8 | 6 | 75 |
| Total | 48 | 37 | |
| Overall Accuracy | 77% | | |

**Table 7 Accuracy Assessment for 2017**

| Land Cover Class | Reference Totals | Number Correct | Individual Accuracy (%) |
|---|---|---|---|
| Built-Up Area | 16 | 14 | 87.5 |
| Farmlands | 14 | 12 | 85.7 |
| Thin Forest | 10 | 8 | 80 |
| Thick Forest | 8 | 8 | 100 |
| Total | 48 | 42 | |
| Overall Accuracy | 87.5% | | |

## 3.2 Discussion

A study of the NDVI image of 1991 Fig. 3 indicates the highest NDVI value of 0.924563 and the lowest value of 0.213669. The image shows that the areas that gave the high NDVI are widely spread. It shows thick vegetation covers and also the fact that the conditions that support vegetation growth such as rainfall is very common. Similar observation can be seen in Figs. 4 and 5.

Fig. 4 shows the NDVI image of 2003. A study of the image shows the highest NDVI value as 0.886565 and the lowest value as 0.079944. The areas with the high NDVI values were moderately spread. The conditions that supported vegetation growth were reduced by 4% when compared with the 1991 image. Fig. 7 shows the land cover classes 2003. The total area had 39% of the area as thick forest, 30% as thin forest, 23% as farmlands and 8% as Built-Up areas.

Fig. 5 shows the NDVI image of 2017. A study of the image shows the highest NDVI value as 0.789169 and the lowest value as 0.009880. The areas with the high NDVI values were considerably small with most of the total areas with average to very small NDVI values. The conditions that supported vegetation growth were reduced by 14% when compared with the 1991 image. Fig. 8 shows that 23% of the total area is covered with thick forest, 37% is covered with thin forest, 28% is covered with farmlands and 12% of the total Built-Up.

Figs. 6 to 9 show the land cover classes. It was revealed that 68% of the total land cover was thick forest, 20% was covered with thin forest, 9% were farmlands and 3% were areas that were Built-Up for 1991.

Although a very small portion of the total area was farmlands (9%), there was a very high food security because one could depend on the large forest lands and the conditions that supported plant growth to produce more food crop. The situation changed considerably in 2003 because of the increase in population and the decrease in plant cover which contributed significant decrease in the other factors that encourage vegetation growth. More land (23%) was to be cleared for agricultural purposes to meet the increasing demand for food. The situation became critical in 2017 with a sharp decrease in forest cover coupled with the increase in population and its attendant decrease in the factors that support crop growth. Therefore more land (37%) was to be used for crop production to support the ever-increasing demand for food.

## 4 Conclusions

This study has determined the state of food security in the Akuapem South District within the intended time period (1991-2017). Furthermore, the annual rate at which the various land covers are changing has been determined.

Remote sensing observations have revealed that there is a direct interdependency between high vegetation cover and the various factors such as rainfall and other factors that support rainfall. From the study it could be observed that as population increases and the factors which aid vegetation growth decreases, more farmlands would be required to grow more food crops to sustain the population. Hence there will also be an increase in the rate at which the forest covers will be cleared to produce more food crops to sustain the population.To ensure food security at the Akuapem South District the NDVI was used to assess the vegetation cover changes in the area.

Food plays a major role in population density distribution in urban areas. Such study will help in planning and development in the area.

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