ASSESSING THE FACTORS THAT INFLUENCE THE DISTRIBUTION OF TREES IN URBAN AREAS

A case of Kumasi Metropolitan Area

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March, 2017

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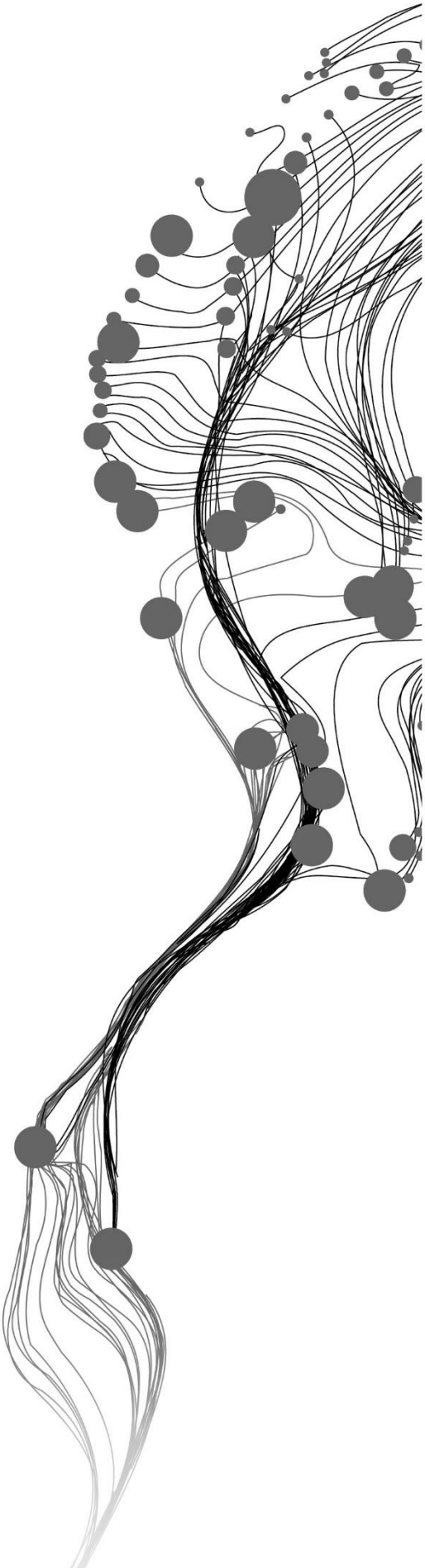

ASSESSING THE FACTORS THAT INFLUENCE THE DISTRIBUTION OF URBAN TREES

A case of Kumasi Metropolitan Area

EMMA BAAH AGYAPONG
Enschede, The Netherlands, March, 2017

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Geo-information Science and GIS for Natural Resources Management

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ABSTRACT

The understanding of Land Use and Land Cover (LULC) changes, as well as socio-economic and biophysical factors that influence the distribution of urban trees at landscape level, is necessary to understand humans and their relationship with the environment. This will support the urban planning process in achieving modernization and cohabitation of nature humanity is seeking for. LULC change is an ongoing phenomenon in Kumasi Metropolitan Assembly (KMA), which require detailed studies. Several studies have realized the importance of urban trees in the provision of ecosystem services and maintenance of urban environment. However, the increasing trend of LULC change and its resultant influence on the urban landscape as well as socio-economic and biophysical factors associated with tree composition have not been well studied and documented. Therefore, this research was intended to answer the question of how LULC has changed over the past 12 years and how the changes affected the surrounding landscapes in KMA. Respondents' socio-economic background and biophysical factors and their relation with tree composition was also studied. The LULC change analysis from 2004 and 2016 was done using Landsat images. Tree species composition in each LULC type was expressed in terms of Shannon-Weiner index, Species richness and density. Socio-economic background of respondents and their influence on trees distribution in the study area was analysed using structured questionnaire. Canonical Correspondence Analysis (CCA) was used to determine the relationship between tree composition and biophysical factors. The results indicated an increase in built-up from 43% to 66% between 2004 and 2016. Agricultural land, forest patches and riverine decreased over the 12-year period. The highest form of land conversion was agricultural land to built-up (50.8 km^2) with forest to agricultural land being the second (20.0 km^2). Conversion of forest to built-up was 7.8 km^2, riverine into agricultural land was 7.8 km^2 and riverine to built-up was 7.5 km^2. Generally, the overall Shannon-Weiner diversity index in the various LULC types were high. Distance to rivers, distance to road and elevation predicted the distribution of tree species diversity and distribution. This was confirmed by the CCA analysis with explanatory variables accounting to 60.59% species variance across the five sites (R^2 =0.61 $p<0.05$). The most important biophysical variables that explained the composition and distribution of trees in KMA were elevation and distance to water (streams/rivers). In general, people could not identify most of the services provided by trees in KMA. Shade was the most important ecosystem service that accounted for the prevalence of trees in KMA since majority of residents relax under shade trees during the day moreover, most people trade under shade trees.

Keywords: Land Use Land Cover, GIS & Remote Sensing, Species diversity, richness & density

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LIST OF ACRONYMS

ANOVA	Analysis Of Variance
CCA	Canonical Correspondence Analysis
CIFOR	Center for International Forestry Research
DBH	Diameter at Breast Height
DCA	Detrended Correspondence Analysis
DEM	Digital Elevation Model
ECA	Environmental Community Analysis
ERDAS	Earth Resource Data Analysis System
ETM	Enhanced Thematic Mapper
ENVI	Environment for Visualizing Images
FC	Forestry Commission
FAO	Food and Agriculture Organization
GTP	Ground Truth Data
GSS	Ghana statistical service
GIS	Geographic Information System
GPS	Global Positioning System
ILO	International Labor Office
ITC	International Institute for Geo-information Science and Earth Observation International
ITTO	International Tropical Timber Organization
LULC	Land Use Land Cover
KMA	Kumasi Metropolitan Assembly
MA	Millennium Ecosystem Assessment
PAST	Paleontological Statistics
PCA	Principal Component Analysis
RS	Remote Sensing
SPSS	Statistical Package for Social Science
SRTM	Shuttle Radar Topography Mission
UN	United Nations
USDA	United States Department of Agriculture
USS	United States Geological Survey
UTM	Universal Transverse Mercator
PHC	Population and Housing Census
KNUST	Kwame Nkrumah University of Science and Technology

1. INTRODUCTION

1.1. Background

The presence of diverse tree species within the urban landscape provide resources and serves as habitat for several life forms (Barbier et al., 2008). Tree is defined "as a woody perennial plant typically having a single stem or trunk growing to a considerable height and bearing lateral branches at some distance from the ground" (Oxford Living Dictionaries, 2016). Trees in urban areas provide ecosystem services that support urban environment and human development (Konijnendijk et al., 2006; Davies et al. 2017). Urban trees are comprised of shade trees, woodlots, fields, wetlands, plantations and riparian trees (Konijnendijk, Ricard, Kenney & Randrup, 2006).

Trees within urban ecosystems provide a wide range of services including biodiversity conservation, carbon sequestration, ground water recharge, soil protection and urban cooling effects (Bolund & Hunhammar, 1999). In West Africa, trees form an integral part of human settlement. Traditionally, people planted trees within their compounds to produce fuelwood, fruits, seeds, fodder and other raw materials and to contribute to the aesthetic value of cities (Dewees, 1992; Fuwape & Onyekwelu, 2011).

In recent times, trees have received more attention internationally in relation to sustainable utilization and management since man cannot survive without trees. Urban trees have become more important since they help to compensate for the continuing loss of forest by providing non-timber products (Gelens, van Leeuwen, & Hussin, 2010). These trees whether natural or artificial are observed as key component in the broader "forest landscape restoration" approach which is presently being developed by prominent international organizations such as IUCN, FAO, ITTO and CIFOR (McCracken et al., 2007).

Several studies have noted that urban expansion leading to LULC changes within urban areas has influence on tree composition within an urban landscape and changes its ability to support human needs (Lambin et al., 2003). The factors associating the distribution of trees require a comprehensive study to inform decision makers during policy formulation (Southworth & Tucker, 2001; Lohr et al., 2004). The rapid urban expansion in most developing countries has resulted in an increase in rural lands taken over and thereby causing land use land cover (LULC) changes at a faster rate (Hassan, 2016). During the process of urban expansion, fallow lands, agricultural land and forested areas are usually at the detriment and this influence the diversity and richness of tree species.

Humans have direct or indirect impact on the landscape through various activities. In order to understand LULC dynamics and its effects on the landscape, understanding of human dimensions and its influence is required. Verburg (2010) indicated that LULC change result from diverse interactions transpired between society and the environment. Liu (2001) emphasizes that to address the relationship between society and environment a study that integrates environment with human dimensions is required, which include perception and socio-economics, for a better understanding and management of environmental and ecological patterns and processes.

Understanding of socio-economic factors, land use/cover and LULC changes and biophysical factors and their relation is key to policy implications (Dadras et al., 2014b) and important in designing sustainable urban landscape (Liu et al., 2016).
Garedew et al. (2009) also emphasized the need to study beyond one disciplinary periphery and explore the techniques which combine LULC change studies, socio-economic information and learning at different stakeholders' levels.

This indicates that there is a need for countries that are undergoing rapid urban expansion to continuously assess and monitor urban expansion for effective management of the urban landscape (Aguayo & Pen, 2005; Fuwape & Onyekwelu, 2011). In present times, the combination of remote sensing and GIS technology can provide powerful tools to assist in better understanding and monitoring of spatial and temporal characteristics of changes in LULC at national, continental and global scales (Dadras et al., 2014b; Butt, et al., 2015). These techniques are useful and efficient to assess urban land cover (Hudak & Wessman, 2000).

1.2. Research problem

There is a current trend of urban expansion, which is leading to LULC changes within Kumasi Metropolitan Area (KMA). This has resulted in the decline in forest cover (Brook & Davila, 2012). Forested areas are being replaced either by human settlements, industries or as agricultural fields. The city that was once referred to as green city due to its varied plant composition has now undergone serious exploitation (Mensah, 2014). There is an urgent need for comprehensive and continuous analysis of these changes (Sudhira, Ramachandra & Jagadish, 2004) which is a challenge in developing countries like Ghana (Aguayo & Pen, 2005; Fuwape & Onyekwelu, 2011). Moreover, analyzing the influence of these changes on the distribution of urban trees would be vital for sustainable tree management (Burgi, Hersperger & Schneeberger, 2005).

Regardless of policies, laws and interventions to restore or reclaim degraded forest lands in urban areas, individual land owners and/or users may have a direct influence on the composition of trees on their surrounding (Oduro, n.d.). Urban dwellers maintain certain trees to serve several purposes that need to be well assessed and understood (Lieu et al., 2016; Cobbinah & Darkwah, 2016) which is not much considered in developing countries like Ghana (Mensah, 2014). The key question is does the public have similar reasons for maintaining trees or what are the most important services provided by trees in urban landscape, which motivate residents to keep trees? Earlier surveys conducted on how people value trees in urban areas in other countries have generated varied results (Sommer et al., 1994; Salam, Noguchi, & Koike, 2000). This implies that factors that influence urban tree composition distribution include socio-economic and biophysical factors (Matsuno & Kida, 2001; Hansen & Rotella, 2002).

Study on socio-economic and biophysical factors and their influence on the distribution of urban trees is key to sustainable management (Hansen & Rotella, 2002; Burgi, Hersperger, & Schneeberger, 2005; Faleyimu & Akinyemi, 2015; Budruk & Lee, 2016). However, lack of a holistic research of the various socio-economic and biophysical factors remains a restraint for urban trees and land use planning in Ghana (Attua & Fisher, 2011; Afrane, & Adjei-Poku, 2013; Mensah, 2014).

1.3. Research objectives

1.3.1. General objective

The main aim of this study was to investigate LULC change and its influence on urban landscape and tree species composition and the relationship between socio-economic and biophysical factors associated with the composition and distribution of trees in Kumasi Metropolitan Assembly (KMA).

1.3.2. Specific objectives.

The specific objectives of the study include the following:

1. To determine LULC changes between 2004 and 2016 in KMA;
2. To assess the composition (richness, diversity and density) of tree within the different LULC classes;
3. To analyze the most important services associated with the prevalence of trees in KMA;
4. To analyse the relationship between socio-economic factors and services associated with the prevalence of trees in KMA and
5. To determine the influence of biophysical factors (slope, elevation, distance to roads and water rivers) on the distribution of trees in changed areas.

1.4. Research questions

1. Which LULC classes have undergone changes between 2004 and 2016?
2. What is the tree composition within the different LULC cover types?
3. What is the most important service associated with the prevalence of tree in changed areas?
4. What is the relation between socio-economic characteristics and services associated with the prevalence of urban trees in changed areas?
5. Which biophysical factors best explain the distribution of trees in LULC classes in changed areas KMA?

1.5. Research hypothesis

H_1: There are differences in trees density, diversity and richness in the different LULC classes.

H_0: There are no differences in trees density, diversity and distribution in different LULC classes.

H_1: Education, origin, occupation and gender has influence on the prevalence of trees in changed areas.

H_0: Education, origin, occupation and gender has no influence on the prevalence of trees in changed areas.

H_1: Elevation, distance to rivers and roads vary in the amount of influence they have on the distribution of trees in changed areas.

H_0: Elevation, slope, distance to rivers and roads do not vary in the amount of influence they have on the composition of trees in changed areas.

2. DEFINITIONS AND CONCEPTS

2.1. Urbanization and urban expansion

Urbanization is the increase in the number of people living in cities and towns, which result in the concentration of people, which usually leads to an increase in urban expansion. Urbanization is a universal phenomenon which is occurring all over the world and almost all the countries are susceptible to this phenomenon (Sudhira, Ramachandra & Jagadish, 2004). In 2014, 54% of the world's population was living in cities and the number is expected to increase to 66% by 2050 (UN, 2014).

Like many other countries, the major cities Accra and Kumasi in Ghana have recorded rapid increase in urban population over the past decade with a growth rate of 3.1 and 2.7 respectively (Ghana Statistical Service, 2012). It has been forecasted that, more than half of Ghanaian population will live in urban areas by 2020 (Naab, Dinye, & Kasanga, 2013). The process is seen as an important stimulant of development of the economy of cities (Dadras et al., 2014a). However, others are of the view that urban expansion results in degrading urban environmental and ecological systems (Liang et al., 2008; Cobbinah & Darkwah, 2016). Urban expansion in Africa has caused many people to live in sensitive areas like riversides, mountainous and other areas conserved for urban greenery (Cobbinah & Darkwah, 2016).

According to Aguayo & Pen (2005), urban expansion is always at the detriment of biodiversity conservation, while native ecosystems are usually replaced by buildings and pavements and the vegetation cover is primarily replaced by non-native ornamental species. Research on 386 European cities revealed a reduction in the area of green spaces/vegetation and attributed urban expansion as the main cause in most cites (Fuller & Gaston, 2009).

In United States of America (USA), about 1.4 million hectares of urban green space, which include forest, has been lost to rapid urbanization in most cities (McDonald, Forman, Kareiva, 2010).This is similar in developing countries and Africa in particular. Urban expansion has resulted in a loss of about 21% to about 12% of green space in Abuja (capital town of Nigeria) between 2001 to 2006 (Fana, Dlama & Oluseyi, 2011). Moreover, Ghana has experienced a fast growth of its cities, which include Kumasi (the second largest city in Ghana). Kumasi has undergone a massive increase of urban expansion from 182 km^2 to 254 km^2 between the years 1963 to 2011, which has resulted to a decline in urban forest and trees (Poku-Boansi & Inkoom, 2011).

2.2. Land use, land over and landscape

The use of the words, land use and land cover mostly create confusion and have been subjected to several studies. Mücher et al., (2010) described land cover as the biophysical cover of the surface of the earth. Land use is described as the activities of human that is directly linked to land (Mücher, Klijn, Wascher, & Schaminée, 2010). In spite of such recognition, the dynamics of land use resulting to changes in the structure of urban setting has not yet been studied broadly and systematically (Afrane &Adjei-Poku, 2013). Within the urban setting are heterogeneous land cover/ use which consist of clusters of recurrent interacting ecosystems that are referred to as landscape (McGarigal & Marks, 1994). For the purpose of this research, the words land use, land cover and landscape would be used concurrently.

The various land cover types in an urban landscape can play vital roles in terms of biodiversity conservation. Research indicated that private gardens in urban areas can have an immense plant diversity or richness and for that reason can be an important source of nature conservation (Rudd et al., 2002; Thompson et al., 2003). Ye et al., (2012) in a highly urbanized area in Shenzhen in China shows an increase in the native plants diversity even though their proportion in relation to other species had declined.

In Ghana the landscape has been classified into various land cover types which include; settlement/built-ups, agricultural land, grassland/savannah, water bodies and forest. Trees (including both exotic and indigenous species) in the various land use land cover (LULC) types in Ghana have the potential of providing various forms of services (Forestry Commission, 2008).

2.3. Land use land cover change

Globally, changes in land cover from natural ecosystem to urban expansion and croplands have increased over time. The resultant effect is the modification of natural ecosystems, which alter and reduce the ability of the ecosystem to provide goods and services necessary for human survival. The main LULC changes observed globally are agricultural expansion, tropical deforestation urban expansion and modification of rangeland (Lambin et al., 2001; DeFries & Bounoua, 2004). Studies have showed that land use change has a proliferating effect on biodiversity by the invasion of exotic plant species. This usually influences the composition of species and the proportion of indigenous plant in the ecosystem (Hassan, 2016). Some of these LULC changes include: encroachment into agricultural land, riverine vegetation, water bodies and forested areas (Addo-fordwuor, 2014).

2.4. Land use land cover change detection

Change detection is described as a process whereby differences in the state of a phenomenon is observed at different time series whereby the extent of changes in the attributes of the phenomenon within that period is measured (Singh, 1989). The process involves the use of multi-temporal datasets to examine the temporal effects of the observed process. The prime goal of any change detection operation is to detect areas in digital images that shows change features between two or more times series images (Hayes & Sader, 2013).

Within a landscape where urbanization is ongoing with continuous demand for more lands, it is necessary to carry out change detection analysis (Bhaskar, 2012). Timely and accurate detection of changes of the features of earth's surface is needed and useful in order to understand and explain the relationships among humans and natural phenomena (Lu et al., 2004; Pauleit, Ennos & Golding, 2005). This technique has been applied in several fields such as; forest and wildfires, urban land use/cover change and in monitoring studies such as coastal erosion control and flood control (Lu et al., 2004; Mayaux et al., 2005).

Data from remote sensing in combination with GIS tools generate important information and possibility to quantify the amount of changes happening on the surface of the earth between given time periods (Hudak & Wessman, 2000; Guerschman et al., 2003 Huang et al., 2009). Selection of suitable remote sensing data such as satellite images and appropriate methodology in monitoring LULC is sometimes quite challenging. With the availability of Landsat image, monitoring urban expansion and its resultant land cover changes has led to an emergent field of research in remote sensing and GIS community.

Even though Landsat images are of medium resolution, many researchers have used them in monitoring LULC changes over the years (Bhattarai & Conway, 2007; Jansen et al., 2008) and have proved to be of higher

potential in mapping urban areas (Salehi et al., 2012). In addition, it is freely available and have the longest recorded data at global scale level for earth observation (Gilani et al., 2014). This has facilitated several studies on LULC changes in highly urbanized areas, using Landsat images as far back as 1970s to 2013 (Fang et al., 2016) and over a relatively larger areas (Butt at al., 2015; Hassan, 2016). The use of Landsat images between 1956 and 2012, revealed that LULC change has resulted to a decrease in agricultural and barren lands in Southern Iran (Dadras et.al., 2014) by. In Ghana, the application of Geographic Information Systems (GIS) and remote sensing techniques in Land cover changes studies, revealed that conversion of forest to agricultural land and natural vegetation into settlement/built-ups were drivers of change in urban areas. Asubonteng, 2007; Benefoh, 2008; Afrane & Adjei-Poku, 2013). Using similar techniques Landsat satellite imagery of 1985 and 2003, indicated that extensive expansion of built-ups, decline in croplands and grass/fallow and projected 70% of expansion of urban infrastructure in 2015, were the key factors that influenced LULC in some parts of Ghana (Attua & Fisher, 2011).

Different change detection methods are available which include; post classification and principal component analysis (Singh, 1989; Lu et al., 2004) and image differencing and ratios (Singh, 1989; Jin et. al., 2013). However, the post classification change detection method has been the most extensively used technique. It has an advantage of operating on more than one independent classified image as an input data and the output is a change map and a change matrix (Chen, 2002). The differences in transfer from one cover to another are seen and changes in percentage can also be calculated (Lillesand et al., 2004). This method has been proven to be the most effective and accurate tool in urban land cover change detection analysis (Afify, 2011).

In assessing the LULC changes between 2004 and 2016 in KMA, post classification change detection technique was employed. This was done after digital image classification process by using supervised classification method where training samples from the field was used for the two Landsat images to generate a land cover map. During land cover mapping process, each pixel of the image was assigned a land cover class based on the spectral characteristics (Jensen, 1981; Richards, 1999).

2.5. Urban trees species composition

Trees are considered as all woody plants that have one or several stems with basal circumference >15cm and branching well above the ground (Werger, Van der Aart & Verhoeven, 1988; Hickey & King, 2000; Curtis & Mannheimer, 2005). Several studies on species composition usually take into consideration species richness, diversity and density. Species diversity is a measure of the spread of species in a given area and this parameter has been used to assess vegetation species composition (Shannon, 1948; Yirdaw, 2001) and range between 1.5 to 3.5 (MacDonald, 2003). Species richness is the total count of individual plant species in an area, which is often related to diversity. Therefore a community with a high diversity, indicate a community with larger number of different species making that particular community richer with species (Kent & Cooker, 1992; Yirdaw, 2001; Zeide, 2005). Species serve as a building block of any ecosystem and serve as a key factor to provide insurance against changes and enhance the efficiency with which resources in the ecosystem are transferred (Kent & Cooker, 1992). Species density is the number of individual species a given area (Yirdaw, 2001).

Urban tree species diversity and richness are usually determined by the magnitude of disturbance of the ecosystem. Moderate disturbance promotes forest and tree maintenance whereas intensive disturbance leads to destruction of biodiversity in forest ecosystems (Fox, 1985; Mackey & Currie 2001; Walpole et al., 2004;

Van & Kellner 2005). However, several forest ecosystems in urban areas have been degraded above their capability to conserve and promote indigenous tree species diversity (Fox, 1985; Mackey & Currie 2001).

2.6. Measurement of biological diversity

Assessment of species diversity in an ecosystem is vital for sustainable management. It gives information that explain the structure and functions of a particular ecosystem (Shannon, 1948). Diversity indices are used to determine species diversity and richness in a given area (Tolera et al., Karltun, 2008). Examples are Fisher's alpha diversity index, Simpson index, and Shannon indices (Kent & Cooker, 1994; Harper, 1999). In most botanical studies, Shannon index is used as a measure of diversity and richness since it takes into consideration the number of individuals, number of taxa as well as equitability/evenness of a community (Hutcheson, 1970; Hunter 1996;). For the purpose of this study Shannon (H') index was used to calculate the diversity. Moreover, species richness and density was also assessed. Shannon's index is calculated from the equation below;

$$H' = -\sum_{i-1}^{s} Pi \ln Pi$$

Where: s = the number of species

p = the proportion of individuals or the abundance of the *i* th species expressed as the total cover

In = log base *n*

The negative sign cancels out when taking the algorithms of the population (Kent & Coker, 1994). Species richness (S) is the number of individual species present in a given area (Shannon, 1948). Whereas the density refers to the number of individual species per unit area (Zeide, 2005). Several studies have also associated species diversity and richness to the broad concept of disturbances (Fox, 1985; Mackey & Currie, 2001; Walpole et al., 2004; Van & Kellner, 2005). It has been broadly specified that species diversity, richness and evenness fall as the rate of disturbance increases, with maximum diversity which occur at intermediate disturbance levels, a concept often explained as "intermediate-disturbance" hypothesis (Fox 1985; Mackey & Currie, 2001). This hypothesis suggest that physical disturbance prevents the ability of competitively dominant species from eliminating others from the community. Therefore, diversity should be anticipated to be low at low levels of disturbance since only the best competitors survive. Similarly, frequent or intensive disturbances result to repeated colonization of few species during the disturbance, which result to low diversity. Zeidler et al., (2002) recorded a high number of plant diversity and richness in sites under low land use intensity in Western Namibia.

Several sampling methods are used to obtain samples that are representative of the population. Both circular and rectangular plots are used to draw samples from a population depending on the characteristics of the community (Gauch, 1982). Rectangular plots are used in areas with a flat terrain where the vegetation is thick which makes it difficult for circular plots. Rectangular/square plots are widely for studies on forest ecosystems (Sanei & Zakaria, 2011; Gauch, 1982). Alongside a well-defined grade/class of an environment and vegetation, a relatively few samples in a range of 5-20 are taken within a fixed interval may be satisfactory (Abd-El-Ghani, 1998).

2.7. Factors associated with the distribution of trees in urban landscape

Trees provide valuable ecosystem services and this serve as motivation for people to maintain trees in a highly urbanized landscape (Lohr et al., 2004). The term 'ecosystem services' can be defined as the benefits people

obtain from nature. Trees are considered to be the primary factor in ecosystem service delivery (Davies et al., 2017). Urban residents usually keep trees within their surroundings to provide them with several ecosystem services (Salam, Noguchi & Koike, 2000). The Economics of Ecosystems and Biodiversity (TEEB) (2011) have grouped ecosystem services provided by trees into three categories. These include: provisioning services (such as such as food, fruits, fuelwood); regulating and maintenance services (responsible for the maintenance of biodiversity, carbon sequestration, water purification, air purification, pollination of plants, nutrient cycling, soil formation); and cultural services; (religious, recreational, aesthetic, spiritual or non-material benefits).

USDA (1996) and Dwyer et al., (2002) emphasized that in an urban landscape, community involvement is crucial for the sustainability of the urban forest. Urban landscapes are seen as multi-layered, complex and dynamic, modified by the people who dwell in and utilize them. For instance, trees within urban landscapes are found in both private and public spaces, with varying benefits and values to residents (Geist & Lambin, 2002). Understanding of how urban residents relate to urban forest and benefits obtained and values attached to services provided by trees and green spaces is therefore, crucial for effective planning and policy formulation to promote well-being and sustainability (Shackleton et al., 2015). Studies by Westphal (1993) and Sommer et al., (1994) revealed that people are motivated by values such as spiritual benefits and aesthetic values, and practical benefits including noise reduction, air purification and increase in property values. Austin (2002) also found similar motivations in urban tree planting in Detroit.

Urban forest concept and its benefits seem not to be well recognized or understood (Stiegler, 1990; Hull, 1992). Stiegler (1990) revealed that, respondents with low education less recognize the concept of "urban forest". Lohr et al., (2004) established the relationship between the values placed on trees in urban areas and the demographic background of respondents in America and revealed that most people strongly appreciated the value of trees in supporting their lives. The few people, who placed a relatively less value on trees, were those with low income, poorly educated, male and young. People in the United States attached different values or reasons for keeping trees in cities, which included social (e.g. to calm people), and esoteric (e.g. making of interesting sounds) and environmental (e.g. smog reduction) reasons. The highest-ranked reason for keeping trees were for cooling and shade whereas the next most important value was for their calming effect. Salam, Noguchi & Koike (2000) reported that people in Bangladesh maintain trees for its economic benefits rather than ecological reasons.

Other factors that influence the distribution of trees and diversity are biophysical factors such as land cover type, soil type, elevation, topography and distance to water bodies (Southworth & Tucker, 2001; Hansen & Rotella, 2002). Ndolo et al. (2016) assessment of biophysical factors and tree diversity and distribution in Kenya, revealed a strong relationship between elevation and tree diversity. According to Serneels & Lambin (2001), understanding of the relationship between biophysical factors (e.g., soil, distance to water bodies and road networks) and tree distribution can contribute to effective management of urban forest and green resources.

3. MATERIALS AND METHODS

3.1. Study area

The study was conducted in Kumasi Metropolitan Area (latitudes 6°38´N and 6°45´N and longitudes 1°41´05´´W and 1°32´W) in Ashanti Region of Ghana (Figure 1). Kumasi Metropolitan Area (KMA) is the largest district in Ashanti Region covering a total land area of 276 km². For effective administration, KMA has been divided into nine sub-metropolitan Districts Councils namely; Bantama, Tafo, Kwadaso, Suame, Nhyiaso, Asokwa, Manhyia, Oforikrom, and Subin. It is a fast growing metropolis in the Ashanti Region with an estimated population is 2,035,064 people with an annual growth rate of about 5.4%. It is estimated that of the total KMA area, 60% is rural, 46% is peri-urban and 48% is urban (GSS, 2012). Currently there is a high rate of urban expansion, which has resulted to changes in land cover leading to depletion of forest and tree resources.

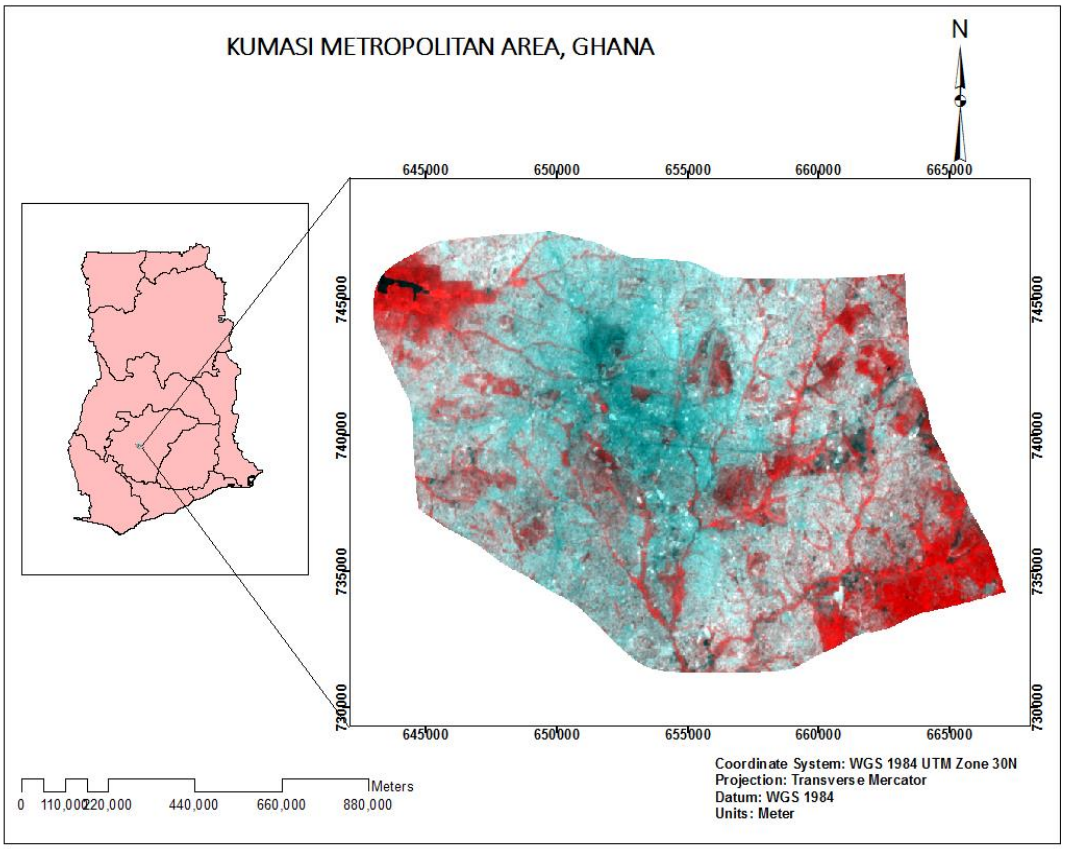

Figure 1: Map showing the location of the study area within the Ashanti Region of Ghana. The false red colour on Landsat 2016 image represented forest and other vegetated areas, while the whitish, greyish and greenish colours showed non-vegetated areas, mostly build-up

3.1.1. Vegetation

KMA falls within the semi-deciduous forest zones of Ghana characterized by patches of vegetation with a divers tree species such as *Celtis*, *Triplochlon* and *Ceiba, morindan* in combination with some exotic species (Oteng-Amoako, 2006). The zoological gardens and the KNUST botanical gardens are examples of patches of vegetation cover which are scattered throughout the peri-urban areas. The vegetation and soil types

promote agricultural activities in the peri-urban areas, which are dominated by cash crops such as cocoa, oil palm and citrus. However, this vegetation is declining due to high rate of urban expansion (KMA, 2010).

3.1.2. Climate, geology and soil

The metropolis falls within the wet sub-equatorial climate type with moderate temperature and humidity. The average minimum temperature is about 21.5°C and a maximum average of 30.7°C. Humidity is about 84.16% before and 60% afternoon with double maxima rainfall regime (214.3mm in June and 165.2mm in September). The metropolis is dominated by middle precambrian rock with forest ochrosols as a predominant soil type which is rich in nutrient and support agricultural activities in the periphery of Kumasi. The demand for both private and commercial land uses has led to about 95% percent of the agricultural/ arable lands being displaced by built-ups and other physical infrastructure (Ghana Statistical Service, 2014).

3.1.3. Relief and drainage

The topography is undulating and falls within the South-West physical region ranging between 250-300m above sea level. Major River (Owabi) and streams such as Subin, Nsuben, Sisai, Aboabo and Wiwi drain the area. River Owabi serve as drinking water for the entire region and promote socioeconomic wellbeing of inhabitants. However, human activities such as farming and building have resulted to the pollution and extinction of some of these water bodies which may partly explain the periodic flooding in the metropolis (GSS, 2014)

3.1.4. Demography

The metropolis has a population of 2,035,064, which comprise of 47.8% males and 52.2% females. It has a population density of 8,075 persons per sq. km with a total number of 440,283 households and an average of four persons. About 63.3 % of the population constitute the potential labour force. The largest ethnic group is Asante (80.7%) followed by Mole Dagbon (8.7%) and Ewe (3.6%) (GSS, 2014). A percentage of 89.5 of the population (between 11 years and above) are literate whereas 10.5% are illiterate (GSS, 2014)

3.1.5. Economic activity

The economically active population is about 66.5 %, which falls within the ages of 15 years and above while 33.5% is economically inactive. About 91.4 % of the economically active people are employed whereas 8.6 percent is unemployed. About 38.9% of the employed population are in the sales and service work, 22.8 % are in craft and other related trades. About 10.3% are into elementary tertiary occupation with only 2.6% into skilled forestry, fishery and agricultural workers

3.1.6. Organization of thesis and study approach

The details of the research methods have been displayed using the flowchart in Figure 2. It shows the pre-process of Landsat images, field sampling and analysis of trees in the various LULC classes, ground truth data for LULC image classification, interview of community members, image processing, and statistical analysis of tree composition in the various LULC classes and biophysical data analysis.

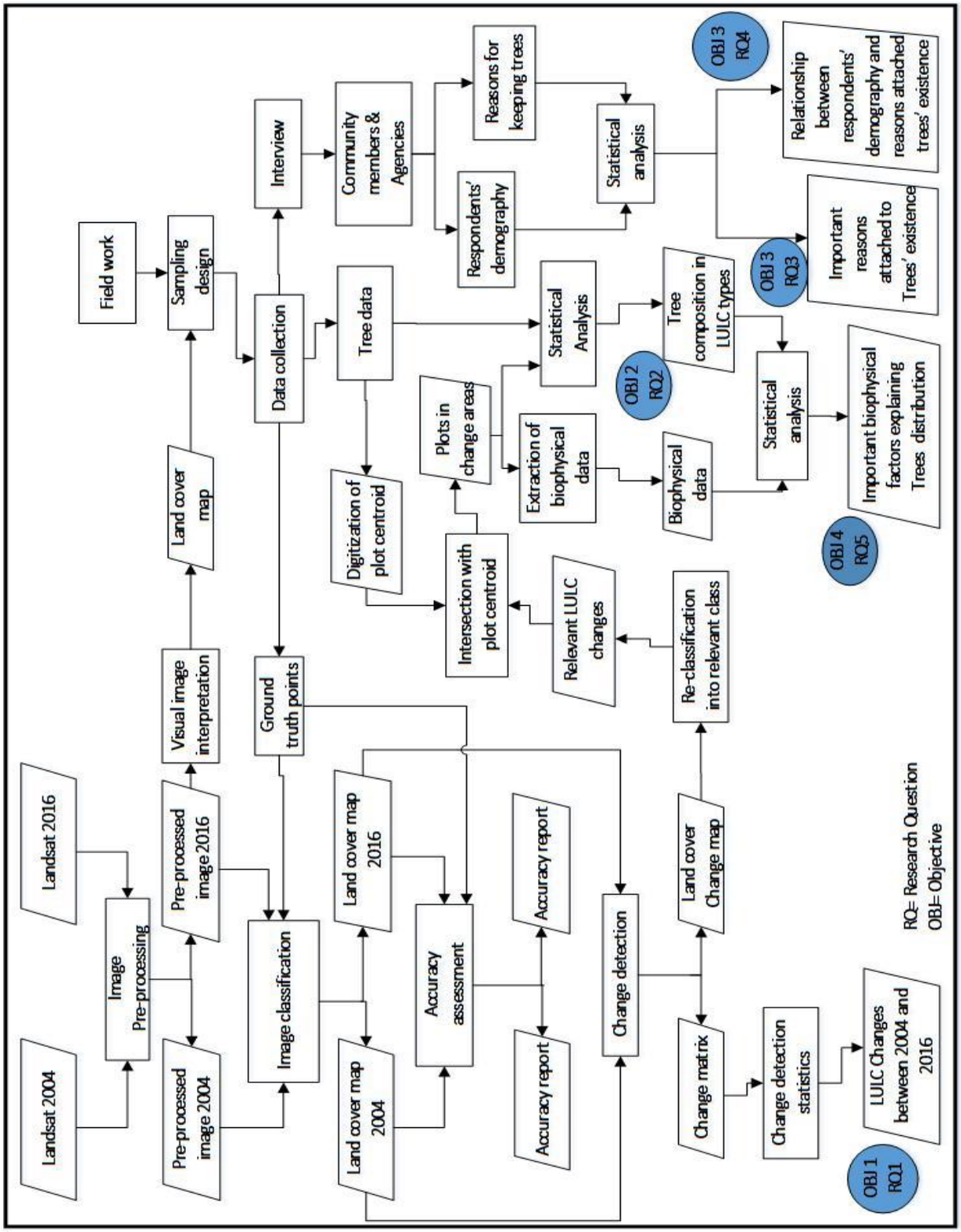

Figure 2: Methodological flowchart of the research

3.2. Materials

3.2.1. LULC image acquisition and processing procedure

Two satellite images of 14th February 2004 and 20th January, 2016 from the Enhanced Thematic Mapper Plus (ETM^+) sensor of Landsat-7 were obtained from the United States Geological Survey (USGS) Earth Resources Observation and Science Data Centre (http://www.usgs.gov). Selection of this sensor was based on its availability and its wide use for studies on LULC changes (Attua & Fisher, 2011; Dadras et. al., 2014; Gilani et al., 2014). KMA boundary was downloaded at Global Administration Areas website (http://gadm.org/) and Google Earth image of January 2004 and February 2016. Other data used included; ground truth data, data on trees, socio-economic data and biophysical data (rivers, road and elevation of KMA).

3.2.2. Instruments used

Table 1: List of Instruments and Software Used for the Study

Instrument	Uses
Global positioning system	Sample plots identification and ground truth data collection
Compass	For the direction of plots creation
Camera	For capturing field images
ArcGIS 10.3, ERDAS Imagine 2014, ENVI 5.3	Take pictures of tree species which were difficult to identify on the field
MS-Excel, MS-Word, SPSS	Write- up and statistical analysis
PAST	Analysis on biodiversity
ECA (Environmental Community Analysis 1.3)	Analysis of biophysical data

3.3. Methods

Data collection was conducted from May to June 2016. The data collected included; ground truth data in the various LULC classes, tree assessment (inventory of all trees with Diameter at Breast Height (DBH) from 10cm and above) within the various LULC classes and interview (questionnaire in Appendix 1) in changed areas. Prior to fieldwork, sample sites were picked from 2016 Google Earth image which was loaded into GPS for field navigation.

3.3.1. Ground truthing data collection for 2016 image classification

Ground truth data of 207 points were randomly taken by using Global Positioning System (GPS) for the purpose of supervised classification of the Landsat image of 2016. Based on reconnaissance survey, literature review and support from local community members, five LULC classes were identified during the filed survey. The Land use system of KMA were studied to know the various LULC types (FC, 2008). Community members were consulted in the identification of land use most especially the identification of agricultural lands. The various LULC classes and their description (Gelens, van Leeuwen & Hussin, 2010; Attua & Fisher, 2011), were shown in Table (2).

Table 2: Land cover classification scheme for the study

Land cover	Explanation
Forest	Tree dominated lands with a close canopy of 900m² /0.09 hectare and above or below 20% crown cover
Water	Rivers and streams without vegetation cover
Agricultural land	Croplands, grassland, abandoned cropland with scattered trees, shrubs and short vegetation
Riverine	Vegetation along waterbodies with trees, shrubs and other plants
Built-up	Lands with man-made infrastructure, paved/unpaved road with patchy vegetation

- **Data for 2004 image classification**

In order to classify 2004 Landsat image, 200 samples were digitized on identified LULC types on the 2004 Google Earth image with the aid of filed data. During the process, some features such as building, road, farmlands and water bodies that can last long, were considered as the basis for picking training samples.

3.3.2. Tree species assessment in the various LULC types

Sample plots were randomly laid in each LULC classes (Fidelibus & Mac Aller, 1993). Quadrat with the dimension of 30 m x 30 m were laid in agricultural land, riverine and forest cover types (Sanei & Zakaria, 2011), because of the absence of buildings and other infrastructures. While in the built-up land cover type, 60 m x 60 m quadrats were laid. A 500 m interval among quadrats in each land cover type was created in order to capture enough information about the inter and intra-specific relationships between trees (Abd-El-Ghani, 1998) (Figure 3). Coordinates were taken at the corners of each quadrat to generate plot centroids for further analysis. An overall of 68 plots were laid which consisted of 19 plots in the built-up, 17 in agricultural land, 11 forest and 21 riverine land cover types.

Within each quadrat an inventory of trees were taken and recorded to species level as well as their uses and origin where possible (Appendix 2). For the identification of native and non-native tree species, a guide to the Forest Trees in Ghana (Hawthorne & Gyakari, 2006) was used. For species that could not be identified on the field, specimen were taken and placed in plant press for identification at the Parks and Gardens in KMA office.

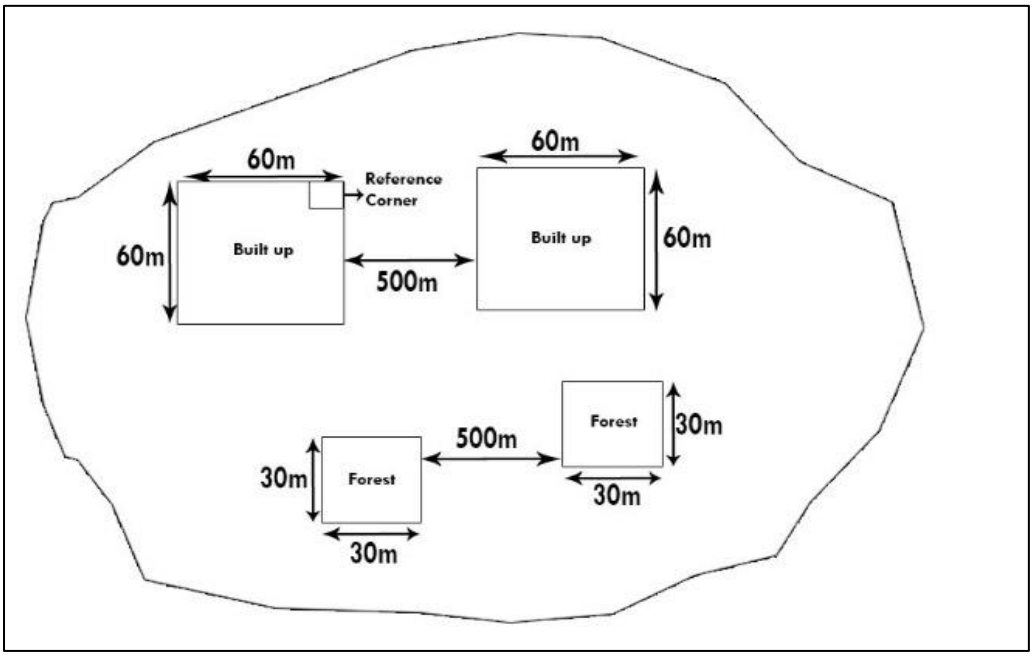

Figure 3: A schematic diagram of square quadrats used to sample tree species in the various LULC classes

3.3.3. Interview of residents and other agencies

Purposive sampling technique was used to select respondents who were willing to provide information by virtue of their experience or knowledge (Bernard, 2002) as well as authorities who manage the trees. The changed map was overlaid on 2016 Google Earth image to identify the presence of trees in compounds houses. The idea was that, even though these areas have undergone land conversions (example conversion of forest, to built-up, agricultural land into built-ups), residents have maintained trees (including remnant and newly planted) on their compounds.

Close and open-ended questions (Faleyimu & Akinyemi, 2015) was used to capture the following information; gender, origin, education and occupational background of respondents and ecosystem services provided by trees (which serve as reasons for the existence of trees) (Sommer et al., 1994; Pauleit & Duhme, 2000). This design was selected to capture relevant information for the objectives of study and at the same time to capture new ideas from respondents (Siniscalco & Auriat, 2005). The various ecosystem services provided by trees were listed for respondents to select all possible applicable factors and at the same time allow them to provide some answers (Appendix 1).

The interview was conducted in local dialect in cases where respondents could not read English and included; landlords/owners and people who lease the land (97 respondents), heads of institutions which included Forestry Commission, Department of Parks and Gardens and Planning Department of KMA (three respondents).

3.3.4. Biophysical data collection and preparation

In order to assess the most important biophysical factors explaining tree species composition and distribution in each LULC type in changed areas, SRTM Digital Elevation Model (DEM) was downloaded at http://www.usgs.gov. Elevation in KMA ranged from 204 to 323 meters (Figure 4). Road map and hydrology map of KMA were obtained from KNUST database to generate distance maps. Distance to water (streams/rivers) and distance to road maps were generated using Euclidean distance in ArcMap (Figure 5). Distance to road ranged from 0 to 6054.06 m with distance to water ranging from 0 to 5994.67 m. The

centroid of plots in changed areas were used to extract values for distance to water, distance to road and elevation. This was done using extract multiple values to points tool in ArcMap.

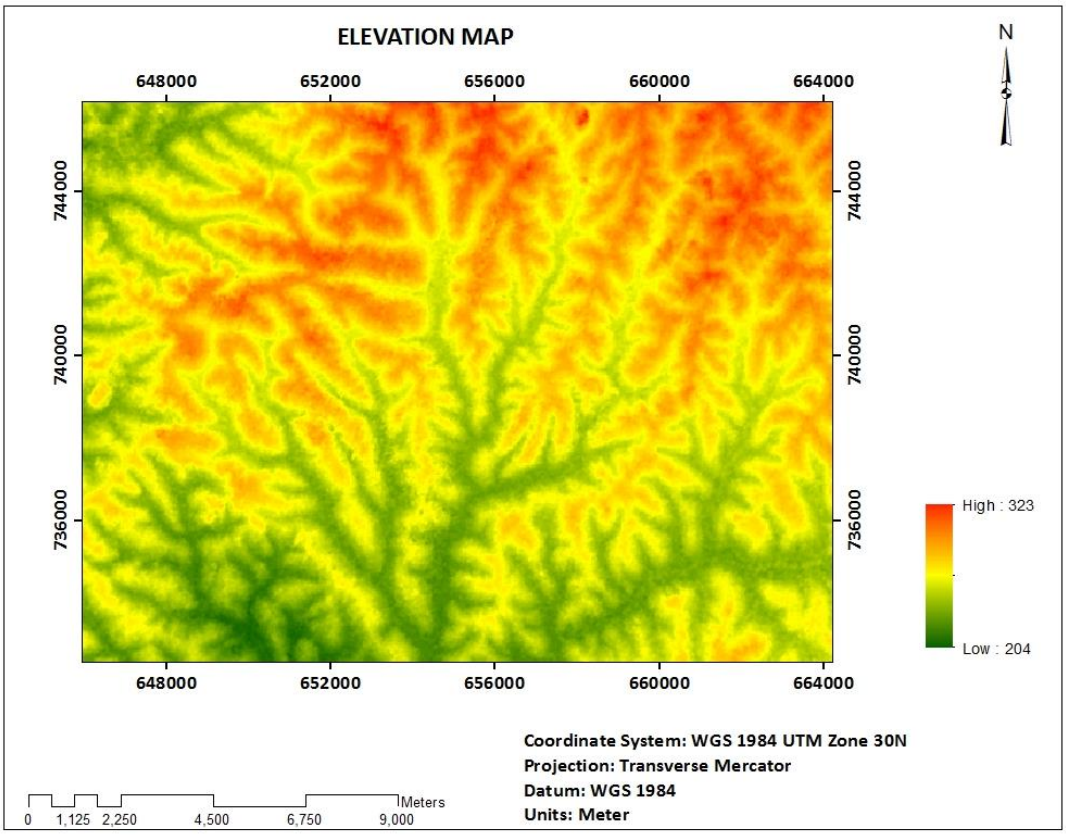

Figure 4: A map showing elevation of KMA, where values were extracted for CCA analysis

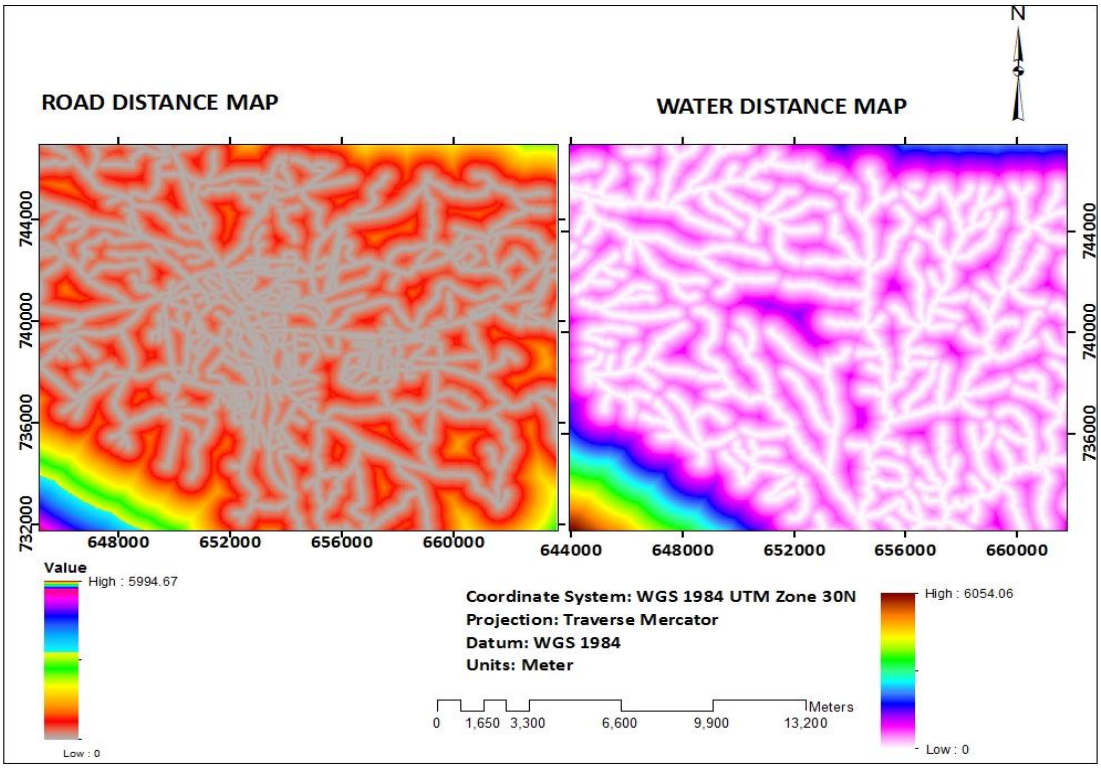

Figure 5: A map showing the Euclidean distance to road and distance to water in KMA where values were extracted for CCA analysis

3.3.5. Procedure for image classification of 2004 and 2016 images

The two satellite images were pre-processed by stacking (band 1, 2, 3, 4, 5 and 7) and projected into the Universal Transverse Mercator (UTM) projection system (zone: 30N, datum: WGS-84). The boundary of the study was delineated by using KMA boundary in ERDAS Imagine. The two Landsat images of 2004 and 2016 were classified using Supervised Classification with Maximum Likelihood Classifier (Jensen 1981; Richards 1999; Lu et al., 2004) in ERDAS Imagine 2014. The usefulness of this classifier is that it takes into account the variability of the various classes and assign pixels to class of highest probability (Lillesand et al., 2004; Dedras et al., 2007). The images were classified into forest, riverine, agricultural land, built-up and water using 70% of the field data as training data for the 2016 image. The 2004 image was also classified using 70% of training samples from 2004 Google Earth image.

- **Accuracy assessment**

Accuracy assessments of the classified maps were conducted by using the error matrix and calculating kappa statistics (Cohen, 1960). The accuracy assessment was done for the two images thus 2004 (by using 30% of samples from Google image data that was captured at the same of the Landsat image) and 2016 (using 30% of the field data).

- **Change detection analysis between 2004 and 2016**

To detect the changes over the past 12 years in the study area, which is one of the objectives of the study, post classification change detection technique was used (Jensen 1981; Singh 1989). This was performed using ENVI software's image differencing algorithm on the classified images. The results of the change matrix were subsequently exported in excel to calculate the area of each cover type and that of the transfers in hectares.

3.3.6. Measurement and comparison of tree species diversity, richness and density

- **Species diversity, richness and density**

Shannon-Weiner and Margalef indices were used to quantify species diversity (H') and richness (D) in the forest patches, riverine, built-up and agricultural land covers (Shannon, 1948; Yirdaw, 2001) using PAST version 3.14 software. Shannon-Wiener index was computed using the formulae:

$$H' = -\sum_{i-1}^{s} Pi \text{ In } Pi$$

Where: s = the number of species

p = the proportion of individuals or the abundance of the *i* th species expressed as the total cover

In = log base *n*

The density of trees per plots in each LULC type was computed, using the formulae: number of tree counts/the size of plot and expressed in hectares.

Test for normality for each set of data (species diversity, richness and density) was done using the Kolmogorov-Smirnov normality test in IBM SPSS Statistics 20. The aim of the test was to aid in selecting between parametric and non-parametric test in the comparison of samples in the LULC classes. Parametric test (e.g., One-way ANOVA test) is a statistical test for the comparison of the means of sample data, which is normally distributed whereas non-parametric test (example Kruskal-Wallis) is used to compare the means of sample data, which is not normally distributed (du Prel et al., 2010). The results indicated that, species diversity was normally distributed however, species richness and density were not normally distributed (see Appendix 7 for details). Kruskal-Wallis test was used to determine the significant difference in species richness and density across the various LULC classes (Pallant, 2007). One-way ANOVA test was used to explore the differences in means species diversity across the various LULC classes.

A Bonferroni post-hoc test, with effect size of 0.008 (i.e. alpha divided by number of comparisons) was done to identify the significant difference in tree species richness and density among pair of land cover types. The purpose of the Bonferroni effect was to adjust the level of significance to control the rate of type one error (Quinn & Keough, 2002).

3.3.7. Statistical analysis of respondents' socio-economic characteristics and identified services of trees in changed areas

To determine the most important service identified by respondents, the cross tabulation tool in SPSS was used. This tool provided the total counts of each service identified by each respondent as against the total counts of services that were not identified (Appendix 10).

The various services identified by respondents were categorized under three main headings for easy analysis; provisioning services (food, fruit, fuelwood, sales of tree products), cultural services (recreation, relaxation, boundary demarcation and aesthetic) and regulating and maintenance services (preservation of biodiversity, moderate of local climate, air purification, windbreaks, climate change, shade and erosion control) (Appendix 10). The services were grouped per respondents' origin, gender, education and occupation to study the relationship between respondent's socio-economic characteristics and services associated with the existence of trees.

A chi-square test (at 95% C.I.) was use to compare the significant difference mean between the socio-economic variables of respondents (gender, origin, education and economic) and the service functions, which was subsequently summarized in excel. Similar method was used by Salam et al., (2000) to determine

the significant difference between urban residents demographic background and reasons attached to the existence of trees in Bangladesh.

3.3.8. Analysis of biophysical factors explaining the composition and distribution of tree species

The extracted values for elevation, distance to water and distance to road were tested for correlation by using band collection statistics in ArcMap (Appendix 15). The values were exported to excel for computation and further analysis. Normality test was subsequently done using IBM SPSS Statistics 21 and the result indicated that the data was not normally distributed (see Appendix 16).

In order to identify the relationship between biophysical variables (elevation, distance to water and distance to road) and tree species diversity in the various LULC classes; forest, riverine, built-up and agricultural land classes in changed areas, Canonical Correspondence Analysis (CCA) was used (ter Braak, 1986). CCA is a direct gradient analysis, which combines weighted averaging technique with multiple regression to determine a linear combination of biophysical/environmental variables (explanatory variables) that influence the distribution of species relative abundances among samples (ter Braak, 1997).

Tree species' relative abundance from sampled plots in the various LULC classes that fell in changed areas was used. Individual species with less than five percent turn over in each land cover class were removed from the CCA analysis, because rare species usually have little influence on multivariate statistics and the results and are usually treated as outliers (Gauch, 1982). Forty-seven plots with 50 dominant tree species were used for the analysis (see Appendix 17 for details).

Biophysical data was log(x+1) transformed (when the initial analysis showed that the variance of the sample were larger than the means) before they were subjected to CCA analysis, using Environmental Community analysis (ECOM) ver. 1.33 software (Henderson, & Seaby, 2000). Monte Carlo permutation test (with 9999 iteration) was done to evaluate the significant difference among eigenvalues for axes 1 and 2 and the sum of all eigenvalues (ter Braak & Verdonschot, 1995).

4. RESULTS

4.1. Land use/cover classification results

Land use land cover classification of the two images revealed the highest land cover transition in built-up land cover class (Figure 6 and Table 3). Built-up areas increased from 118.1 km² to 175 km² from 2004 to 2016. All the other land cover classes decreased in size over the 12 Year period. Agricultural land decreased from 90.1 to 70.5 km² and riverine vegetation also decreased from 19.7 km² to 9.1 km². Forest patches decreased from 47.7 km² to 20.8 km² over the 12 years change period.

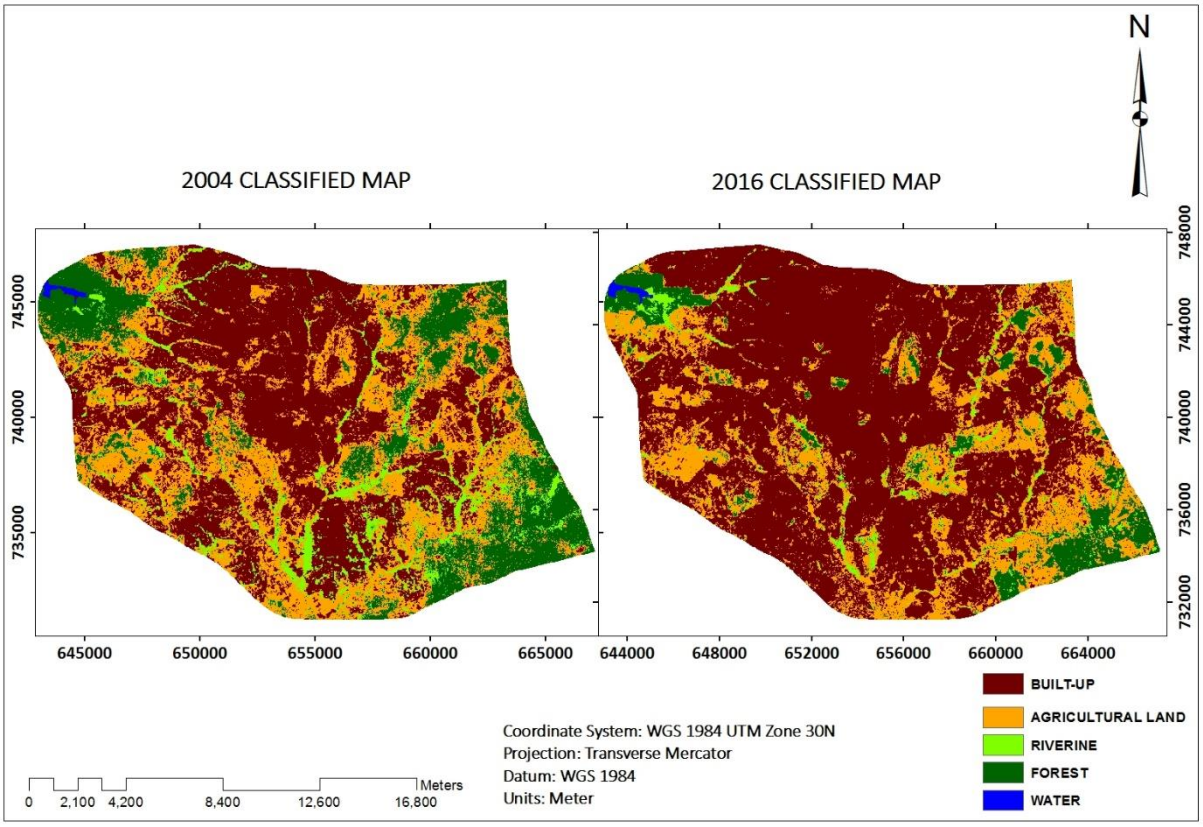

Figure 6: Classified Landsat images of 2004 and 2016, showing the various land cover classes in Kumasi Municipal Area

Table 3: Percentage area coverage in km² of LULC from 2004 to 2016

LULC	2004	% Cover	2016	% Cover
Water	0.51	0.20	0.590	0.20
Forest	47.70	17.30	20.80	7.50
Riverine	19.70	7.10	9.10	3.30
Agricultural land	90.10	32.60	70.50	25.50
Built-up	118.10	42.80	175.00	63.40
Total	276.00	100.0	276.00	100.00

4.1.1. Accuracy assessment of the classified image

The overall classification accuracy for the 2004 image was 82.58% with a kappa of 0.782 (Table 4). Producer and user accuracy for water was 100%. Built-up had the second producer accuracy of 93.18%, followed by forest (87.5%) and agricultural lands (61.11%). On the other hand, forest has the second highest users' accuracy (96%), while agricultural land (64.71) had the least in 2004 (Table 4). The remaining 35.29% accuracy of agricultural land, was indicative of wrong classified pixels in relation to the reference data. This is a common feature in most agricultural lands that lie bare during dry season, leading to a wrong classification as built-up areas.

The overall classification accuracy for the 2016 image was 86.70% with a kappa of 0.8284. Water had the highest accuracy of 100% and 92.31 for user's accuracy and producers' accuracies, followed by riverine (90.32%) and forest (77.78%) (Table 4). On the other hand, built-up had the second highest producers' accuracy (87.8%), followed by forest (87.5%) and riverine (77.78%). The remaining 22.22% least users' accuracy in forest cover, was due to misclassification. The overall accuracy obtained was 86.70% with a Kappa coefficient of 0.8284.

Table 4: Accuracy result of classified 2004 and 2016 images

		Reference Totals	Classified Totals	Number Correct	Producers Accuracy (%)	Users Accuracy (%)
2004 image	Water	13	13	13	100	100
	Forest	26	25	24	92.31	96
	Riverine	24	23	21	87.5	91.3
	Agricultural land	18	17	11	61.11	64.71
	Built-up	44	55	41	93.18	74.55
	Overall Classification Accuracy =			**82.58%**	**Kappa coefficient**	**0.7828**
2016 image	Water	13	12	12	92.31	100
	Forest	24	27	21	87.5	77.78
	Riverine	36	31	28	77.78	90.32
	Agricultural land	74	73	64	86.49	87.67
	Built-up	41	40	36	87.8	90
	Overall Classification Accuracy =			**86.70%**	**Kappa coefficient**	**0.8284**

4.2. Change detection of the classified images

Figure 7 showed re-classified changed areas from 2004 to 2016. These areas were purposely re-classified to assess the tree species composition and how they were influenced by socio-economic and biophysical factors.

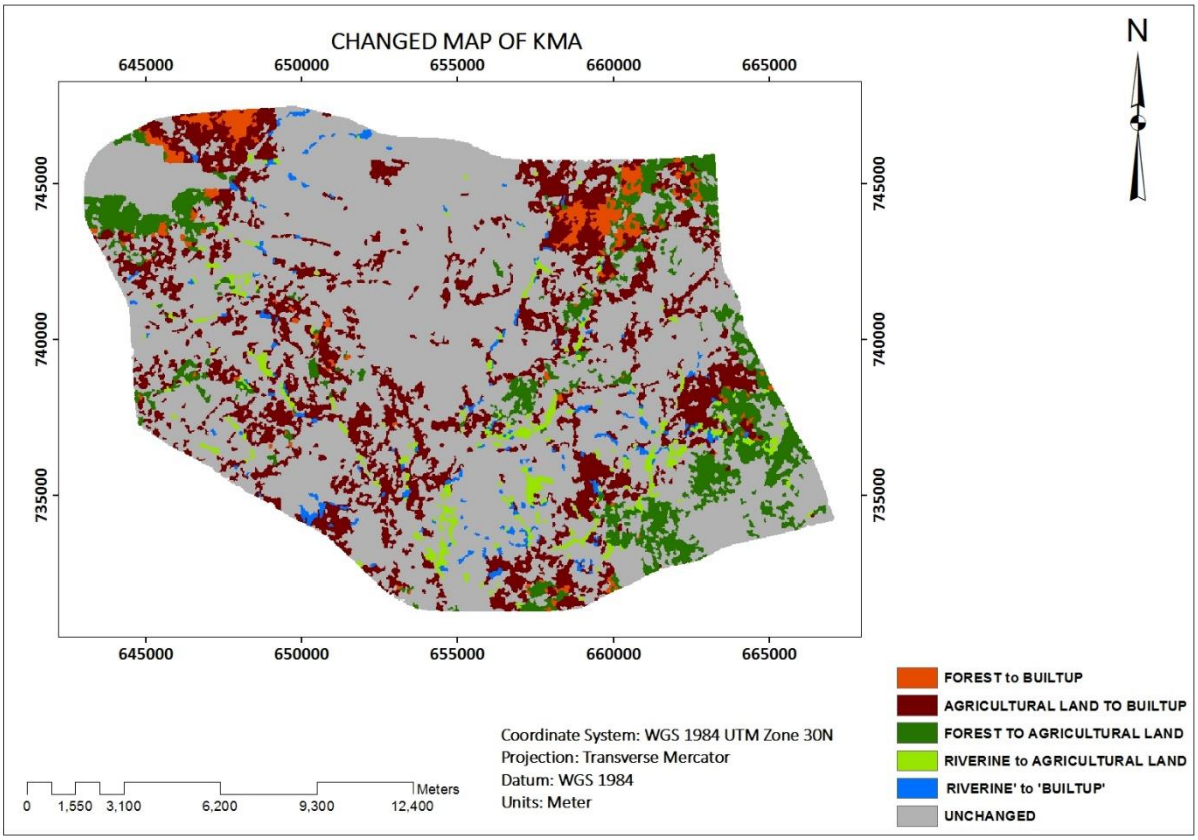

Figure 7: Changed map showing re-classified changed areas between 2004 and 2016 in KMA

The results of change detection over the 12 Year period indicated that, the highest land conversion was agricultural land into built-up covering an area of 50.8 km². The second highest land conversion of 20.0 km² of forest to agricultural land was detected. An area of 7.8 km² forest was converted to built-up and 7.8 km² riverine was converted to agricultural land. In addition, a conversion of 7.5 km² riverine to built-up was detected (table 5).

Table 5: Change detection matrix showing areas of change in Km²

		2016					
	LULC	Water	Forest	Riverine	Agricultural land	Built-up	Column Total
	Water	0.50	0.00	0.00	0.00	0.00	0.50
	Forest	0.10	16.50	3.10	20.00	7.80	47.70
2004	Riverine	0.00	1.40	3.10	7.80	7.50	19.70
	Agricultural land	0.00	2.50	2.60	34.10	50.80	90.10
	Built-up	0.00	0.40	0.40	8.50	108.80	118.10
	Row Total	0.60	20.80	9.10	70.40	174.90	276.00

4.3. Tree composition and abundance in the various LULC classes

Eight hundred and sixty one (861) individual trees representing 150 species were recorded in all the four LULC classes. Forest recorded the highest individuals of 280, followed by built-up patches with 264 individuals. Riverine recorded 190 individuals, whereas agricultural recorded the least individuals (127).
Out of the 861 trees enumerated, 58.7% were exotic species while the remaining 41.3 % were indigenous tree species (Table 6). Nine species, namely; *Albizia zygia, Alstonia boonei, Azadirachta indica, Blighia sapida, Elaeis guineensis, Ficus exasperate, Persea Americana, Pithecellobium dulce* and *Psidium guajava*, were common to all the 4 classes.

Table 6: Summary of tree species composition in the various LULC types

LULC type	Number of individuals	Number of species	Origin of trees	
			Indigenous	Exotic
Forest	280	46	18 (41.9%)	25 (58.1%)
Built-up	264	39	13 (32.5%)	27 (67.5%)
Riverine	190	36	16 (42.1%)	22 (57.9%)
Agricultural land	127	29	15 (52.75)	14 (48.7%)
Total	861	150	62 (41.3%)	88 (58.7%)

4.3.1. Tree composition and abundance in forest patches cover

A total of 280 individual trees, belonging to 46 species were recorded in the forest cover. Exotic species were 58.1%, while 41.9% constituted indigenous species (Figure 8). The dominant species numbered 15 in total. Some of which included: *Senna siamia* (16%); *Gmeliana arborea* (12%); *Delonix regia* (11%) and *Mangifera indica*; *Moringa lucida; and Margaritaria discoidea* (3%), respectively (Figure 8).

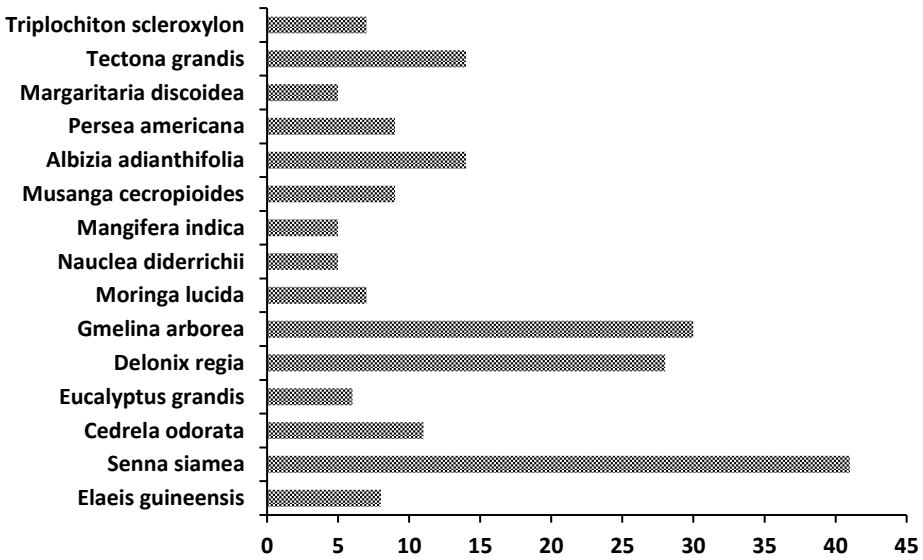

Figure 8: A graph showing the dominant tree species enumerated in forest patches land cover class in KMA

4.3.2. Tree composition and abundance in built-up land cover class

A total of 280 individual trees, belonging to 46 species were recorded in the forest cover. Exotic species were 58.1%, while 41.9% constituted indigenous species (Figure 8). The dominant species numbered

15 in total. Some of which included: *Senna siamia* (16%); *Gmeliana arborea* (12%); *Delonix regia* (11%) and *Mangifera indica*; *Moringa lucida; and Margaritaria discoidea* (3%), respectively (Figure 9).

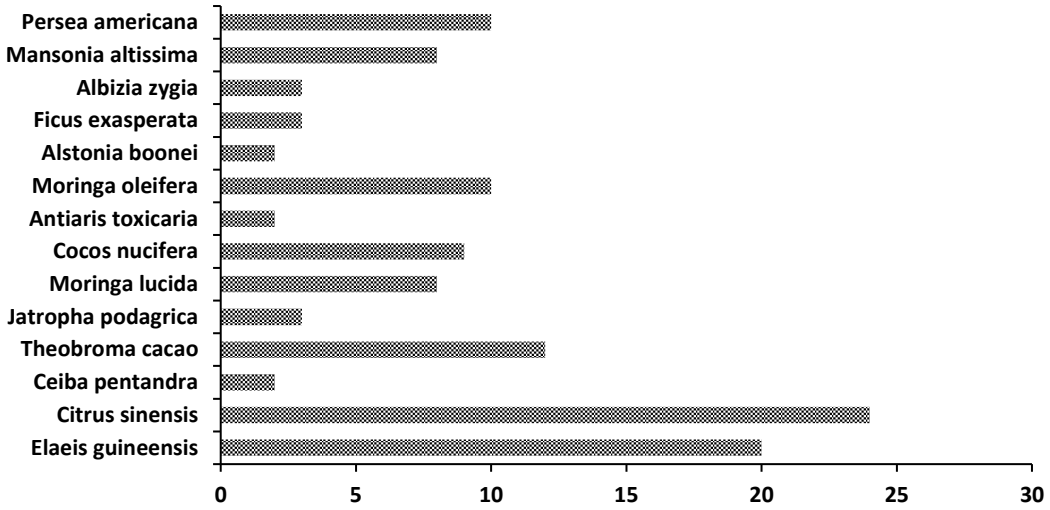

Figure 9: A graph showing dominant tree species enumerated in agricultural land cover class in KMA

4.3.3. Tree composition and abundance in agricultural land cover class

Agricultural lands recorded 127 individual trees, belonging to 29 species. Exotic species constituted 58.1%, while 37.2% represented indigenous species (Figure 10, Appendix 5). Fifteen dominant species were identified and included: *Citrus sinensis* (18%); *Elaeis guineensis* (15%) and *Theobroma cacao* (9%). These fruit trees are perennials and cultivated for subsistence use and for commercial purposes in the Municipality (Figure 10).

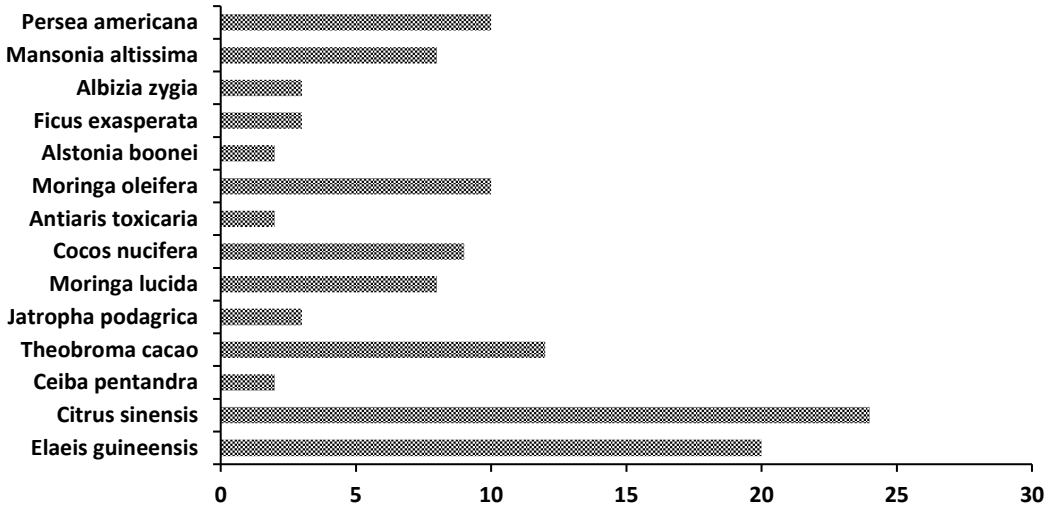

Figure 10: A graph showing dominant tree species enumerated in agricultural LULC land cover class in KMA

4.3.4. Tree composition and abundance in riverine cover class

Riverine land cover class recorded 190 individual trees, belonging to 36 species. Exotic trees represented 57.9%, while indigenous species were 42.1% (Figure 11, Appendix 6). *Elaeis guineensis* recorded the highest individuals (24 %), while the least included: *Cocos nucifera* and *Raphia spp* (10%), respectively

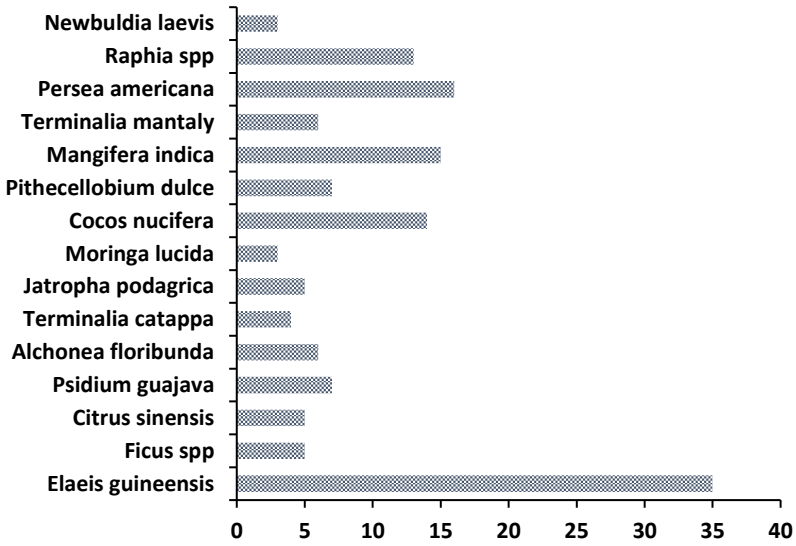

Figure 11: A graph showing dominant tree species enumerated in riverine land cover class in KMA

4.4. Comparisom of tree species richness, density and diversity in the various LULC types

The overall tree diversity (Shannon H') was generally high across the four land cover classes (forest, built-up, riverine and agricultural land) and ranged between (H' =2.79 to 3.31) (Figure 12, Table 7). Forest patches recorded the highest tree diversity (3.31 ±1.40), followed by built-up (3.33 ±1.0) and agricultural lands (2.79 ±1.1). Overall, mean diversity among the four sites did not differ significantly (F_3 = 2.52; p > 0.05, One-way ANOVA) (Appendix 8).

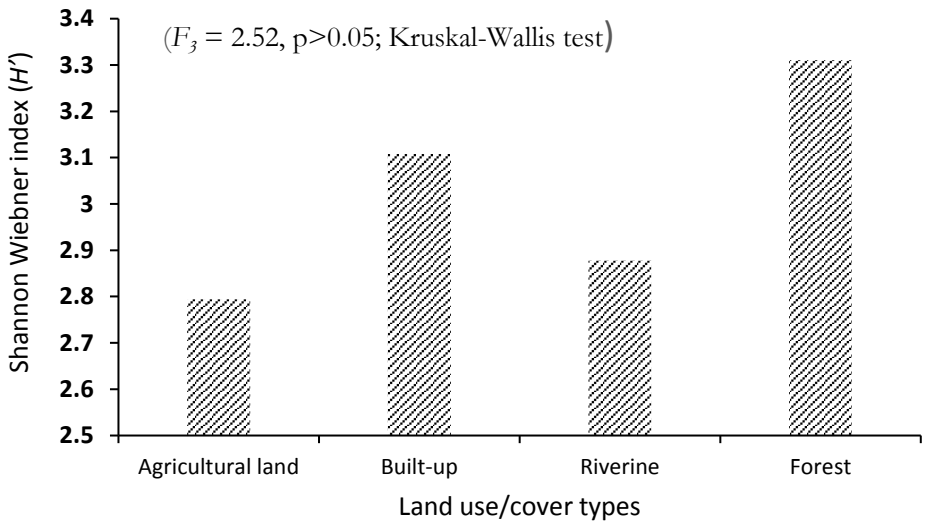

Figure 12: Tree community, showing variations in diversity index among the four land cover classes

Species richness (Margalef D) ranged between (D= 5.78 to 7.99). Forest patches recorded the highest tree richness (D= 7.99 ±0.76), while agricultural land recorded the least richness (D=5.78 ±0.53) (Figure 13, Table 7). Mean species richness across the four land cover classes, varied significantly ($F3$ = 14.48, p<0.05; Kruskal-Wallis test) (Appendix 8).

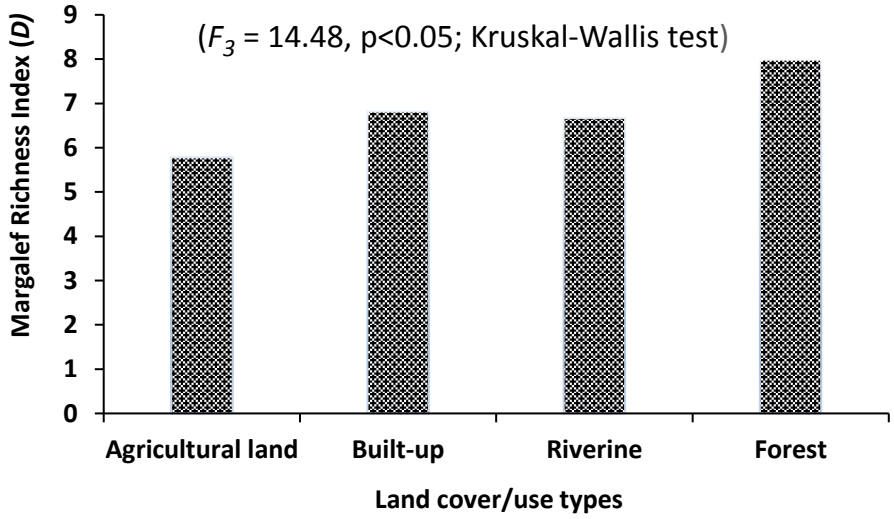

Figure 13: Tree community, showing tree richness across the four land cover classes
Tree species richness appear to increase from farmland land to forest patches cover classes

Mean species density differed significantly among the four LULC classes (F_3 = 35.597; p<0.05; Kruskal-Wallis test) and ranged between (251/ha to 84/ha) (Appendix 8). Forest patches recorded the highest mean density of 251/ha, while built-ups registered the least of (38/ha) (Figure 14, Appendix 8).

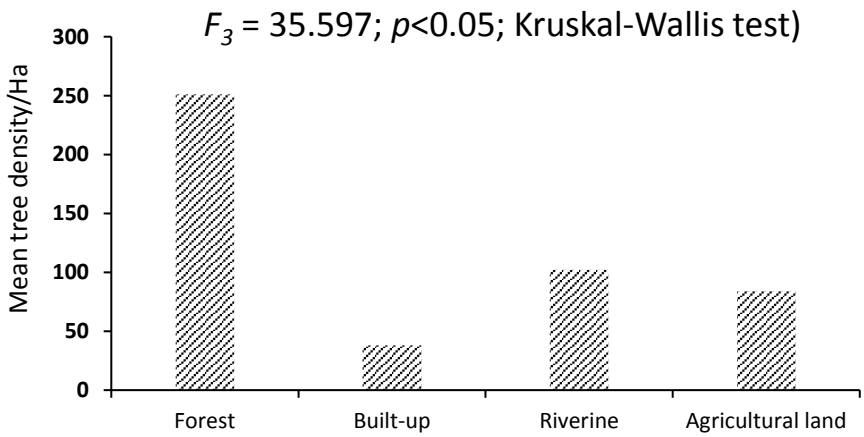

Figure 14: Graph, showing tree density across the LULC classes

Table 7: Tree abundance and richness in the various LULC classes

LULC	Taxa S	Individual	Shannon H (SE +/-)	Richness Margalef D (SE +/-)
Agricultural land	29	127	2.79 (1.1)	5.78 (0.53)
Built-up	39	264	3.11 (1.0)	6.82 (0.77)
Riverine	36	190	2.88 (1.56)	6.67 (0.42)
Forest	46	280	3.31 (1.40)	7.99 (0.76)

Post-hoc comparisons (using Bonferroni test) indicated that the mean score in tree richness was significantly different between the following LULC types: agricultural land and forest cover ($p<0.001$); forest and riverine land cover ($p<0.001$). However, species richness in agricultural and riverine, agricultural and built-up, built-up and riverine land and built-up and forest cover classes, did not differ significantly differ ($p>0.008$) (Appendix 9).

Tree density significantly differed between agricultural land and forest ($p<0.000$); agricultural land and built-up ($p<0.000$); riverine and built-up ($p<0.000$); and riverine and forest ($p<0.00$). However, species density between agricultural land and riverine and built-up and forest, did not differ significantly ($p>0.008$) (Appendix 9).

4.5. Description of respondents' demographic characteristics and tree ownsership in KMA

- **Demographic characteristics based on all people surveyed**

Sixty- seven percent of the people surveyed were female and 33% were males. The ages ranged from 18 to 38 (45%) and 39 to 50 and above (55%). Sixty-three percent identified themselves as indigene and 37% were migrant. Their educational background included: primary (46%), secondary (30%), tertiary (11%) and none (13%). Respondents' occupational background included: tertiary (3%), secondary (35%), primary (46%) and not working (16%) (Table 8).

Table 8: Profile of respondents that were involved in the study

Biography of respondents		%
Age	18 to 38	45.0
	39 to 50 and above	55.0
Origin of Respondent	Indigene	63.0
	Migrant	37.0
Gender of Respondent	Male	33.0
	Female	67.0
Educational Background of Respondent	Primary	46.0
	Secondary	30.0
	Tertiary	11.0
	None	16.0
Land use/Land cover type respondent is located on	Built-up	86.0
	Farm	5.0
	Forest	4.0
	Riverine	5.0
Occupation of Respondent	Primary Sector	46.0
	Secondary Sector	35.0
	Tertiary Sector	3.0
	Not Working	16.0

- **The state and ownership of trees in KMA**

About 79% of respondents indicated that tree cover in KMA had reduced, 12% indicated an increase, while 9% pointed to a stable tree cover.

Respondents' perception about the current state of trees in KMA, was evidenced in the change detection results, which showed a decrease in forest cover between 2004 and 2016.

On the ownership of trees in KMA, respondents were of the view that private individuals own majority of the trees (77%), while 17% and 7% were owned by community members and the government, respectively (Figure 14).

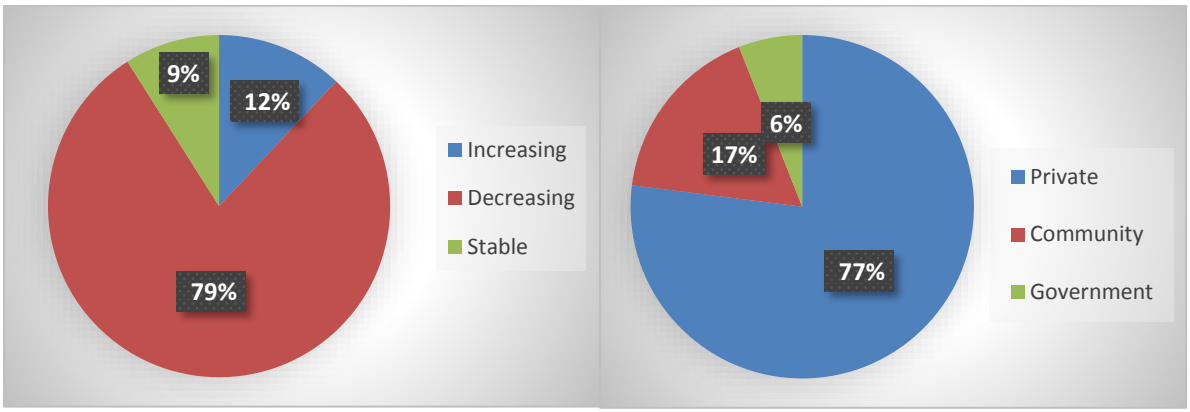

Figure 15: A chart showing respondents' perception on the state of tree cover and tree ownership in KMA

4.6. Role of trees in ecosystem services

In general, about 89% of the respondents did not associate the various services of trees to their prevalence, while 11% of the respondents associated the various services of trees to their prevalence in the study area. Shade was identified as the most important role in of trees in ecosystem services (32.9%), followed by air purification/dust reduction (32.1%). The least included: boundary demarcation, preservation of biodiversity & erosion control (0.7%) (Table 9).

Table 9: Important services associated with the existence of trees in KMA

Services provided by trees	A*	Relative %	B*	Relative %
Shade	94	67.1	46	32.9
Air purification/ dust reduction	95	67.9	45	32.1
Food	98	70	42	30
Income from sales of tree products	113	80.7	27	19.3
Wind breaks	115	82.1	25	17.9
Traditional medicine	122	87.1	18	12.9
Fuel wood	133	95	7	5
Relaxation	133	95	7	5
Moderate local climate	136	97.1	4	2.9
Climate change combat	137	97.9	3	2.1
Aesthetic	137	97.9	3	2.1
Recreation	138	98.6	2	1.4
Boundary demarcation	139	99.3	1	0.7
Preservation of biodiversity/ nature	139	99.3	1	0.7
Erosion control	139	99.3	1	0.7
TOTAL	1868	89	232	11

A* number of respondents which did not identify a particular service based on total counts
B* number of respondents which identified a particular service based on total counts

4.7. Respondents' socio-economic characteristics and the services associted with trees

The various services were grouped under the main ecosystem services for easy representation thus; cultural (recreation, relaxation, boundary demarcation and aesthetic), regulatory/supporting (erosion control, moderation of local climate, air purification/dust reduction, climate change combat, shade, preservation of biodiversity/nature and windbreak) and provisioning services; (food, income from sales of tree products, fuel wood and traditional medicine). Table 10 contain the summary of the relationship between the services and respondents socio-economic characteristics thus; gender, origin, occupation and education.

4.7.1. Relationship between socio-economic characteristics and cultural services of trees

There was a significant difference between gender of respondents and recreational services provided by trees; (χ^2 =4.143, $p<0.05$, n= 100), as well as origin and recreational services of urban trees; (χ^2=3.475, $p<0.05$, n= 100). Only males identified the recreational service of trees (100%). Furthermore, migrants identified recreation as the reason of keeping trees (100%) whereas indigenes attached no value to recreational service of trees (Table 10, Appendix 11).

There was a significant difference respondents' occupation and aesthetic value; (χ^2 = 6.368, $p<0.05$, n= 100) (Table 10). Respondent with higher education (43%) and secondary education (33%), identified the aesthetic values of trees. Few respondents (24%) with primary education identified the aesthetic values, whereas respondents who had no educational background did not assigned the aesthetic value to trees as provisions of ecosystem services. There was no significant difference between respondents' socio-economic background and shade, relaxation and boundary demarcation $p>0.05$ (Appendix 11).

4.7.2. Relationship between socio-economic characteristics and regulating services of trees

There was no significant difference between respondents' socio-economic characteristics and the following services: erosional control, air purification/dust reduction, biodiversity preservation, moderation of local climate and climate change combat as reasons for keeping trees $p>0.05$ (Appendix 12). However, there was a significant difference between respondents' gender and the service of windbreak; (χ^2 7.975, $p<0.05$, n= 100) (Table 10). Majority of males (55%) identified the services of windbreak as the reasons for keeping trees, while 44% females who did not identify the role of trees as windbreak.

4.7.3. Relationship between socio-economic characteristics and provisioning services of trees

There was a significant difference between respondents' educational background and the service of fuelwood; (χ^2 =6.585, $p<0.05$, n= 100), as well as respondents' occupation and fuelwood; χ^2 =8.873, $p<0.05$, n= 100 (Table 10). A relatively high proportion of respondents with no formal education (57%) identified the services of fuelwood as the reason for keeping trees as against respondents with tertiary education who did not identify the services of fuelwood. There was no significant difference between respondents' socio-economic background and the services of food, income from sales of tree products and traditional medicine provided by trees $p>0.05$ (Appendix13).

Table 10: Relationship between socio-economic background and reasons attached to trees in KMA

Services provided by trees	Gender	Place of origin	Education	Occupation
Recreation	*	*	-	-
Aesthetics	-	-	-	*
Windbreaks	*	-	-	-
Fuel Wood	-	-	*	*

* Variables significant at $p<0.05$

4.8. Biophysical factors that explain the distribution of tree species in change areas

- **Predictors of urban tree composition and distribution**

CCA analysis revealed that the impact of biophysical factors on tree distribution in each four sites differed significantly ($p<0.05$), following Monte Carlo permutation test. The inherent biophysical conditions in each of the four land cover classes, jointly explained 60.59% ($R^2 = 0.61$, $p<0.05$) of variability in tree distribution and diversity by the two axes (axes I= 53.7 and Axes 2=6.585) (Figure 15, Table 11). Because axes 1 and 2 accounted for more than 50% in explaining biophysical data influence on tree diversity, richness, density and distribution, axes III and IV were not considered in the cumulative % variance (ter Braak, 1986).

Distance to water and distance to road were correlated in axis 1 and were the key biophysical factors. In axis 2 elevation and distance to water were highly correlated and constituted the most important factors, which explained variance in tree diversity in the four sites (Figure 15) as confirmed by their correlation coefficients. Distance to road showed a weak correlation with species diversity and distribution along axis I (Table 11).

CCA analysis diagram showed the various groups of tree communities' distribution according to the type of biophysical mediating factors and the type of land cover sampled (with yellow circle). It was observed that, *Eucalyptus grandis, Margaritaria discoidea* and *Moringa oleifera* on the right side of the diagram strongly correlated with an increase in distance to road. These were species, which fell in forest F-R (forest) and B-T (built-up) land cover classes. Although species composition in the study area was low, forest and built-up land classes had a relatively high tree diversity as compared with the other land cover classes as this was evident in its correlation in axis I. *Raphia spp, and Gmelina arborea* were strongly influenced by distance to water. Even though distance to water was highly negatively correlated with axis II, only few species were influenced by this biophysical factor, due to agricultural activities in riparian vegetation with a relatively low species diversity (Figure 15). Species such as *Annona squamosal* and *Terminalia mantaly* were also influenced by an increase in elevation, which felt in built-up class.

Species from nearly each land cover type, clustered around the centre or origin of the CCA diagram (in blue circle), responded to the influence of the average biophysical factors (Figure 14). Example of these species include: *Moringa lucider, Tecktona grandis, Blighia sapida, Persea americana, Citrus sinensis* and *Delonix regia.* The position is an indication of either weak association of these species with the biophysical variables or a strong association with intermediate values of the variables. From the diagram, majority of the species were cantered away from the centroid which might have resulted to a high percentage of variance (60.59%) explained in species distribution as indicated in table 11.

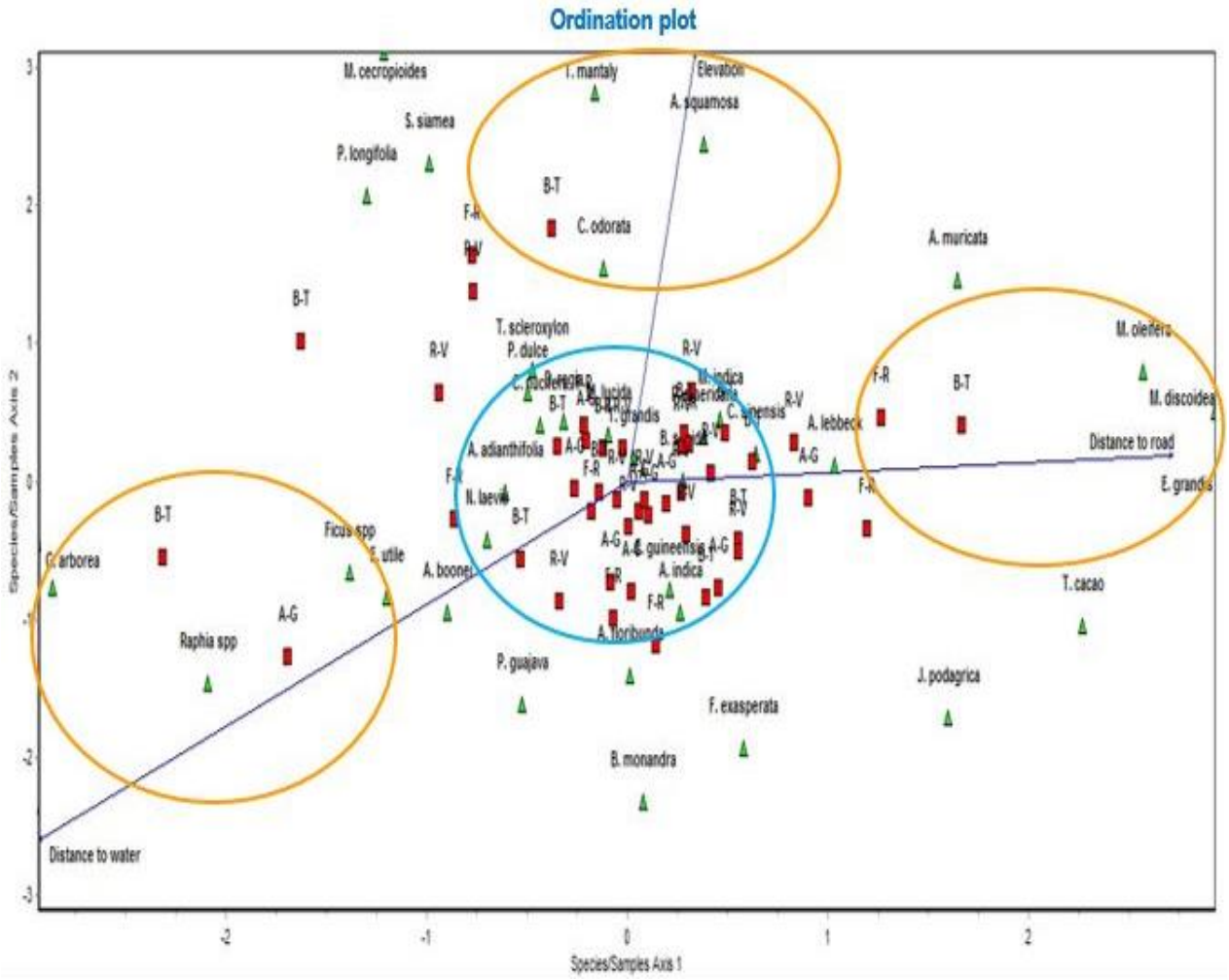

Figure 16: Figure 16: Canonical correspondence analysis (CCA) ordination diagram, showing the influence of biophysical factors on species diversity and distribution, explained by the first two axes (axes I= 53.7 & Axes 2=6.585) and accounted for 60.59% percentage variance across the four sites (R^2= 0.61, $p<0.05$). The green triangle represents abbreviated plant species (e.g., *Eucalyptus grandis*= *E. grandis, Margaritaria discoidea* = *M. discoidea* & *Moringa oleifera* = *M. oleifera*). The red square represents abbreviated sample sites: R-V = riverine; F-R= forest; B-T= built-up; A-G = agricultural land) and the arrows represent each of the biophysical variables plotted pointing in the direction of maximum change of explanatory variables across the four land covers

Table 11: Canonical coefficients and the correlations with the first three axes of the biophysical variables of the canonical correspondence analysis (CCA) for the four sites. Percentage variance of species, explained by the first two axes of explanatory variables. Inter-set correlations were significant ($p < 0.05$) for the two axes, following Monte Carlo permutation test

	Axis 1	**Axis 2**	**Axis 3**
Elevation	0.038	0.756*	0.2341
Road distance	0.304	0.045	-0.5458*
Water distance	-0.328	-0.634*	0.352
Canonical eigenvalues	5.712	0.701	0.304
% variance explained (60.59%)	53.7	6.585	2.855
Cumulative % variance	53.7	53.7	63.14
Pearson correlation	0.729*	0.069	0.056
Kendall rank correlation	0.4998	0.069	0.0019
Total variance explained	10.64		
No. of biophysical variables	3		
No. of species	40		
No. of sites	47		

($R^2=0.61$, $p<0.05$)

5. DISCUSSION

5.1. LULC changes in Kumasi Metropolitan Assembly

Conversion of agricultural lands to built-up areas, constituted the major driver of LULC between 2004 and 2016. Population growth, resulting in increasing demand for shelter and other social amenities, probably led to the extension of built-up into agricultural lands and also forest and riverine areas. According to GSS (2012), KMA is undergoing a fast urban expansion of about 48% with an annual growth rate of 5.4%. Mensah (2014) and Attua & Fisher (2011) also observed that agricultural and arable lands, are the immediate lands converted urban expansion in Ghana. The expansion of built-up into agricultural land, subsequently led to the movement of farmers into forest patches and riverine areas. Similar finding was observed by Yankson & Bertrand (2012) in their study on the challenges of urbanization in Ghana. The authors emphasized that urban expansion has led to the depletion of sensitive areas such as forest and riparian vegetation. There is a current trend of unauthorized and indiscriminate building resulting in encroachment into all other lands in urban areas in Ghana including Kumasi Metropolis, due to lack of institutional constraints, cooperation and coordination among stakeholders (Kasanga et al. 1996; Larbi et al. 2004). There is a general trend of inefficiency in land administration in Ghana such as; delayed documentation, ineffective policing and unauthorized acquired lands which consequently lead to people building in vulnerable areas such as along rivers (Larbi et al., 2004).

5.2. Differences in trees species diversity, density and richness in the various LULC classes

Species diversity among the various land cover types in Kumasi Metropolitan was generally high in real ecosystems (MacDonald, 2003). Tree diversity and richness in an ecosystem has been broadly associated with the intensity of disturbance or land use. The higher the intensity of disturbance the lower the composition of species in a given area and vice versa (Ramirez-Marcial, Gonzalez-Espinosa & Williams-Linera, 2000; Zeidler et al., 2002). On the other hand, medium or "intermediate disturbance" improve species composition (Zeidler et al., 2002; Veach, Lee & Philippi, 2003). A relatively high tree diversity in forest land cover class suggest that the area have been subjected to intermediate disturbance, which has altered their species diversity status.

The high tree species richness between the various land cover classes was probably due to the location of KMA in the semi-deciduous forest zone, which is characterized by vegetation types that support tree species including exotic and indigenous trees species (Oteng-Amoako, 2006). Forest patches in KMA are sensitive ecosystem with a relatively higher biodiversity, which are usually protected by Forestry Commission and other agencies in Ghana (Forestry Commission, 2008). Even though forest areas had the highest tree species composition, the presence of nearly 58% exotic species suggest that the forest type in KMA is more an artificial/secondary forest than primary or indigenous. Mensah (2010) assessment of indigenous trees species in urban landscape of Kumasi, revealed that majority of the trees in KMA are exotic species.

The built-up land cover class had the second highest species richness and diversity in the study area. This is quite unexpected and contrary to some findings which have revealed that urban expansion and its associated LULC changes reduce trees species composition especially in built-up areas (Lambin et al., 2001; DeFries & Bounoua, 2004). This could be attributed to the practices of home garden by some residents in the study area. Most houses with large compounds have diverse tree species established on their compounds and this reflected in the majority ownership of trees in built-ups areas, to be private individuals than the State (which include trees in riverine and streets). This corresponds with the findings of Appiah et al., (2009). The relatively high tree species richness in built-up areas can be attributed to the fact that, during urban expansion

process, remnant trees that fall outside the boundary of the buildings are maintained and protected. It was observed that indigenous trees such as *Albizia adianthifolia and Margaritaria discoidea* that were found in forest areas were equally found in the built-up areas; of which 45% can be described as remnant trees.

A relatively lower tree species diversity and richness in riverine areas can be explained by encroachment of riverbanks for farming activities. This was evident in the change detection results of the studies where 7.8 km^2 of riverine areas were being converted into agricultural lands. During farming and crop cultivation, trees are felled and replaced with annual cropping, which was observed during the fieldwork. Wetlands encroachment is a practice that has increased currently in most parts of the city even though a minimum of 100 m from river banks are demarcated as no development area by the Ministry of Lands and Natural Resources (Water Resources Commission, 2008). On the contrary, houses and farms are established within 100 m along stream banks where trees within these areas are felled. Campion (2012) indicated that about 34% of the wetlands at Atonsu that falls within the study area have been converted into settlements within 100 m stream channel. This is confirmed by the findings of this studies, which revealed that 60% of trees in riverine areas were exotic species that have replaced indigenous species. In addition, reforestation activities of portion of riparian vegetation by some organizations such as Friends of Rivers and Water Bodies (an NGO) in Kumasi area is in a form of mono plantation of exotic tree species which grow faster than indigenous species (Mensah, 2010).

A comparatively lower tree diversity and richness in agricultural and riverine areas may be due to poor regeneration and recruitment and high competition, because of dense ground layer due to intense land cultivation (Veach, Lee & Philippi, 2003). Davis et al., (1999) reported that the establishment of woody seedlings is always limited or poor due to competition with herbaceous plants for nutrients and water most especially at the seedling stage as well as competition for sun light (Zeidler et al., 2002; Veach, Lee & Philippi, 2003). The effects of cutting down trees to give more space for food crops also accounted for a reduction in tree density in riverine to agric/fallow.

Low tree density in agricultural land and built-up areas was due to competition of settlements and agricultural crops with trees at a disadvantage. However, Sekhwela (2003) observed an increase in tree density to a decrease in distance from settlements in Botswana. Sheuyange (2002) found that areas around settlements had an average of 62% bush density as compared to areas situated far from villages in northern Namibia. The availability of land for building purposes can also influence tree density since built-ups with big compounds had usually more trees than smaller compounds. Farmlands with a relatively lower tree density can be explained that the technique of agroforestry is less practiced in the study area.

5.3. The most important service determining the existence of trees in KMA

Even though people have planted/maintained trees within their compounds in areas that have undergone land cover changed however, the numerous services provided by trees were not well known to residents (Stiegler 1990; Hull 1992). Respondents could not identify majority of the services provided by trees within their surroundings. This is attributed to low level of knowledge or awareness of the importance of trees to human life and the environment as a whole in KMA. Sommer et al., (1994) & Lohr et al., (2004) reported that people with lower educational background could not identify most services provided by urban trees, especially the regulatory/ non- tangible functions.

Provision of shade as the most important ecosystem service could be attributed to majority of people including hawkers and artisans in KMA, trading and relaxing under trees with good canopy cover.

Customers in the tropics with continually hot temperature usually prefer to buy goods that are under shade. Lohr et al., (2004) found out that shade was the most important reasons attached to the existence of trees in built-up areas in USA. Faleyimu & Akinyemi (2015) revealed that, trees in retail areas increase consumer's readiness to pay for goods and services in Nigeria. In Ghana, men typically relax under trees during their leisure times where they play games and share ideas which was observed in the study area during the field survey. Chiesura (2004) observed that tree-dominated urban landscape could serve as a place for recreational activities.

Air purification/dust reduction also played a vital role in ecosystem services in KMA, due to the increase in dust particles in the atmosphere, during the dry. Similar findings on the role of trees in air/dust purification was reported by Sommer et al., (1994) and Dwyer, Nowak & Watson (2002). People have come to realize the importance of trees in trapping dust (MA, 2003), and this served as motivating reasons in maintaining trees. The provision of food by trees, was equally regarded as important to their well-being, especially in built-up areas, where human population was dominant. Most the fruits from trees like *citrus sinensis*, *Persea americana* and *mangifera indica,* served as natural vitamins sources.

5.4. Relationship between respondents' socio-economic characteristics and the services associated with prevalence of trees in KMA

A significant difference between respondents' socio-economic characteristics; education, occupation and educational and origin and the service of recreation, aesthetic, windbreak and fuelwood was an indication that people with different socio-economic backgrounds associate different importance to the services provided by trees which need to be well understood during policy formulation for effective management (Shackleton et al., 2015).

Migrants and people with high educational background identified the service of aesthetic value provided by trees as reasons that motivated them to keep trees than indigenous people and people with low educational background in KMA. Educated people appreciate the value of scenic beauty provided by trees than the less educated. People with low educational and occupational background associated the service of fuelwood as reason for keeping trees whereas people with high educational and occupational background with probably better jobs and higher income, rely on other source of energy such as the use of gas since they can afford it. Men associated the service of windbreak to protect their home whereas women did not identify the service of windbreak. This is because men in general are responsible to provide shelter for the family and therefore planted trees to protect their houses from wind damage.

5.5. Relation between biophysical factors and the distribution of trees in KMA

Trees outside forest, which include urban trees, have received global attention due their ability to provide forest services (Gelens, et al., 2010). This has driven the interest several studies with the aim of understanding the distribution of trees species and biophysical factors that influence their distribution (Serneels & Lambin, 2001; Hansen & Rotella, 2002). The findings revealed that biophysical factors namely; distance to road, distance to rivers and elevation predicted species tree diversity and distribution across four sites.

The presence of *Raphia spp* in the riverine land cover type, accounted for their distribution in relation to water distance. Obahiagbon (2009) revealed that *Raphia spp* grow best in swampy soils with high relative humidity. The encroachment of farming in riverine areas had affected indigenous tree species composition and distribution, with the presence of higher proportion of exotic trees. This suggests that future

intensification of farming activities could accelerate species extinction that can result to an impairment on the functional status wetland ecosystems in urban areas.

The abundance of *Terminalia mantaly* and *Annona squamosal* in high elevation areas, suggest their tolerance to low water tables and well drained areas. These species were dominant in built-up areas, with a relatively high species diversity and richness. This suggest that people living in high elevations purposefully maintain trees to serve as a windbreak. Studies by Ndolo et al., (2016) on the socioeconomic and biophysical influence on tree diversity, revealed a strong relationship between elevation and tree diversity in Nairobi, Kenya

The abundance of *Margaritaria discoidea*, *Eucalyptus grandis* and *Moringa oleifera* in distance away from road is an indication of high disturbance along roads in KMA, limit the survival of plant growth (Ramirez-Marcial, Gonzalez-Espinosa & Williams-Linera, 2000; Zeidler et al., 2002). The high species diversity and richness among these species in forest and built-up areas could be linked to their distance farther away from roads, leading to low disturbance.

7. CONCLUSION AND RECOMMENDATION

7.1. Conclusions

The research has showed the use of Remote Sensing data (spatial and temporal) and (GIS) tools in assessing and quantifying LULC changes in the last 12 years due to urban expansion and how the changes have influenced surrounding landscapes in Kumasi Metropolitan Areas (KMA). Urban expansion and its resultant LULC changes is an ongoing phenomenon in KMA and information about the dynamics of such changes and how they are associated with tree species composition is crucial as well as integrating socio-economic and biophysical influence on the distribution of urban trees. This is vital to better understand humans and their relationship with the environment in KMA. This very important for urban planning and sustainable land use management in KMA.

Research Question 1**:** Which LULC classes have undergone changes between 2004 and 2016?

The findings revealed an increase in built-up areas from 118.1 km^2 (43%) to 175.0 km^2 (66%) in 2004 and 2016, respectively, while agricultural land, forest and riverine decreased over the 12- year period. While built-ups extended into agricultural land towards the exterior part of the municipality, there was a shift of agricultural lands into forest and riverine areas. This reflected in the change detection results with the highest conversion of 50.8 km^2 of agricultural lands into built-up. Forest patches also saw a 20.0 km^2 of its original size converted into agricultural lands. Riverine areas had about 7.8 km^2 of its original size, transformed into agricultural lands and built-up were 7.8 km^2.

Research Question 2**:** What is the tree composition in the different LULC cover types?

Forest patches had the highest species diversity and richness followed by built-up areas. With farmlands having the least tree species density, diversity and richness. In the course of LULC changes, urban residents in KMA have planted trees in their surroundings in a form of home gardens. Riverine (a sensitive land cover type), has undergone several reforestation activities in the Metropolis, due to intensity of agricultural activities along its fringing areas. This probably led to low tree species composition, which is also an indication of farmers not embracing the technology of agroforestry in the Metropolis.

Research Question 3: What is the most important service associated with the prevalence of tree in changed areas?
Shade was the most important reason for the existence of trees in KMA since majority of residents relax under shade trees during the day and most people trade under shade trees. Most people in the Metropolis have come to realize the importance of trees in trapping dust. The third most important service associated with the existence of trees was the service of food/fruit, which was recognised by the dominance of tree fruit trees (67%) in built-up areas. Even though majority of the trees assessed in KMA belonged to private individual, less significance was attached to other important services provided by trees such as erosion control, preservation of biodiversity, recreation, aesthetic value which is an indication that the numerous benefits of trees appear not to be well known and understood by the people. The findings revealed that, knowledge level in relation to the importance of trees to human life and the environment as a whole is low in KMA.

Research Question 4: What is the relation between socio-economic characteristics and services associated with the prevalence of urban trees in changed areas?

The findings revealed that, people with higher educational background identified the aesthetic landscape as reasons for keeping. There was a significant difference between respondents' socio-economic characteristics and trees prevalence. Respondents' gender, origin, education and occupational background showed a significant relation to the services of windbreak, fuelwood and recreational values provided by trees in KMA.

Research Question 5: Which biophysical factors best explain the distribution of trees in LULC changed areas KMA?

Distance to rivers, distance to road and elevation predicted species diversity and distribution in change areas. This was confirmed by the CCA analysis with explanatory variables accounting to 60.59% species variance across the five sites (R^2 =0.61, $p<0.05$). The most important variables that explained the distribution were distance to water and elevation.

7.2. Recommendations and limitations

- The medium resolution of Landsat image and digital image classification could not provide a spatial inventory to estimate tree cover therefore further research should explore the use of a high resolution and digital image classification for proper inventory of tree cover in KMA.
- The Forest Services Division in KMA should pay much attention to the management of riverine vegetation owing to their low richness, diversity and density.
- There is a need to carry out more research into other biophysical/environmental factors that are likely to influence tree species distribution such as soil.

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9. APPENDICES

Appendix 1: Sample of questionnaire sheet

Interview No: …… Date: …… Name of Town: ……
GPS coordinates of the house…….
Land cover type…….
Please tick where appropriate
1. Demography
1.1. Age
1. 18-27
2. 28-38
3. 39-49
4. 50+
1.2. Gender……..
1 Male
2 Female
1.3. Educational background
1 Primary
2 Secondary
3 Tertiary
4 None
1.4. Origin
1. indigene
2. migrant
1.4.1. If migrant where are you from?

Please specify…….

1.5. Occupation
1. Primary (including; Farming, petty trading, carpentry, masonry, tailoring, cleaning etc.)
2. Secondary (including; Teaching, policing, office clerks etc.)
3. Tertiary (including; Managers, professionals, associate professionals, etc.)

2. Information on the state of urban trees

2.1 Do you like trees? Yes/ No
2.2 Who owns the trees in your compound/ surroundings/ other trees?
1. Private
2. Community
3. Government

2.3 What is the current state of urban trees?
1. Increasing
2. Decreasing
2.4 If decreasing what are the causes of reduction?

1. Construction activities (expansion of building, felling for construction etc.)
2. Farming activities
3. Tree tenure
4. Others, please …….…..

2.4 Can you specify some of the most common and important trees that were here which are nomore?.....

3. Human perception on urban trees rank according to order of importance.

Indicate the services provided by the trees in your compound and in other areas including farms, streets parks etc. and select as much as applicable to you.

Number	Factors (reasons for the presence of trees)	Tick where appropriate (√)
1	Relaxation	
2	Noise Reduction	
3	Boundary demarcation	
4	Shade	
5	Recreation	
6	Moderation of local climate	
7	Air purification/ dust reduction	
8	Climate change combat	
9	Erosion control	
10	Wind breaks	
11	Preservation of biodiversity/ nature	
12	Spiritual	
13	Historic	
14	Aesthetic	
15	Tourism	
16	Education	
17	Food	
18	Fuel wood	
19	Income from sales of tree products	
20	Traditional medicine	

3. If you were given the chance to plant a tree, which tree do you prefer to plant?

……

4. Where do you prefer to plant?

1. In Farmlands
2. Along roads,
3. Near the house
4. Riverine
5. Others please specify……

Appendix 2: Sample sheet for tree data collection

No	Names			uses	LULC	Coordinates	Remarks
	Scientific	Local/common	Origin				
1							
2							
3							
4							
5							
6							
7							

Appendix 3: Tree species recorded forest patches cover class

Local name	Scientific name	Origin	Uses
African oil palm	*Elaeis guineensis*	indigenous	fruit
Akye	*Blighia sapida*	indigenous	timber
Bauhinia	*Bauhinia monandra*	exotic	avenue
black pepper	Xylopia spp	indigenous	fruit
Casia	*Sena apetabelis*	exotic	others
Cassia	*Senna siamea*	exotic	others
Cedrela	*Cedrela odorata*	exotic	timber
Ceiba	*Ceiba pentandra*	indigenous	timber
Chrysophyllum	*Chrysophyllum spp*	indigenous	timber
Cinamon	*Cinnamomum verum*	exotic	others
Dahoma	*Piptadeniastrum africanum*	indigenous	timber
Edinam	*Entandrophragma angloense*	indigenous	timber
Eucalyptus	*Eucalyptus grandis*	indigenous	timber
Flamboyant tree	*Delonix regia*	exotic	others
Gmelina	*Gmelina arborea*	exotic	timber
Guava	*Psidium guajava*	exotic	fruit
Gyama	*Alchonea floribunda*	indigenous	others
Indian almond	*Terminalia catappa*	exotic	timber
Konkroma	*Moringa lucida*	indigenous	others
Kusia	*Nauclea diderrichii*	indigenous	timber
Lagerstroemia	*Lagerstroemia speciosa*	exotic	avenue
Leuceana	*Leuceana leucocephala*	exotic	others
Madras Thorn	*Pithecellobium dulce*	exotic	avenue
Mango	*Mangifera indica*	exotic	fruit
Neem	*Azadirachta indica*	exotic	others
Nyamedua	*Alstonia boonei*	indigenous	others

Nyankyerene	*Ficus exasperata*	indigenous	others
Odwuma	*Musanga cecropioides*	indigenous	others
Ofram	*Terminalia superba*	indigenous	Timber
Okoro	*Albizia zygia*	indigenous	others
Okuo	*Zanthoxylum gilletii*	indigenous	others
Oprono	*Mansonia altissima*	indigenous	timber
Pampena	*Albizia adianthifolia*	indigenous	others
Pear	*Persea americana*	exotic	fruit
Pepea	*Margaritaria discoidea*	indigenous	others
Royal palm	*Roystonea regia*	exotic	avenue
Sesemasa	*Newbuldia laevis*	indigenous	others
Spatodia	*Spathodia campanulata*	indigenous	others
Teak	*Tectona grandis*	exotic	timber
Tetetoa	*Millettia rhodantha*	indigenous	timber
Utile	*Entandrophragma utile*	indigenous	timber
Wawa	*Triplochiton scleroxylon*	indigenous	timber
Whistling pine	*Casuarina equisetifolia*	exotic	others

Appendix 4: List of tree species in built-up

Local name	Scientific name	Origin	Uses
African oil palm	*Elaeis guineensis*	indigenous	fruit
Akye	*Blighia sapida*	indigenous	timber
Albizia	*Albizia lebbeck*	indigenous	others
Amangyedua	*Ficus spp*	indigenous	others
Ankaa	*Citrus sinensis*	exotic	fruit
Awiemfosamina	*Albizia ferruginea*	indigenous	others
Cashew nut	*Anacardium occidentale*	exotic	fruit
Cassia	*Senna siamea*	exotic	others
Cocoa	*Theobroma cacao*	exotic	fruit
Croton	*Codiaeum variegatum*	exotic	avenue
Dahoma	*Piptadeniastrum africanum*	indigenous	timber
Dracenea	*Dracenea fragrance*	indigenous	timber
Esa Kosua	*Celtis adolfi-friderici*	indigenous	timber
Ficus	*Ficus elastica*	exotic	others
frangipani	*Plumeria rubra*	exotic	avenue
Gmelina	*Gmelina arborea*	exotic	timber
Guava	*Psidium guajava*	exotic	fruit
Indian almond	*Terminalia catappa*	exotic	timber
Jatropha	*Jatropha caucus*	exotic	others
Konkroma	*Moringa lucida*	indigenous	others
Kube	*Cocos nucifera*	exotic	fruit
Madras Thorn	*Pithecellobium dulce*	exotic	avenue
Mango	*Mangifera indica*	exotic	fruit

Mantaly	*Terminalia mantaly*	exotic	timber
Mast tree	*Polyathia longifolia*	exotic	avenue
Moringa	Moringa oleifera	exotic	others
Neem	*Azadirachta indica*	exotic	others
Norfolk palm	*Araucaria heterophylla*	exotic	avenue
Nyamedua	*Alstonia boonei*	indigenous	others
Okoro	*Albizia zygia*	indigenous	others
Onyono	*Vernonia spp*	indigenous	others
Paper Mulberry	*Broussonetia papyrifera*	exotic	timber
Pear	*Persea americana*	exotic	fruit
Queen of the night	*Cestrum nocturnum*	exotic	avenue
Royal palm	*Roystonea regia*	exotic	avenue
Sesemasa	*Newbuldia laevis*	indigenous	others
Sour sop	*Annona muricata*	exotic	fruit
Sugar Apple	*Annona squamosal*	exotic	fruit
Teak	*Tectona grandis*	exotic	timber
Whistling pine	*Casuarina equisetifolia*	exotic	others

Appendix 5: Tree species in agricultural land

Local name	Scientific name	Origin	Uses
African oil palm	*Elaeis guineensis*	indigenous	fruit
Akye	*Blighia sapida*	indigenous	timber
Albizia	*Albizia lebbeck*	indigenous	others
Amangyedua	*Ficus spp*	indigenous	others
Ankaa	*Citrus sinensis*	exotic	fruit
Cassia	*Senna siamea*	exotic	others
Cedrela	*Cedrela odorata*	exotic	timber
Ceiba	*Ceiba pentandra*	indigenous	timber
Cocoa	*Theobroma cacao*	exotic	fruit
Esa Kosua	*Celtis adolfi-friderici*	indigenous	timber
Guava	*Psidium guajava*	exotic	fruit
Jatropha	*Jatropha podagrica*	exotic	others
Konkroma	*Moringa lucida*	indigenous	others
Kube	*Cocos nucifera*	exotic	fruit
Kyenkyen	*Antiaris toxicaria*	indigenous	timber
Madras Thorn	*Pithecellobium dulce*	exotic	avenue
Mantaly	*Terminalia mantaly*	exotic	timber
Moringa	Moringa oleifera	exotic	others
Neem	*Azadirachta indica*	exotic	others
Nyamedua	*Alstonia boonei*	indigenous	others
Nyankyerene	*Ficus exasperata*	indigenous	others
Okoro	*Albizia zygia*	indigenous	others

Onyono	*Vernonia spp*	indigenous	others
Oprono	*Mansonia altissima*	indigenous	timber
Pampena	*Albizia adianthifolia*	indigenous	others
Pear	*Persea americana*	exotic	fruit
Royal palm	*Roystonea regia*	exotic	avenue
Sugar Apple	*Annona squamosal*	exotic	fruit
Tweapea	*Garcinia kola*	indigenous	others

Appendix 6: Tree species in riverine

Local name	Scientific name	Origin	Uses
African oil palm	*Elaeis guineensis*	indigenous	fruit
Akye	*Blighia sapida*	indigenous	timber
Albizia	*Albizia lebbeck*	indigenous	others
Amangyedua	*Ficus spp*	indigenous	others
Ankaa	*Citrus sinensis*	exotic	fruit
Bamboo	*Bambusa vulgaris*	exotic	others
Bauhinia	*Bauhinia monandra*	exotic	avenue
Bougainvilla	*Bougainvilla alba*	exotic	avenue
Calophyllum	*Callophylum innophyllum*	indigenous	others
Ceiba	*Ceiba pentandra*	indigenous	timber
Cocoa	*Theobroma cacao*	exotic	fruit
Croton	*Codiaeum variegatum*	exotic	avenue
Duranta	*Duranta spp*	exotic	avenue
Esabese	*Cola gigiantia*	indigenous	timber
Flamboyant tree	*Delonix regia*	exotic	others
Gmelina	*Gmelina arborea*	exotic	timber
Guava	*Psidium guajava*	exotic	fruit
Gyama	*Alchonea floribunda*	indigenous	others
Indian almond	*Terminalia catappa*	exotic	timber
Jatropha	*Jatropha podagrica*	exotic	others
Konkroma	*Moringa lucida*	indigenous	others
Kube	*Cocos nucifera*	exotic	fruit
Leuceana	*Leuceana leucocephala*	exotic	others
Madras Thorn	*Pithecellobium dulce*	exotic	avenue
Mango	*Mangifera indica*	exotic	fruit
Mantaly	*Terminalia mantaly*	exotic	timber
Milk Bush	*Euphorbia tirucalli*	exotic	avenue
Neem	*Azadirachta indica*	exotic	others
Nyamedua	*Alstonia boonei*	indigenous	others
Nyankyerene	*Ficus exasperata*	indigenous	others
Okoro	*Albizia zygia*	indigenous	others
Okuo	*Zanthoxylum gilletii*	indigenous	others
Paper Mulberry	*Broussonetia papyrifera*	exotic	timber

Pear	*Persea americana*	exotic	fruit
Raffia palm	*Raphia spp*	indigenous	others
Sesemasa	*Newbuldia laevis*	indigenous	others
Sour sop	*Annona muricata*	exotic	fruit
Spatodia	*Spathodia campanulata*	indigenous	others

Appendix 7: Normality test for tree species and biophysical data

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
Richness	0.176	47	0.001
Density/ha	0.169	47	0.002
Diversity	0.102	47	0.200*
Elevation	0.127	47	0.057
Road distance	0.156	47	0.006
Water distance	0.211	47	0.0002

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Appendix 8: Tree species richness, density and diversity in the LULC classes

	LULC	No of plots	Mean Rank	Median	Test Statistic Chi-square	(df)	P-value
Richness	Agricultural land	17	25.29	4.00	14.477	(3)	0.002
	Built-up	19	39.47	6.00			
	Riverine	21	29.57	4.00			
	Forest	12	51.17	7.50			
Density/ ha	Agricultural land	17	84	63	35.597	(3)	0.000
	Built-up	19	38	34			
	Riverine	21	102	93			
	Forest	12	251	244			
Diversity	Agricultural land	17	27.15	1.15	2.52	(3)	0.062
	Built-up	19	40.21	1.62			
	Riverine	21	30.93	1.28			
	Forest	12	45	1.59			

Appendix 9: Post-hoc test of tree species richness and diversity in the various LULC classes

Land Cover	Richness	Density/ha	Richness	Density
Agricultural land	10.71	9.94	[29 (-3.282); p=.001]*	[16 (-3.816); p=.000]*
Forest	21.08	22.17		
Agricultural land	17.74	16.97	[148.5 (-0.896); p=.383]	[135.5 (-1.270); p=.209]
Riverine	20.93	21.55		

Agricultural land	14.85	22.35	[99.5 (-1.982); p =.049]	[24.5 (-4.346); p=.000]*
Built-up	21.76	15.05		
Built-up	23.66	28.95	[139.5 (-1.641); p= .105]	[39(-4.352); p=.000]*
Riverine	17.64	12.86		
Built-up	14.05	17.84	[77 (-1.51); p=.141]	[79 (-1.421); p=.164]
Forest	19.08	13.08		
Riverine	13	12.07	[42 (-3.167); p=.001]*	[22.5 (-3.880); p = .000]*
Forest	24	25.63		

Note: *Significance at p < .008
Source: Field Data, 2017

Appendix 10: The services provided by trees and their respective counts

Services	No count (not identified)	Relative %	Count (Identified)	Relative %
Shade	94	67.1	46	32.9
Air purification/ dust reduction	95	67.9	45	32.1
Food	98	70	42	30
Income from sales of tree products	113	80.7	27	19.3
Wind breaks	115	82.1	25	17.9
Trado-medicine	122	87.1	18	12.9
Fuel wood	133	95	7	5
Relaxation	133	95	7	5
Moderate local climate	136	97.1	4	2.9
Climate change combat	137	97.9	3	2.1
Aesthetic	137	97.9	3	2.1
Recreation	138	98.6	2	1.4
Boundary demarcation	139	99.3	1	0.7
Preservation of biodiversity/ nature	139	99.3	1	0.7
Erosion control	139	99.3	1	0.7
TOTAL	1868	89.0	232	11.0

Appendix 11: Relationship between respondents' socio-economic background and cultural services of trees

Socio-economic * Cultural services	Categories Proportions	Chi-square test (df)	Asympt. Sig. (p-Value, 2-sided)
1. Recreation			
Gender (Male, Female)	[100% : 0%]	4.143 (1) *	0.042
Origin (Indigene and Migrant)	[0%:100%]	3.475(1) *	0.044

Education (Uneducated, Primary, Secondary level, and Tertiary)	[0%:50%:50%:0%]	0.769(3)	0.857
Occupation (Not working, Primary, Secondary, and Tertiary)	[50%:50%:0%:0%]	2.239 (6)	0.870
2. Relaxation			
Gender (Male, Female)	[43%: 57%]	0.331 (1)	0.421
Origin (Indigene and Migrant)	[57%:43%]	0.111(1)	0.739
Education (Uneducated, Primary, Secondary level, and Tertiary)	[0%:43%:43%:14%]	1.483(1)	0.686
Occupation (Not working, Primary, Secondary, and Tertiary)	[0%:100%:0%:0%]	2.123 (3)	0.547
3. Boundary demarcation			
Gender (Male, Female)	[100%:0%]	0.498 (1)	0.481
Origin (Indigene and Migrant)	[100%:0%]	0.593(1)	0.441
Education (Uneducated, Primary, Secondary level, and Tertiary)	[0%100%:0%:0%]	2.357(3)	0.502
Occupation (Not working, Primary, Secondary, and Tertiary)	[0%:100%:0%:0%]	0.285 (3)	0.963
4. Aesthetics			
Gender (Male, Female)	[100%:0%]		
Origin (Indigene and Migrant)	[0%:100%]	5.266(1)	0.220
Education (Uneducated, Primary, Secondary level, and Tertiary)	[33%:0%:33%:33%]	3.820(1)	0.282
Occupation (Not working, Primary, Secondary, and Tertiary)	[0%:24%:33%:43%]	6.368 (3) *	0.04

*Significant at p < .05 2-tailed; **Significant at p < .01 2-tailed; ***Significant at p < .001, 2-tailed

Appendix 12: Relationship between respondents' socio-economic and regulating/supporting services of trees

Socio-economic *Regulating /supporting	Categories Proportions	Chi-square test (df)	Asympt. Sig. (p-Value, 2-sided)
1. Erosion			
Gender (Male, Female)	[0%:100%]	0.498 (1)	0.481
Origin (Indigene and Migrant)	[100%0%]	0.593 (1)	0.441
Education (Uneducated, Primary, Secondary level, and Tertiary)	[0%:0%:100%:0%]	1.186(3)	0.756

Occupation (Not working, Primary, Secondary, and Tertiary)	[0%:100%:0%:0%]	0.285 (3)	0.863
2. Moderate local climate			
Gender (Male, Female)	[50%:50%]	0.545 (1)	0.461
Origin (Indigene and Migrant)	[75%:25%]	0.257(1)	0.612
Education (Uneducated, Primary, Secondary level, and Tertiary)	[75%:25%:0%:0%]	2.239 (3)	0.524
Occupation (Not working, Primary, Secondary, and Tertiary)	[25%:75%:0%:0%]	0.466 (3)	0.926
3. Air purification/ dust reduction			
Gender (Male, Female)	[38%:42%]	0.845(1)	0.358
Origin (Indigene and Migrant)	[62%:38%]	0.021(1)	0.884
Education (Uneducated, Primary, Secondary level, and Tertiary)	[13%:47%:27%:13%]	0.723(3)	0.868
Occupation (Not working, Primary, Secondary, and Tertiary)	[20%:78%:2%:0%]	2.900 (3)	0.407
4. Climate Change Combat			
Gender (Male, Female)	[33%:67]	0.000(1)	0.524
Origin (Indigene and Migrant)	[33%:67%]	1.168(1)	0.28
Education (Uneducated, Primary, Secondary level, and Tertiary)	[33%:67%:0%:0%]	2.539(3)	0.468
Occupation (Not working, Primary, Secondary, and Tertiary)	[33%:67%:0%:0%]	0.817 (3)	0.845
5. Windbreaks			
Gender (Male, Female)	[56%:44%]	7.975(1) *	0.005
Origin (Indigene and Migrant)	[52%:48%]	1.730(1)	0.188
Education (Uneducated, Primary, Secondary level, and Tertiary)	[20%:44%:24%:12%]	1.716 (6)	0.633
Occupation (Not working, Primary, Secondary, and Tertiary)	[12%:76%:8%:4%]	3.950 (3)	0.267
6. Preservation of Biodiversity			
Gender (Male, Female)	[0%:100%]	0.498(1)	0.481
Origin (Indigene and Migrant)	[100%:0%]	0.593	0.441
Education (Uneducated, Primary, Secondary level, and Tertiary)	[0%:0%:100%:0%]	2.357(3)	0.502

Occupation (Not working, Primary, Secondary, and Tertiary)	[0%:100%:0%:0%]	0.285 (3)	0.963
2. Shade			
Gender (Male, Female)	[37%:63%]	0.603 (1)	0 .437
Origin (Indigene and Migrant)	[61%:39%]	0.166 (1)	0.684
Education (Uneducated, Primary, Secondary level, and Tertiary)	[9%:50%:28%:13%]	1.802(3)	0.614
Occupation (Not working, Primary, Secondary, and Tertiary)	[15%:78%:4%:2%]	1.280(3)	0.734

*Significant at p < .05 2-tailed; **Significant at p < .01 2-tailed; ***Significant at p < .001, 2-tailed

Appendix 13: Relationship between respondents' socio-economic background and provisioning services of trees

Socio-economic * Provisioning	Categories Proportions	Chi-square test (df)	Asympt. Sig. (p-Value, 2-sided)
1. Food			
Gender (Male; Female)	[26%:74%]	1.519(1)	0.218
Origin (Indigene and Migrant)	[71%:29%]	2.202 (1)	0.137
Education (Uneducated, Primary, Secondary level, and Tertiary)	[7%:55%:31%:7%]	4.121 (3)	0.249
Occupation (Not working, Primary, Secondary, and Tertiary)	[14%:79%:7%:0%]	1.525 (3)	0.676
2. Sale of Tree products			
Gender (Male, Female)	[37%:63%]	0.273(1)	0.602
Origin (Indigene and Migrant)	[52%:48%]	1.972(1)	0.160
Education (Uneducated, Primary, Secondary level, and Tertiary)	[14%:41%:33%:11%]	0.454(3)	0.929
Occupation (Not working, Primary, Secondary, and Tertiary)	[26%:67%:7%:0%]	3.685(3)	0.298
3. Fuel Wood			
Gender (Male, Female)	[14%:86%]	1.192(1)	0.275
Origin (Indigene and Migrant)	[57%:43%]	0.111(1)	0.739
Education (Uneducated, Primary, Secondary level, and Tertiary)	[57%:14%:18%:0%]	6.585 (6)	0.04*
Occupation (Not working, Primary, Secondary, and Tertiary)	[57%:39%:4%:0%]	8.873 (3)	0.031*
4. Trado-medicine			
Gender (Male, Female)	[33%:67%]	0.001(1)	0.974
Origin (Indigene and Migrant)	[50%:50%]	1.591(1)	0.201
Education (Uneducated, Primary, Secondary level, and Tertiary)	[22%:56%:17%:7%]	3.764 (3)	0.288
Occupation (Not working, Primary, Secondary, and Tertiary)	[22%:78%:0%:0%]	1.848 (3)	0.604

*Significant at p < .05 2-tailed; **Significant at p < .01 2-tailed; ***Significant at p < .001, 2-tailed

Appendix 14: Biophysical data used for the CCA analysis

LULC	Elevation	Distance To Road	Distance To Water
F-R	258	174.929	108.167
F-R	284	210	270
F-R	279	30	335.41
F-R	278	174.929	201.246
F-R	259	234.307	60
F-R	276	94.8683	468.615
R-V	264	42.4264	0
R-V	238	335.41	0
R-V	262	241.868	30
R-V	259	201.246	0
R-V	238	0	30
R-V	265	30	201.246
R-V	270	0	134.164
R-V	266	432.666	436.807
R-V	245	339.411	150
R-V	249	0	0
R-V	249	436.807	30
R-V	247	510	30
R-V	250	134.164	60
R-V	273	60	0
R-V	246	169.706	67.082
R-V	249	30	400.25
A-G	270	67.082	360
A-G	256	0	123.693
A-G	264	420	192.094
A-G	237	0	67.082
A-G	250	0	30
A-G	235	161.555	94.8683
A-G	259	180	0
A-G	264	690.652	0
A-G	266	216.333	516.14
A-G	250	161.555	0
B-T	269	0	30
B-T	242	0	84.8528
B-T	272	240	362.491
B-T	259	313.209	30
B-T	273	169.706	630.714
B-T	268	30	120
B-T	256	30	324.5
B-T	249	60	94.8683
B-T	249	30	0

B-T	252	90	0
B-T	245	174.929	30
B-T	259	421.07	30
B-T	236	67.082	42.4264
B-T	245	108.167	0
B-T	281	94.8683	94.8683

F-R	Forest
R-V	Riverine
A-G	Agricultural land
B-T	Built-up

Appendix 15: Multicollinearity text of environmental variables

Correlation Matrix				
Variables	Distance to road	Elevation	Slope	Distance to water
Distance to road	1.0000	-0.22346	0.93253	-0.03184
Elevation	-0.22346	1.0000	0.0442	0.03303
Slope	0.93253	0.0442	1.0000	-0.00388
Distance to water	-0.03184	0.03303	-0.00388	1.0000

Appendix 16: Descriptive statistics of biophysical variables used for the CCA

	Units	Minimum	Maximum	Mean	SD	Test Statistics	
						Chi-square (df)	p-value
Elevation	meters	235	284	257.66	12.979	33.77(2)	0.000
Distance to Road	meters	0	691	161.89	160.052		
Distance to Water	meters	0	631	133.44	162.168		

Appendix 17: List of dominant species used for the CCA analysis and their abbreviation

Species full name	Species abbreviated name
Albizia adianthifolia	*A. adianthifolia*
Alstonia boonei	*A. boonei*
Alchonea floribunda	*A. floribunda*
Azadirachta indica	*A. indica*
Albizia lebbeck	*A. lebbeck*
Annona muricata	*A. muricata*
Annona squamosa	*A. squamosa*

Bauhinia monandra	*B. monandra*
Blighia sapida	*B. sapida*
Cocos nucifera	*C. nucifera*
Cedrela odorata	*C. odorata*
Citrus sinensis	*C. sinensis*
Ceiba. pentandra	C. pentandra
Codiaeum variegatum	C. variegatum
Delonix regia	*D. regia*
Eucalyptus grandis	*E. grandis*
Elaeis guineensis	*E. guineensis*
Entandrophragma utile	*E. utile*
Ficus exasperata	*F. exasperata*
Ficus spp	*Ficus spp*
Gmelina arborea	*G. arborea*
Jatropha podagrica	*J. podagrica*
Musanga cecropioides	*M. cecropioides*
Mansonia altissima	M. altissima
Nauclea diderrichii	N. diderrichii
Margaritaria discoidea	*M. discoidea*
Mangifera indica	*M. indica*
Morinda lucida	*M. lucida*
Moringa oleifera	*M. oleifera*
Newbouldia laevis	*N. laevis*
Persea americana	*P. americana*
Pithecellobium dulce	*P. dulce*
Psidium guajava	*P. guajava*
Polyalthia longifolia	*P. longifolia*
Raphia spp	*Raphia spp*
Senna siamea	*S. siamea*
Theobroma cacao	*T. cacao*
Tectona grandis	*T. grandis*
Terminalia mantaly	*T. mentalii*
Triplochiton scleroxylon	*T. scleroxylon*