# TREE BIOMASS AND CARBON SEQUESTRATION POTENTIAL OF FEDERAL FOREST RESERVE, ILORIN EAST LGA, KWARA STATE

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## Declaration

No component of the work in this dissertation has been submitted in support of any application for another qualification, at this or any other university or institution of learning. The contributions of others, in terms of provision of data, and their analysis and interpretation, is acknowledged and described fully in the Methods section of this dissertation.

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## Certification

This is to certify that this research work was carried out by Yusuf RABIU (16/27/MPEB001) in partial fulfillment for the award of Master of Science (M.Sc.) degree in Plant and Environmental Biology, Department of Plant and Environmental Biology from Kwara State University, Malete.

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# Dedication

I dedicate this thesis to God Almighty for giving me the strength and will power to make the project a reality.

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## Abstract

Forest reserves are significant part of global carbon cycle. They play a significant role in checkmating the menace of greenhouse gases through carbon sequestration. This study therefore assessed the woody species distribution, diversity and richness in Federal Forest Reserve Ilorin, Kwara State. Two separate sampling techniques were employed - one for tree sampling and another for sampling soil and litter. The plotless Point Center Quarter sampling (PCQ) technique was employed. PCQ was placed in 15 random points based on the sample size determined using species area curve. The study area was also stratified into three regions (proximal, intermediate and inner) based on distance, gradient and observed disturbance. Within each of these three strata, six sampling sites were randomly selected where soil samples were collected at a depth of 15cm. *Gmelina arborea* (31) was found to be the most dominant while *Carica papaya* (one) was found to be the least andant. Based on the data collected from PCQ, tree height, diameter at breast height, basal area, volume and biomass were measured to determine the carbon content and carbon sequestration potential. Species frequency, density, coverage, importance value and diversity were determined. Shannon and Simpson diversity indices revealed that H' = 1.58509; D' = 0.306109; J = 3.266810. The results showed that the percentage of sandy soil (90.9%) was found to be the highest, with the silt (7.4%) and clay soil (1.7%) obtained in a smaller quantity. The average concentration of soil nutrients found in the sampled soil are calcium (8.44mol/kg), magnesium (3.31mol/kg), potassium (1.32mol/kg), sodium (1.16mol/kg), manganese (39.56mol/kg) and cupper (1.00mol/kg). Others are zinc and iron found in high concentrations with an average of 100.35mg/kg and 2.95mg/kg respectively. The average organic carbon content of the forest is 29424.37kg. The total carbon sequestration potential of the forest was found to be 107869.75ton/ha. Baseline data and information on basic taxonomy, above-below-ground biomass, carbon sequestration potential of trees and soil physicochemical properties were finally generated.

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background Information

Global temperature is believed to be rising due to anthropogenic activity, i.e., global warming and the major cause has been identified to be fossil fuel burning, which is releasing increasing amounts of carbon dioxide into the atmosphere (IPCC, 2007). Increasing levels of atmospheric carbon dioxide ($CO_2$) and other “greenhouse” gases [i.e. methane ($CH_4$), chlorofluorocarbons (CFCs), nitrous oxide ($N_2O$), and tropospheric ozone ($O_3$)] are thought to be contributing to an increase in atmospheric temperatures by the trapping of certain wavelengths of radiation in the atmosphere (Meinshausen *et al.,*2009). Globally averaged air temperature at the Earth’s surface has increased between 0.3˚C and 0.6 ˚C since the late 1800s (IPCC, 2007). A current estimate of the expected rise in average surface air temperature globally is between 1˚C and 3.5˚C by the year 2100 (Hamburg *et al.,* 1997). Global warming is implicated in the recent discovery that floating ice over the Arctic Ocean has thinned from an average thickness of 10 feet in 1950 to <6 feet in the late 1990s, and a large expanse of ice-free water that has opened up at the North Pole in 2000 (Appenzeller, 2000; BBC News, 2000). Every greenhouse gas has a Global Warming Potential (GWP), a measurement of the impact that a particular gas has on “radiative forcing”; that is, the additional heat/energy which is retained in the Earth's atmosphere system through the addition of the gas to the atmosphere (Wertz-Kanounnikoff *et al.,* 2008).

Carbon dioxide is a dominant greenhouse gas. Increased atmospheric $CO_2$ is attributable mostly to fossil fuel combustion (about 80–85%) and deforestation worldwide (Hamburg *et al.,* 1997). Atmospheric carbon is estimated to be increasing by approximately 2600 million metric tons annually (Sedjo, 1989., Nowak & Crane 2002). The carbon dioxide ($CO_2$) level of the atmosphere has been altered as a result of human activities leading to the rise in global temperature and its consequences (Sandberg, 2013). Sequestration could be a major tool for reducing $CO_2$ emissions, it will allow greater flexibility in the future primary energy supply, and could offer other collateral benefits such as manufactured products, improved agricultural practices and enhanced recovery of oil and methane.

The term "carbon sequestration" is used to describe both natural and deliberate processes by which carbon-dioxide is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments (vegetation, soils, and sediments), and geologic formations (Sedjo *et al.,* 2012).According to Azar *et al.,* (2006), terrestrial carbon sequestration is carbon stored in the biomass created by perennial vegetation such as root systems (below biomass) and tree trunks (above biomass). Trees remove carbon dioxide from the atmosphere through the natural process of photosynthesis and store the carbon (C) in their leaves, branches, stems, bark and roots. Approximately half the dry weight of a tree's biomass is carbon (Gorte, 2009). The purpose of carbon sequestration is to keep anthropogenic carbon emissions from reaching the atmosphere by capturing them, isolating them, and diverting them to secure storage and/or to remove $CO_2$ from the atmosphere by various means and store it (Matthews and Weaver, 2010). Carbon dioxide equivalents ($CO_2^{-e}$) provide a universal standard of measurement against which the impacts of releasing (or avoiding the release of or actively sequestering) different greenhouse gases can be evaluated (Elliason *et al.,* 2013).

Forest ecosystems, as with vegetation in general, are excellent sinks of $CO_2$; they mop up $CO_2$ that would otherwise be present in the atmosphere through the process of photosynthesis (Wani *et al*., 2012). Large quantities of biomass are stored in stable (undisturbed) forest ecosystem compared to agriculture and other systems (Devagiri *et al.,* 2013) thereby generating a considerable interest in forest ecosystems. Biomass can be defined as the organic material that has been generated and accumulated above- and below-ground in the forest ecosystem, expressed as mass per unit area (FAO, 2004). The above-ground biomass of forests, which is mainly made up of trees, accounts for a large proportion of the total tree biomass (IPCC, 2006) as such majority of biomass estimation studies are concentrated on the above-ground biomass (Salmaca, 2007). In terrestrial ecosystems, above-ground biomass is associated with components such as carbon cycle, soil nutrients allocation, fuel accumulation and habitat environment (Lu, 2005). The below-ground biomass constitutes all the living roots (ICCP, 2006) and is said to account for approximately 30% of the above-ground biomass (Rey de Vinas and Ayanz, 2000). The below-ground biomass is crucial in the carbon cycle because of the role it plays in transferring and storing carbon in the soil (Ravindranath and Ostwald, 2008).

Forest Studies have attributed loss of forest resources to actions by many agents, including individuals, groups and institutions that directly convert forested lands to other uses or intervene in forests to substantially reduce the productive capacity of the forest ecosystem (Myers 1988). The human agents also include those who practice shifting cultivation, extensive agriculture activities, private and government logging companies, mining and oil corporations, forest concessionaires and ranchers whose activities often result into removal of trees, especially in areas without adequate provision for reforestation (Putz et al. 2001). Loggers destroy trees and vegetation while creating access roads to the desired location within the forest; conventional agriculture practices, open grazing or intensive collection of forest trees to provide fodder for grazing animals, fuelwood collection, as well, open up the forest for further degradation (Myers 1991; Mather 1991; Kaimowitz and Angelsen 1998; Orimoogunje 2014).

Urbanization also opens the land to development and brings increasing numbers of people to the forest frontier (Wilkie et al. 2000). DeFries et al. (2010) noted that urban population growth in Africa is associated with forest loss, and that poor data quality has plagued country-level information on forest area in the region. In Nigeria, urban population increased by 45% and 48.9% in 2004 and 2010 but deforestation tends to occur at 4000 km2/year; forested area tends to decrease by 10.8%, annually, since 2010 (United Nations Statistics Division 2013).

Soils also have the potential to sequester carbon from the atmosphere with proper management. Based on global estimates of historic carbon stocks and projections of rising emissions, soil’s usefulness as a carbon sink and drawdown solution appears essential (Lal, 2004; 2008). Since over one-third of arable land is in agricultural use globally, (World Bank, 2015), finding ways to increase soil carbon in agricultural systems will be a major component of using soils as a sink.

## 1.2 Statement of Problem

The increase in carbon emission is one of the current major concerns, which was well addressed in the Kyoto Protocol (Ravindranath *et al*., 1997). This is due to its identification as the main causal factor for global warming (Lal, 2001). Since forest ecosystems contain between 62% and 78% of the total terrestrial carbon (Hagedorn *et al*., 2002), the response of forests to the rising atmospheric $CO_2$ concentrations is crucial for the global carbon cycle. The world is witnessing mounting and undeniable evidence that nature's cycles are profoundly changing i.e. on land and in water, in melting ice and disappearing snow, during heat waves and droughts and in the eyes of hurricanes and in the tears of refugees (Harris *et al.*, 2012). The evidence today indicates that forests are expanding in the temperate regions of the world, while declining in much of the tropics. The tropical region harbours more species diversity than the temperate region and serve as a major carbon store in the world. Therefore, there is a need to evaluate biomass and carbon sequestration potential of the forest ecosystem in tropics.

## 1.3 Aim and Objectives

The broad focus of this study was to generate baseline data and information on basic taxonomy, above- and below-ground biomass, and carbon sequestration potential of trees within Federal Forest Reserve Ilorin, Kwara State.

The specific objectives were to:

- evaluate trees species abundance and diversity within the study area.
- quantify basic allometric properties of trees within the study area.
- estimate the above and below ground tree biomass as well as carbon sequestration potential of the study area.
- determine the physicochemical properties of soil within the study area

# CHAPTER TWO

# LITERATUREREVIEW

## 2.1 Species diversity in forest ecosystem

Species diversity is the number of different species in a particular area (species richness) weighted by some measure of abundance such as number of individuals or biomass. However, Harrison *et al., (*2004) explained that conservation biologists often use the term species diversity even when they are actually referring to species richness, i.e. to number of present species. Merganič *et al., (*2012) define species diversity as a composition that refers to the identity and variety of elements in a population that includes species lists and measures of species diversity and genetic diversity.

Species diversity could be structural or functional. Structural diversity refers to the physical organisation or pattern of a system, including the spatial patchwork of different physical conditions in a landscape, habitat mosaics, species assemblages of different plant and animal communities, and genetic composition of subpopulations (Stokland *et al* 2003). The main structural indicators that are used to describe the conditions for forest biodiversity include stand vertical structure, age class distribution and the amount of dead wood (Christensen *et al*., 2004). They represent an indirect approach as they show, typically on a rather gross scale, how the house is built, but gives no information on whether the inhabitants have moved in.

Functional diversity involves all ecological and evolutionary processes, including gene flow, disturbances, and nutrient cycling. "Functional diversity involves processes of temporal change, including disturbance events and subsequent succession, nutrient recycling, population dynamics within species, various forms of species interactions, and gene flow" (Stokland *et al*., 2003).

The term species richness was introduced by McIntosh (2007) to describe the number of species in the community. Surely, the number of species S in the community is the basic measure of species richness, defined by Hill (2007) as diversity number of $0^{th}$ order, i.e.

N0. The basic measurement problem of N0 is that it is often not possible to enumerate all species in a population. In addition, S depends on the sample size and the time spent searching, due to which its use as a comparative index is limited. Hence, a number of other indices independent of the sample size have been proposed to measure species richness. These indices are usually based on the relationship between S and the total number of individuals observed (Kottè-Mapoko *et al*, 2017). Two such well-known indices are R1 and R2 proposed by Barnhill (2006) and Sagar and Puspa (2016) respectively. Hubálek (2000), who examined the behaviour of 24 measures of species diversity in a data from bird censuses, assigned to the category of species richness-like indices also the index $\alpha$ (Pedro *et al*., 2013), Q (Henderson and Seaby, 2007) and R500 (Hurlbert, 2007).

Lloyd and Ghelardi (1964) were the first who came with idea to measure the evenness component of diversity separately. The principle of the evenness measures is to quantify the unequal representation of species against a hypothetical community in which all species are equally common. (Kottè-Mapoko., 2017) present five evenness indices E1 (Pedro., 2013), E2, E3, E4 (Hill, 2007), and E5, each of which may be expressed as a ratio of Hill´s numbers. The most common index E1, also known as J′ expresses H′ relative to maximum value of H′ (= log S). Index E2 is an exponentiated form of E1. Based on the analysis of Hubálek (2000), McIntosh`s diversity D (McIntosh, 2007; Pedro *et al*., 2013), McIntosh`s evenness DE, index J of Pedro and Tamara (2013) and G are also evenness measures.

This concept of diversity was introduced by Simpson and combines species richness and evenness as reported by Sagar and Sharma (2012). Many ecologists consider this concept to be synonymous with diversity. According to Kottè-Mapoko *et al*., (2017), an infinite number of diversity indices exist. Simpson proposed the first heterogeneity index, which gives the probability that two individuals picked at random from the community belong to the same species. This means that if the calculated probability is high, the diversity of the community is low (Kottè-Mapoko *et al*., 2017). To convert this probability to a diversity measure, the complement of Simpson´s original measure is used (Gilbert & Luis, 2008).

Probably the most widely used heterogeneity index is the Shannon-Weiner index H′ (or Shannon-Wiener function), which is based on information theory (Charles and Richard, 2016). It is a measure of the average degree of “uncertainty” in predicting to what species an individual chosen at random from a community will belong. Hence, if H´ = 0, the community consists of only one species, whereas H´ is maximum (= log(S)) if all species present in the community are represented by the same number of individuals. Shannon index places most weight on the rare species in the sample, while Simpson index on the common species (Gilbert and Luis, 2008). From other heterogeneity measures, Brillouin Index H was mentioned (Lesne, 2014), which was first proposed by Barnhill (2006) as a measure of diversity. This index is preferred being applied to data in a finite collection rather than H´. However, if the number of individuals is large, H and H´ are nearly identical (Gilbert and Luis, 2008). The indices N1 and N2 from Hill`s family of diversity numbers (Hill, 2007), which characterize the number of “abundant”, and “very abundant” species, respectively, also belong to diversity measures.

The McIntosh index is based on the representation of a sample in an S-dimensional hyperspace, where each dimension refers to the abundance of a particular species. According to the evaluation performed by Hubálek (2000), NMS “number of moves per specimen” proposed by (Glover1, 2012). H´adj, which is an adjusted H´ by the d (H) correction and R100 (Hurlbert, 2007) can also be regarded as heterogeneity indices.

Diversity could be horizontal and vertical. The indices characterising forest horizontal structure usually compare a hypothetical spatial distribution with the real situation (Neumann and Starlinger, 2001). Probably the most well-known index is the aggregation index R proposed by Laura., *et al* (2018) that describes the horizontal tree distribution pattern, or positioning as defined by Paula and Margarida (2003). It is a measure of the degree to which a forest stands deviates from the Poisson forest, where all individuals are distributed randomly (Basiri., 2011). It is the ratio of the observed mean distance to the expected mean distance if individuals were randomly distributed.

While there are many indices that measure horizontal structure, there are only few for vertical structure (Neumann and Starlinger, 2001). Simple measures such as the number of vegetation layers within a plot can be used as an index of vertical differentiation (Gilbert and Luis, 2008).

The index A developed by Pretzsch for the vertical species profile is based on the Shannon-Weiner index H′ (Ana, 2018). In comparison with H′ the index A considers species portions separately for a predefined number of height layers (Pretzsch distinguished 3 layers). The index takes the cover per layer into account, but needs special field assessments (Neumann and Starlinger, 2001). Therefore, using the same principles as (Merganič., 2012), i.e. Shannon-Weiner index and stratification into height layers, Neumann and Starlinger (2001) suggested an index of vertical evenness VE that characterizes the vertical distribution of coverage within a stand. The differentiation index T of Diana., *et al* (2009) is also applicable for the description of vertical differentiation, if the index is calculated from tree heights.

## 2.2 Allometric properties of trees

Estimates of tree biomass are useful in assessing forest structure and condition (Goodale, 2004); forest productivity, carbon stocks and fluxes based on sequential biomass measurements (Clark *et al*., 2001); and sequestration of carbon in biomass components, including wood, leaves, and roots; as well as being a useful indicator of forest productivity. Several generalized biomass prediction equations have been developed for tropical species (Chave *et al*., 2005). For temperate species, Ter-Mikaelian and Korzukhin (1997) reported a list of biomass equations for 66 North American tree species.

However, single species and mixtures of species differ in allometry, wood density, and architecture, all of which can affect the relationship between the measurements taken during forest inventories and the biomass of individual trees (Chave *et al*., 2003). Therefore, biomass equations are required for other forest ecosystems where little is known and there is a great need for the development of environmental projects to conserve native forests.

Equations developed from single species and from mixtures of species yield useful estimates for specific sites and for large-scale global and regional comparisons. These two types of equations are important for forest inventory data to which single or mixed-species equations are often applied. In cases where species-specific information is available, equations tailored to estimate biomass of the particular species can provide more accurate estimates of biomass (Litton and Kauffman, 2008). This situation typically arises in cases of plantations of high-value tree species or when precise estimates are needed for research or environmental management. In natural forests, equations must incorporate a variety of species to provide accurate biomass estimates. However, Litton and Kauffman 2008 developed an allometric equation for 10 species of temperate and tropical dry forests regarding branches and leaves, boles, and roots, taking advantage of measurements made during an intensive study of carbon sequestration in 19 forestry communal lands (ejidos) of northwestern Mexico. Sampled trees spanned a wide range of sizes and were of the largest sizes attainable by the species. These samples are typical of today's native forests grown in the Sierra Madre Occidental mountain range of Durango and Chihuahua and of the tropical dry forests of the lowlands of the Pacific Ocean. They developed an allometric equations for each component, as each harvested tree was dissected into various biomass components (branches and leaves, bole, total above-ground, and roots). They then applied the equations to forest inventory data (637 plots of temperate forests and 166 quadrats of dry tropical forests) to estimate biomass and carbon stocks. The economic and ecological value of the species studied, the uniquely large sample sizes, the breakdown of each species into morpho-logical components, and the application to forest inventory data make this a rich data set that can provide insights into biomass allocation and carbon stocks of temperate and tropical trees and forests in northwestern Mexico.

There is a significant need globally to develop equations that estimate forest biomass and carbon for national measuring, reporting, and verification systems. Under the United Nations Framework Convention on Climate Change, countries must report the state of their forest resources through initiatives such as the United Nations collaborative programme on Reducing Emissions from Deforestation and Forest Degradation Plus UN-REDD+ programme in developing countries (UNFCCC 2014).

Estimating the carbon stocked in forests is important to assess the mitigation effect of forests on global change and to predict the potential impact of mechanisms to reduce carbon emission. Although many techniques exist to estimate carbon stocks in forests at different scales (Gibbs *et al*. 2007), all techniques ultimately rely on ground measurement of tree biomass. Measuring the biomass of a tree is tedious and time consuming.

Moreover, it is destructive. This is why biomass equations have been developed. These are equations that predict the biomass of a tree from dendrometrical characteristics such as diameter or height that are easier to measure. Species-specific biomass equations have been developed for temperate forests (Zianis *et al*., 2005). In highly diverse ecosystems such as tropical rainforests, either specific or local equations with good precision but narrow range of application (Araújo *et al*., 1999, Basuki *et al*., 2009) or general multispecies pantropical equations (Brown 1997, Chave *et al*., 2005) have been developed. Although the Congo Basin is the second largest block of tropical forest in the world after Amazon, it has contributed little to the development of pantropical biomass equations. It is symptomatic; for instance, the pantropical biomass equations Chave *et al*., *(*2005) relied on data from the neotropics and South-East Asia but not from central Africa.

Biomass equations for tropical rainforests in the neotropics or South-East Asia have been developed (Lescure *et al*., 1983, Nelson *et al*., 1999, Chave *et al*. 2001., Basuki *et al*., 2009). Biomass equations for African tropical dry forests are common because the supply of fuel wood is a long lasting issue in these areas. Specific biomass equations can be found for most species of the Soudano–Sahelian and miombo woodlands (Tietema 1993, Smektala *et al*., 2002, Chamshama *et al*., 2004, Hofstad 2005).

On the contrary, in African tropical rainforests where the issue is classically to build volume equations to predict timber volume, biomass measurements are scarce. Allometric equations for indigenous species of the rainforests of central Africa have been constructed from biomass data collected in plantations (Onyekwelu 2007) or secondary forests (Deans *et al*., 1996). As a consequence of the scarcity of data on tree biomass in central Africa, most of the current estimates of the carbon stocks in central Africa (Baccini *et al*., 2008, Lewis *et al*., 2009) are paradoxically based on pantropical biomass equations that do not rely on any data from Africa. There is debate whether this paradoxical situation is a shortcoming or not a problem given the precision of the pantropical biomass equations. Some authors such as Gibbs *et al*., *(*2007) considered species-specific or site-specific allometric equations as not needed to generate reliable estimate of forest carbon stocks. It would not improve accuracy with respect to general pantropic equations. On the contrary, authors such as Basuki *et al., (*2009) are of the opinion that pan tropical biomass equations lead to significantly biased estimates of carbon stocks.

Below-ground biomass estimation in comparison to above-ground biomass has very little studies. However, this could be largely attributed to the small percentage of tree total below-ground biomass are thought to account, financial burden and the rigorous nature of below-ground biomass estimation. Biomass estimation is crucial for resource use and environmental management (Salmaca, 2007), in the case of resource use, it gives us an insight of the potential amount of carbon that can be emitted when the forest is destroyed as well as the amount of carbon that can be sequester from the atmosphere (Vashun and Jayakumar, 2012). For management purpose biomass estimation is important for determining the productivity and sustainability of forest ecosystems (Salmaca, 2007) & (Lu, 2006) categorized above-ground biomass estimation methods into three (3) namely; Field measurement, remote sensing and geographic information system and the combination of field measurement and remote sensing.

Below-ground biomass is an important carbon pool for many vegetation types and land-use systems and accounts for about 20% to 26% (Cairns *et al*., 1997) of the total biomass. Below-ground biomass accumulation is linked to the dynamics of above-ground biomass (Richard, 2019). Revegetation of degraded land leads to continual accumulation of below-ground biomass whereas any disturbance to topsoil leads to loss of below-ground biomass. To estimate below - ground biomass (BGB), the following equation was used:

Where Y=Below Ground Biomass

Y =0.26* Above Ground Biomass

Y =0.26* Above Ground Biomass

Tree biomass is the sum total of all the components of a tree, below-ground as well as above-ground, (Hogarth, 1999). The estimation of biomass in woody ecosystems, such as mangroves, is required for a number of reasons. Foresters are interested in yield of wood as a function of age, stand density and other factors. Ecologists require information about stand biomass for a variety of reasons because of its relevance to nutrient turnover, stand structure and function and competition studies. Ecophysiologists have used biomass as an indicator of atmospheric and soil pollution input and forest health. More recently, governments have realized that there is potential for woody ecosystems to store carbon and thereby contribute to mitigation strategies to offset carbon emissions (Eamus *et al.*, 2000).

Although mangroves occupy only 0.4 % of the forested areas globally, they are important sinks for atmospheric $CO_2$ along tropical coastlines. Mangroves are estimated to store carbon in excess of 8.7 gigatons dry weight (Le. 4.0 gigatons of carbon), (Twilley *et al.*, 1992; Ong, 1993). This carbon is stored in both above and below-ground tree components as well as in the sediment (Twilley *et al.*, 1992). Studies have shown that root productions contribute about half of the total standing biomass (Briggs, 1977).

While there are extensive studies on above-ground biomass of mangrove forests (Komiyama *et al.,* 2002), there have been fewer detailed studies on below-ground biomass (Komiyama *et al.,* 2000). The reason for this disparity in studies is the logistical difficulty of estimating below-ground biomass.

## 2.3 Carbon sequestration in the forest

A mass-based carbon concentration of 47% (0.47) in dry wood is widely accepted as a constant factor for conversion of biomass to carbon stock (Lewis *et al.,* 2009). Carbon concentration varies with tree species. Terrestrial carbon sequestration is the process through which $CO_2$ is absorbed from the atmosphere through photosynthesis and stored in biomass and soils (Sundquist *et al.,* 2008). Forestry is the most important means of sequestrating carbon and giving positive effect on the livelihood of the rural farmers because of its cost effectiveness and associated environmental and social benefits. Forest vegetation and soil share almost 60% of the world's terrestrial Carbon. Its quantity may vary according to land use system. The global carbon cycle represents the most important set of processes linking forests and other vegetation with global warming. Forest ecosystems covers about 4.1 billion hectares of the world and considered as the major reserve of terrestrial Carbon stock and forest cover is decreasing at the net rate of about

9.4m ha/year mostly due to deforestation (Sivakumar, 2007). Deforestation is responsible for up to 20 percent of greenhouse gas emissions worldwide, with most forest land cleared for agricultural use. When managed effectively, forests are net carbon sinks, able to permanently absorb about one-tenth of global $CO_2$ emissions into biomass, soil and forest products. It is believed that the goal of reducing carbon sources and increasing the carbon sink can be achieved efficiently by protecting and conserving the carbon pools in existing forests (Brown, 1997). Forests and wooded areas are natural carbon sinks.

Forests represent an ecosystem. It is a habitat dominated by an array of bio diversified species of plants and animals ranging from trees, shrubs and herbs etc. It also homes several array of vertebrates and invertebrates (Sheram, 1993). The forest is an essential part of the universe, as it provides a lot of benefits to every part of the universe ranging from the role it plays as a settlement for animals and plants and it also serves as a form of livelihood for forest dependent community who uses the forest for gaming (hunting). The reservation of trees of different species helps in mitigating climate change by absorbing the carbon-dioxide ($CO_2$) (a greenhouse gas being emitted by the actions of development) and releasing an environmental friendly gas $O_2$ which is essential to all living things that respires including plants. The forest is important as it also homes different species of fruit trees and from the forest comes most of the trado-medical herbs used in curing most diseases affecting people in the rural areas (Tee, 2010).

However, in this present world, the forest is regarded as not as important as our development and civilization, as it's now a subject of destruction for building of infrastructure, industries, houses, companies, stations etc. It was recorded that as at the 19$^{th}$ century, the global warming rate was as low as 10% in developing countries and 2-3% in underdeveloped countries however, in the 20$^{th}$ century/ 21$^{st}$ century, this global warming has increased because the underdeveloped countries are getting developed and rural areas are also turning to urban areas(Myers, 1994), civilization and development everywhere whereas the forest instead of being left to clear the issues, bad chemicals, emitted gases being popped up through burning of some materials and also Trans boundary waste being deposited by importers from developing countries. Deforestation (a situation whereby trees are being cut) is a hardly solved problem in most part of the developing countries because the forests are being traded for industries, companies, and other functions causing loss of habitat for plant species, animals and also contributing to global warming due to emissions or waste generated from this buildings (van Kooten and Bulte, 2000).

Global forest cover was just under 4 billion ha in 2005, 36% of which were classified as primary forests. Forests provide approximately 1.6 billion people with food, medicines, fuel and other basic necessities. Over two thirds of known land-based species live in forests. Approximately 8000 tree species, or 9% of the total number of tree species worldwide, are currently under threat of extinction. The latest deforestation rates are estimated around 13 million hectares per year: a net loss of about 7.3 million hectares per year for 2000—2005 Deforestation is estimated to have been the cause of 20% of annual greenhouse gas emissions in the 1990 (IPCC, 2007).

Awareness of this issue is growing in the world and an ambitious nationwide reforestation programme with indigenous species and local involvement has been launched to simultaneously regain forest cover and improve community livelihoods across the countries, REDD as a policy with the acronym Reducing Emissions from Deforestation and Forest Degradation in developing countries has continued to attract wide spread notifications across the world due to their impact and supports to countries undergoing REDD+ (The "+" indicates the inclusion of the following activities, i) conservation of forest carbon stocks, ii) sustainable management of forests and iii) enhancement of forest carbon stocks) mechanisms. Nigeria's forests, which currently extend over 9.6 million hectares, have been on deteriorating mode over the past decades. The current deforestation rate is estimated at 3.7%, which is one of the highest in the world (Bryant *et al.*, 1997). In addition, Cross River State, which has more than 50% of Nigeria's remaining tropical high forests, declared a non-timber forest extraction in 2008, now extended indefinitely, while starting to explore new environmental finance mechanisms to further protect the forests, with a priority focus on enhancing the livelihoods of forest-dependent communities and rural dwellers. These initial steps to better protect the forests with a community focus and by exploring innovative means suggest a policy shift in Nigeria in the forest domain.

However, the country needs further and more intense actions, coupled with external cooperation and support, to succeed in this crusade.

Climate change is one of the globally rising and insistent issues in the world today. According to most school of thoughts, one way to diminish $CO_2$ emissions is to reduce our subordinate to fossil fuels and use renewable resources like biomass (US Environmental Protection Agency 2006). In the assessment report collated by IPCC, it was estimated that about 100 billion metric tonnes over the next 50 years could be sequestered through forest management, which would offset 10-20% of the worlds projected fossil fuel emissions (IPCC 2007). The profuse emissions of greenhouse gases, in recent years has enlighten the society's perception of the social and economic damage that may be caused by climate changes, leading to an increasing interest in mitigating the potential impacts of these changes (Parry *et al.*,2007). Schneider (2009) suggests that between 50 and 150 million metric tons of additional carbon sequestration per year could be achieved through changes in agricultural soil and forest management. However, continued existence of these trees species is in jeopardy; because deforestation, logging and other various forms of unsustainable activities have drastically increased in recent times, thereby posing appreciable risk of local extinction to some species. Indeed, the tree species growing in the study area, situated in the most commercial city of Nigeria, and also the most urbanized state in Nigeria, and accommodates about 10% of the entire population of the country (Pelemo *et al.*, 2011), are however not spared from the above aforementioned threats. Rapid increase in population have led to the development of several infrastructural facilities so as to provide comfort to insatiable humans wants, have of course led to the destruction of almost all the ancestral vegetation in and within the study area and its proximate vegetation for urbanization and other commercial activities which are socioeconomic problems, and are too difficult to be controlled. Biomass is known to be a renewable energy source that are derived from organic matter and they include dead trees, branches, wood chips, bark, sawdust, livestock manure, paper products etc. However, the use of forest resources for energy consumption comes with challenges, Hall and Scrase (2003) believe that there is a detrimental effect if biomass harvesting resulted in a net loss of carbon or land management practices decrease the sequestration potential of terrestrial sinks. According to the Middlebury College Biomass Report

(Middlebury College 2004), it is believed that beyond 2010, the fossil fuel governing factors such as the price, supply, and the demand can eventually change for two major reasons, the demand for petroleum is growing rapidly as the supply is reducing drastically and the supply may possibly be scarce or used up between 2020 and 2030 (Middlebury College 2004).

The most common example in nature is during the photosynthesis process of trees and plants, which store carbon as they absorb carbon dioxide during growth. Trees both in above and below-ground biomass continue to accumulate carbon until they reach the maturity; at that point about half of the average tree's dry weight will be carbon (Bhatta, 2016).

The carbon stock in forest vegetation varies according to geographical location, plant species and age of the stand (Van Noordwijk *et al*., 1997). Estimates of the biomass contained within forests are critical aspects of determination of the carbon loss associated with a wide range of land use and land-cover change processes. In order to assess the impact of deforestation and re-growth rates on the global carbon cycle, it is necessary to know the stocks of carbon as biomass per unit area for different forest types. The above-ground biomass and below-ground root biomass both need to be measured to enable better calculations of total forest carbon (Hamburg, 2000). Quantification of sequestered C in different forest types with different management regimes and soil profiles could be important for better planning of natural resources, and the making of good mitigation strategy for climate change effects. Most studies on carbon sequestration have focused on carbon stocks in different land uses. Others have focused only on organic carbon stocks in different forest soils (Shrestha *et al*., 2004). Carbon sequestration potential of different forest types under different management regimes need to be explored.

Carbon dioxide ($CO_2$) is natural greenhouse gas in the atmosphere and is in part responsible for the earth's relative stable climate. It is a greenhouse gas because it traps heat near the earth surface, contributing to observe and predicted global warming (Ian and Rebecca 2010), Carbon Dioxide is composed of a molecule Carbon and two molecules of Oxygen, however the atomic weight of carbon is given as 12 and the atomic weight of

Oxygen is given as 16. The overall weight of Carbon dioxide is the addition of the atomic weight of carbon and Oxygen which is:

$$12 + (2)16=44$$

The ratio of carbon dioxide to carbon is calculated as $CO_2$/C which is:

$$44/12=3.666$$

## 2.4 Forest soil as a carbon sink

Study conducted by Peichl *et al*., (2012) on above and belowground ecosystem biomass, carbon and nitrogen allocation in a recently afforested grassland and adjacent intensively managed grassland in southwest Ireland compared the ecosystem biomass, C and N allocation and storage. A considerable shift in biomass allocation from below- to aboveground within five years following afforestation was recorded. However, ecosystem C and N storage was dominated by the belowground pool in both land-use systems. Compared to the grassland, greater Soil Organic Carbon (SOC) and Total Nitrogen (TN) concentrations in the upper forest soil layer were counterbalanced by a decrease in bulk density, resulting in no significant change in total soil C and N stocks. It was concluded that significant losses of ecosystem C and N did not occur following afforestation of this intensively managed grassland. Peichl *et al*., (2012) further suggested that initial patterns in the development of ecosystem biomass, C and N allocation and storage following afforestation of intensively managed grassland may differ from those resulting from afforestation of extensive grassland due to factors such as initially improved site conditions, a greater fine root pool, enhanced external C and N input and output, and soil disturbance during site preparation activities.

As a consequence of chronically high N depositions in forest ecosystems, the C-to-N ratio of forest floors has narrowed in many forest ecosystems. This might affect the sequestration of soil C and the partitioning of C during decomposition. Michel and Metzner (2002) conducted a study on how nitrogen content of forest floor layers affects carbon pathways and nitrogen mineralization of 15 different forest floors under Norway spruce with varying C-to-N ratios in respect to soil respiration, N mineralization and dissolved organic carbon (DOC) release under standardized laboratory conditions. Result obtained indicated that the release of DOC increases with increasing C-to-N ratio, while N-mineralization was not affected by C-to-N ratio and N content. This finding support the hypothesis that low C-to-N ratios in later stages of decomposition stabilize soil organic matter and that chronically high N deposition will lead to increased accumulation of C in forest floors.

Increasing atmospheric $CO_2$ concentrations and widespread deposition of N to terrestrial ecosystems has increased the focus on soil C and N pools. Vejre *et al*., (2003) estimated the size and distribution of organic C and N pools in well-drained Danish forest soils. Results obtained indicated high average total organic C and N contents. Large differences in total C and N among soil orders were recorded. It was observed that Spodosols had the greatest C content, and Alfisols have the least, while the N content was highest in Alfisols and least in Spodosols. Vejre (2003) concluded that the main contributor to the high C content in Spodosols is the spodic horizons containing illuvial humus, and thick organic horizons. Carbon and N concentrations decreased with soil depth. Soil clay content was negatively correlated to C content and positively correlated to N content. Soil order and horizon designations may be useful in predicting the total C and N content of Danish forest soils, and may also predict potential for C sequestration following afforestation of arable land.

Forests have a key role as carbon sinks, which could potentially mitigate the continuing increase in atmospheric carbon dioxide concentration and associated climate change. Carbon dioxide enrichment, although causing short-term growth stimulation in a range of European tree species, also leads to an increase in soil microbial respiration and a marked decline in sequestration of root-derived carbon in the soil (Thompson *et al*.,2005).

The extent to which plant communities are determined by resource availability is a central theme in ecosystem science, but patterns of small-scale variation in resource availability are poorly known. Studies of carbon and nutrient cycling provide insights into factors limiting tree growth and forest productivity. To investigate rates of tropical forest litter production and decomposition in relation to nutrient availability and topography in the absence of confounding large-scale variation in climate and altitude, Daisy *et al*., (2006) quantified nutrient fluxes via litter fall and leaf litter decomposition within three distinct floristic associations of tropical rain forest growing along a soil fertility gradient at the Sepilok Forest Reserve (SFR), Sabah, Malaysia. It was found that the quantity and nutrient content of small litter decreased along a gradient of soil nutrient availability from alluvial forest (most fertile) through sandstone forest to heath forest (least fertile). Temporal variation in litterfall was found to be greatest in the sandstone forest, where the amount of litter was correlated negatively with rainfall in the previous month. Mass loss and N and P release were fastest from alluvial forest litter, and slowest from heath forest litter. All litter types decomposed most rapidly in the alluvial forest. Stand-level N and P use efficiencies (ratios of litter dry mass to nutrient content) were found to be greatest for the heath forest followed by the sandstone ridge, sandstone valley and alluvial forests, respectively. According to Dent *et al*., 2006 they concluded that nutrient supply limits productivity most in the heath forest and least in the alluvial forest. Nutrient supply limited productivity in sandstone forest, especially on ridge and hill top sites where nutrient limitation may be exacerbated by reduced rates of litter decomposition during dry periods. The fluxes of N and P varied significantly between the different floristic communities at SFR and these differences may contribute to small-scale variation in species composition. Some of the major nutrients that support tree growth in the forest are: nitrogen, phosphorous, potassium, sulphur, calcium, magnesium, Nitrogen and organic carbon.

# CHAPTER THREE

# METHODOLOGY

## 3.1 Description of Study Area

The study area (Federal Forest Reserve) is a protected conservation area situated within Ilorin metropolis in Kwara State, North-Central Nigeria. It covers an area of about 53,291$m^2$ (5.3291ha) surrounded by an urban environment within the city as shown in Figure 3.1. The area is located in the Guinea Savanna Biome, which is defined by a tropical hinterland climate with two alternate wet and dry seasons in May – October and November – April, respectively. The length of the raining season is over 180days with an annual average of about 1000 to 1,500 *mm*. The raining season also exhibits bimodal peaks in the months of June and September. The temperatures are highest on average in March, while August is the coldest month, with temperatures averaging 30 to 35 °C (Animashaun, 2013).

The Reserve had been designated and conserved for over 35 years (Mohammed, 2016). It is being conserved and managed by the Kwara State office of the Federal Department of Forestry in the Federal Ministry of Environment. The area was fenced off to protect against cattle grazing which can disturb understory vegetation growth (Stormer and Valentine, 1981). Due to its strict protection status, which precludes fire, herbivory and other savanna-maintaining factors, the Reserve is largely dominated by dense tree species as well as other plant life forms such as shrubs and herbs. It also serves as a natural home for some animals and microbes co-inhabiting in micro-communities.

## 3.2 Study Design

The study was conducted using a cross-sectional experimental survey approach comprising desktop, field, herbarium, and laboratory investigations to draw inference about the tree community and soil within the study area. Pertinent literature was sourced from physical libraries and online indexing databases using keywords search. The literature was then reviewed based on the theoretical framework of the study as well as to contextualize the findings of the study.

## 3.3 Pre-Field Activities

Permission to access the study area was sought and received from the Controller of the Federal Department of Forestry in Ilorin, Kwara State. An application was written to the Federal Department of Forestry Ilorin Kwara State for permission to have access to the study area which was graciously granted. A pilot study was conducted in November 2017 for familiarisation and to evaluate the study area as well as to ascertain the most suitable methods of conducting the exercise.

## 3.4 Field Sampling Strategy

In examining the understory vegetation, four layers of design was used, which includes; Desktop, Field, Herbarium and Laboratory investigation. Study Materials used in this study were; GPS, Digital Compass, Diameter tape, Quadrant, Google Earth Pro, Field Book and Herbarium.

The total dimension of the study area was determined using Google Earth distance measurement approach. Basic Forestry techniques were used to sample trees and obtain some allometric measurements as described in subsection 3.7. Sample plot were also set up for soil and leaf litter. Other habitat characteristics like elevation and habitat conditions were also recorded using a hand held device Garmin (Rino 120) and a digital camera. (Yu and Gong, 2012; Google, 2017).

Two separate sampling techniques were employed one for tree sampling and another for sampling soil and litter. The Plotless Point Centre Quarter sampling (PCQ) technique was used for trees within the study area as described by Brower *et al., (*1998). The PCQ was laid along a random transect with relevant data obtained from trees encountered. A species area curve was used to determine sample size (that is, total number of PCQ to be sampled) based on data saturation. The study area was stratified into three regions A,B and C based on gradients and observed disturbance. The proximal region had considerable human activities such as a presence of a horticultural nursery and an office building. The middle region had intermediate disturbance while the inner region was relatively undisturbed. The locations sloped inwards with the proximal being the highest and the inner region the lowest points. Within each of these three strata six sampling sites were randomly selected where soil samples were collected at a depth of 15cm.

## 3.5 Taxonomic Survey

Tree species were identified *in-situ* using selected taxonomic manuals and flora (Arbonnier, 2004; Poorter *et al*., 2004; Hawthorne and Jongkind, 2006). Specimen of other unidentified tree species were collected using plant press and Photographs of whole trees to be identified were also obtained and taken for professional *ex-situ* identification and issuance of herbarium number by a qualified Taxonomist at the Plant Biology Herbarium in the University of Ilorin.

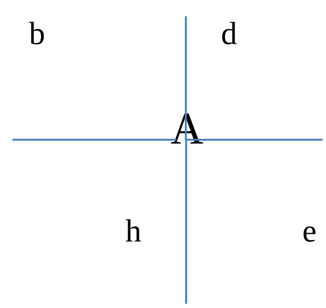
## 3.6 Tree Species Abundance and Diversity

### 3.6.1 Species Diversity, Richness and Evenness

The PCQ method was initially used to record the incidence or occurrence (richness) of each tree species in the study area. In order to measure biodiversity, Shannon-Weiner and Simpson's index of species were used to assess the species diversity of the trees. (Gimaret-Carpenter *et al*., 1998; Blanc *et al*., 2000; Parthasarathy., 2001; Addo-Fordjour *et al*., 2009). The indices were used to ascertain and compare if there were differences in diversity value.

3.6.1.1 Point Centered Quadrant Tree Sampling

The point-quarter technique is perhaps the most popular of the plotless sampling techniques. Each sample is taken at a random location in the area to be sampled. This is frequently done by choosing random points along a transect. The area near each random point (sample point) is divided into four imaginary quadrants as indicated below. Within each quadrant, the nearest tree is included in the field sample. There are four quadrants, so a total of four trees were measured at each sample point. In the diagram below, point A represents a random point (sample point) and the letters b through h represents trees. The trees b, d, e and h would be included as the four nearest trees within each quadrant that are nearest to A.




3.6.1.2 Shannon-Weiner index of Diversity

Shannon-Weiner index of diversity was employed because it takes cognizance of the species richness and proportion of each species in the sampled plot. It has been established that, the value of H’ obtained from empirical data usually falls between 1.5 and 3.5 and rarely surpasses 4 (Margalef, 1972; Magurran, 2004).

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

Where:

*H’*=Shannon diversity index

$P_i$=Proportion of individual in species i which can be estimated as $P_i = n_i / N_i$

$n_i$=Number of individuals in the community

Therefore, $P_i$ is the proportion of $i^{th}$species/abundance of species /total abundance of all species.

In$P_i$= Natural logarithm of $P_i$ to e

S is the number of species in the community

3.6.1.3 Shannon-Weiner Index of Species Evenness or Equitability

An index of evenness (j') can be derived from Shannon-Weiner Index. This index of evenness range from 0-1 and due to its meaningfulness for comparisons between communities rather than as a stand-alone measure it was employed. This index would reveal the extent that a community is dominated by only a few of its species (uneven) or has its entire species in similar numbers (even). It is defined by the equation:

$$J = H' / H'\ max$$

Where:

H'=Shannon-Weiner diversity index

H'max= In s

S=Number of Species in the community

3.6.1.4 Simpson's Index of Diversity

Simpson's index was also used to determine diversity since it takes account of number of species present as well as the relative abundance of each in the total sample. It weighs dominant species somewhat more than rare species in its measure of diversity than the Shannon-Weiner does. Simpson's index tends to differ less between samples and it ranges from 0 to ∞. Values are commonly a few points higher than calculations of the Shannon-Weiner index. (Brower *et al*., 1998).

Simpson's index is defined as:

$$D = \sum P_i^2$$

Where:

D=Simpson's Index

$P_i$=Proportion of $i^{th}$Species

### 3.6.2 Species Occurrence Density Important Value Index

This study adopted the technique described in Brower *et al*., *(*1998) Data obtained were quantitatively analyzed for Total density(*TD*), Relative density (*RD*), Frequency(*f*), Relative frequency (*Rf*), Coverage(*C*) Relative Coverage(*RC*) and the relative values were summed up to obtain Importance Value (IV) (Misra, 1968, Dallmier, 1992; Sabogal, 1992; Abdullahi, 2010). The formulae used to calculate *TD, RD, f, Rf, C, RC* and (*IV*) are as follows:

$$Total\ Density = \frac{4u(sum\ of\ all\ species\ counted - 1)}{\pi(sum\ of\ squares\ of\ total\ point\ to\ point\ distanc)^{\ \ 2}}$$

$$Relative\ Density\, \frac{total\ number\ of\ individual\ species\ counted}{total\ number\ of\ individual\ of\ all\ species\ counted}$$

$$Frequency = \frac{Number\ of\ sampling\ points}{Total\ number\ of\ points\ sampled}$$

$$Relative\ Frequency = \frac{Frequency\ of\ species}{Total\ of\ all\ frequencies}$$

$$Coverage = \frac{Sum\ of\ basal\ area * Density\ of\ species}{Total\ of\ all\ number\ of\ individual\ sampled\ of\ that\ species}$$

$$Relative\ Coverage\ \frac{Total\ coverage}{Total\ of\ all\ coverage}$$

$$Important\ Value\ = Relative\ density + Relative\ frequency + Relative\ coverage$$

## 3.7 Tree Allometry

### 3.7.1 Estimation of height

Tree height measurements were made by means of a digital clinometer (spirit level) and measuring tape. Elementary trigonometric relations were used to estimate height using the formula:

H= (d tan Ø) +Height of the Viewers Eye

Where d is the horizontal distance between the observer and the tree while Ø is the angle from the observer's eye to the top of the tree. The height of the viewer's height as added to the height to get the absolute height of the tree. This method is in conformity with Hemery (2011).

### 3.7.2 Diameter at breast height (DBH)

The DBH of each tree was obtained with the use of a diameter tape measured at a height of 1.4m

### 3.7.3 Tree volume

Since form factors were not known for the tree species, the volume (V) of the trees were calculated using the formula Husch *et al.* 2003.

$$V = \frac{\pi D^2 Hs}{4}$$

Where:

**$\pi$=**3.142

D= Diameter

H= Height

### 3.7.4 Basal area

The Basal Area (BA) was calculated using the formula:

$$BA=\pi\times r^2$$

Where:

$\pi$= 3.142

$r^2$= radius

### 3.7.5 Estimation of Above-ground Biomass for Trees (AGB)

The AGB was measured by calculating the Volume ($m^3$) per tree multiplied by density (kg per $m^3$) of each tree (Schongart, 2003).

### 3.7.6 Estimation of belowground biomass of trees (BGB)

The BGB was estimated as 26% of the AGB of each tree following (Cairns *et al.*, 1997) hence, the equation:

BGB= 0.26*ABG

Where

ABG =Above-ground biomass

BGB =Below-ground biomass

### 3.7.7 Calculation of Carbon Content for Trees

Since carbon concentration and specific wood density of tree species were not known (Yeboah, 2011), the constant factor of 0.47 proposed by Lewis *et al*., (2009) was used to convert total biomass to estimated carbon stock. Thus, the carbon content (C) for each tree species was calculated as:

$$C = 0.47 \times \text{Biomass}$$

### 3.7.8 Carbon Sequestration Potentials (CSP) for Trees

Thus, weight of Carbon sequestered in a tree was calculated by multiplying the Carbon content in a sample unit with 3.666. (Coto-millian *et al.*, 2008)

## 3.8 Laboratory investigation

Soil and litter samples were collected and transported to the laboratory for assessment. Analysis was carried out to determine Soil pH, Nitrogen, and Organic Carbon. Estimates of the dry-weight of the leaf litter sample were estimated.

### 3.8.1 Determination of soil pH

Soil pH is the measure of the acidity and alkalinity to measure it, 10g of 2mm sieved soil sample was weighed into a cup (extraction cup) and 10ml of distilled water was added. The cup mixture was sieved with a stirring rod for five minutes. An electrode of pH meter was put inside the agitated mixture and the pH was displayed on the digital read out of the meter.

### 3.8.2 Determination of Ca, Mg, K, Na

To determine the Calcium, Magnesium Potassium and Sodium, 2g of the 2mm sieved soil sample was weighed into an extraction cup and 20ml of Ammonium acetate was added, this was agitated using stirring rod or placed on a mechanical shaker for 10 minutes. The content was filtered using 9cm filter paper and the filtrate collected was read on Buck scientific atomic absorption Spectrophotometer model 210/211 VGP to determine Ca, Mg, K, and Na.

### 3.8.3 Determination of Mn, Fe, Cu, Zn

To determine the Manganese, Iron, Copper and Zinc, 2g of 2mm sieved soil was weighed into an extraction cup and 20ml of 0.01N HCl was added and was agitated on a mechanical stirrer for 10minutes and was filtered using 9cm filter paper. The filtrate collected was read on the Buck scientific atomic absorption Spectrophotometer model 210/211 VGP to determine Mn, Fe, Cu, and Zn.

### 3.8.4 Determination of Nitrogen in Soil

To measure the quantity of N in the soil sample, 0.5g of the 0.5mm sieved soil was weighed into a digestion tube, a selenium tablet and 5ml of concentrated $H_2SO_4$ was added to the content. This was placed on a digestion block for hours between 50$^{o}$C and 350$^{o}$C until it becomes colourless. The digest was made upto 50ml with distilled water and 5ml of it was distilled with Sodium hydroxide (5ml) and 5ml of boric acid indication. A colour change of greenish was observed and the distillate was collected at 50ml mark and thus filtrated with 0.01N Hcl and there was a change in colour from green to pink (end point colour) then the titration value was observed.

### 3.8.5 Determination of Nitrogen in Litter sample

The litter samples were oven dried and milled to powder form. 0.2g of the milled sample was weighed into a digestion tube and 5ml of concentrated $H_2SO_4$ and One tablet of selerium (catalyst) was added, the tube content was placed on digestion block at a regulated temperature from 50$^{o}$c to 200$^{o}$c for about two hours under a fume cupboard. The digest turns colourless and was allowed to cool and made up to 50ml with distilled water. 5ml of the 50ml digest was distilled with 5ml of Sodium Hydroxide solution and 5ml of boric acid indicator and there was change in colour to green. The content was then titrated with 0.01N HCl and pinkish colour was obtained as an end point and the measurements were taken.

### 3.8.6 Determination of organic carbon in both soil and litter

Soil organic Carbon (SOC) is the amount of carbon stored in the soil which is a component of the Soil organic matter to determine the quantity, 0.5g of the 0.5mm sieved soil or 0.1g of the litter was weighed into a conical flask (250ml) and 1.0ml of Potassium dichromate and 20ml of concentrated $H_2SO_4$ was added. This was allowed to cool and was made upto 100ml mark with distilled water. 1 or 2 drops of ferione indicator was added and this was titrated with ferrous sulphate. There was a change in colour from pinkish to maroon brown which indicated end point.

## 3.9 Data Analysis

SPSS v.23 was utilized in analyzing all data obtained from the study. Given the small size of each data set, they were subjected to Shapiro-Wilk's test of normality. Appropriate parametric or non-parametric descriptive statistics (i.e. mean or median and standard deviation, standard error of the mean, 95% confidence interval or interquartile range) and graphical illustrations were used to summarize the data.

Inferential statistics were then applied based on the data meeting the parametric criteria or not, as determined by the Shapiro-Wilk's test. The critical significance (α) level was set at 0.05 with a decision rule to reject null hypothesis ($H_0$) if $p < \alpha$. $H_0$ was not rejected in cases where $p \geq \alpha$.

# CHAPTER FOUR

# RESULTS

## 4.1 Occurrence of Tree Species

A total of eight species belonging to eight families and eight genera were observed in the study area (Table 4.1). The table also shows that all families are equally represented by one species each. Similarly, no genera were represented by multiple species. Four of the species observed in the study were found to be exotic (i.e species of plant that are growing in a non-native environment) while the remaining four were found to be native species. However, the International Union Conservation of Nature(IUCN) conservation status of *Vitellaria paradoxa* was found to be threatened, while no record was found about the conservation status of others.

## 4.2 Abundance of tree species

*Gmelina arborea* was found to be the most abundant species within the study area (PCQ quadrant) with 31 individuals closely followed by *Ficus exasperata* with 7 individual species while the least in abundance are *Cocos nucifera*, *Vitellaria paradoxa* and *Carica papaya*. *Gmelina arborea* that occurred in almost all the sampled units had the highest representation (Table 4.2) and is followed by *Azadirachta indica* with in the entire sample unit. However, the least abundant are *Ficus exasperata* and *Carica papaya* showed the least abundance as obtained from the study.

**Table 4-1: List of tree species occurring in the Federal Forest Reserve, Ilorin**

| Scientific name | Local name (Yoruba) | Common name (English) | Family | Origin | IUCN conservation status |
|---|---|---|---|---|---|
| *Gmelina arborea* Roxb. | Igi melina | Gmelina | Lamiaceae | Exotic | NR |
| *Azadirachta indica* A | Eke oyinbo | Neem | Meliaceae | Exotic | NR |
| *Cocos nucifera* L. | IgiAgbon | Coconut tree | Arecaceae | Native | NR |
| *Albizia lebbeck* Benth | Igbagbo | Silk tree | Fabaceae | Exotic | NR |
| *Mangifera indica* L. | Igimangoro | Mango | Anacardiaceae | Native | NR |
| *Vitellaria paradoxa* G | Igi Emi | Shea butter | Sapotaceae | Exotic | Threatened |
| *Ficus exasperata* Vahl | Igi ipin | Sandpaper Tree | Moraceae | Native | NR |
| *Carica papaya* L | IgiIbepe | Pawpaw | Caricaceae | Native | NR |

NR: No Record

**Table 4-2: Abundance of trees species from PCQ sampling**

| Species | *n* | *RD* | *D* | *j* | *f* | *Rf* | *C* | *RC* | *IV* | *N* |
|---|---|---|---|---|---|---|---|---|---|---|
| *Gmelina arborea* Roxb. | 31 | 0.52 | 262.54 | 14 | 0.93 | 0.37 | 0.07 | 0.10 | 0.98 | 1399.09 |
| *Azadirachta indica* | 7 | 0.12 | 59.28 | 6 | 0.40 | 0.16 | 0.07 | 0.09 | 0.36 | 315.92 |
| *Cocos nucifera* | 5 | 0.08 | 42.34 | 4 | 0.27 | 0.11 | 0.11 | 0.15 | 0.34 | 225.66 |
| *Albizia lebbeck* | 5 | 0.08 | 42.34 | 5 | 0.33 | 0.13 | 0.19 | 0.26 | 0.47 | 225.66 |
| *Mangifera indica* Linn. | 4 | 0.07 | 33.88 | 2 | 0.13 | 0.05 | 0.07 | 0.10 | 0.22 | 180.53 |
| *Vitellaria paradoxa* | 4 | 0.07 | 33.88 | 3 | 0.20 | 0.08 | 0.16 | 0.22 | 0.37 | 180.53 |
| *Ficus exasperata* Vahl | 3 | 0.05 | 25.41 | 3 | 0.20 | 0.08 | 0.04 | 0.05 | 0.18 | 135.40 |
| *Carica papaya* Linn | 1 | 0.02 | 8.47 | 1 | 0.07 | 0.03 | 0.02 | 0.03 | 0.08 | 45.13 |
| **Total** | **60** | **1.00** | **508.14** | | **2.53** | **1.00** | **0.74** | **1.00** | | **2707.91** |

**Key:**

*n* = PCQ sample size

*RD* = Relative density

*D* = Density

*j* = No of points with species

*f* = Frequency

*Rf* = Relative Frequency

*a* = Area covered from all Quadrants

*C* = Coverage

*RC* =Relative Coverage

*IV* = Importance Value

*N* = Number of individual

## 4.3 Diversity Indices

### 4.3.1 Shannon-Weiner index of diversity

The trees species found in the study are eight. From the table below, the proportion Pi was obtained for individual trees while H measure ($P_i InP_i$). However, Shannon-Weiner H is given as:

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

and therefore obtained as -1.58509 = (1.58509) as shown in Table 4.3. For Shannon-Weiner index of evenness which is J'=(H/InS) = 0.762267

### 4.3.2 Simpson's index of Diversity

This diversity index is similar to Shannon-Weiner index, it used to measure diversity of trees within vegetations. Simpson's index measured as:

$$D' = \sum_{i=1}^{s} Pi^2$$

and is obtained as D=3.266810 for the trees. The component that yield the Simpson's index for the trees within the vegetation are shown in Table 4.4.

**Table 4-3:Shannon-Weiner Index of tree diversity in Federal Forest Reserve, Ilorin**

| Species | No of individuals | $P_i$ | $InP_i$ | $P_iInP_i$ |
|---|---|---|---|---|
| *Gmelina arborea* | 31 | 0.516667 | -0.66036 | -0.34118 |
| *Azadirachta indica* | 7 | 0.116667 | -2.14843 | -0.25065 |
| *Albizia lebbeck* | 5 | 0.083333 | -2.48491 | -0.20708 |
| *Cocos nucifera* | 5 | 0.083333 | -2.48491 | -0.20708 |
| *Ficus exasperata* | 4 | 0.066667 | -2.70805 | -0.18054 |
| *Mangifera indica* | 4 | 0.066667 | -2.70805 | -0.18054 |
| *Vitellaria paradoxa* | 3 | 0.05 | -2.99573 | -0.14979 |
| *Carica papaya* | 1 | 0.016667 | -4.09434 | -0.06824 |
| | | | | -1.58509 |

**Table 4-4: Simpson's Index of tree diversity in Federal Forest Reserve, Ilorin**

| Scientific name | $P_i$ | $P_i^2$ |
|---|---|---|
| *Gmelina arborea* Roxb. | 0.516667 | 0.266944 |
| *Azadirachta indica* | 0.116667 | 0.013611 |
| *Cocos nucifera* | 0.083333 | 0.006944 |
| *Albizia lebbeck* | 0.083333 | 0.006944 |
| *Mangifera indica* Linn. | 0.066667 | 0.004444 |
| *Vitellaria paradoxa* | 0.066667 | 0.004444 |
| *Ficus exasperata* Vahl | 0.05 | 0.0025 |
| *Carica papaya* Linn | 0.016667 | 0.000278 |
| | | 0.306109 |

Since Simpson's Index $D' = \frac{1}{D}$; and $D = \sum P_i^2$

Therefore, $D' = \frac{1}{0.306109} = 3.266810$

## 4.4 Allometric properties of trees

### 4.4.1 Height of the tree

Based on allometric properties measured from the study area, the mean ± SE height of the tree species are outlined in figure 4.2. Among the trees measured *Azadirachta indica* was found to be the tallest trees within the area with an estimated mean height of about 27.10m±26.2m. The tree with the lowest average height was *Carica papaya* with an average height of 4.47m according to the measurements within the study area. In between these two, the other tree species exhibited the following order of average height of the trees: *C. nucifera> F. exasperata> V. paradoxa. > G. arborea> A. lebbeck>M. indica.*

### 4.4.2 Diameter at breast height (DBH)

Based on allometric properties measured from the study area, the mean ± SE DBH of the trees within the study area are outlined in figure 4.3. Among the trees measured *Cocos nucifera* had the widest DBH with an average width of about 0.49m±0. 31m.The tree with the lowest average DBH is *Carica papaya* with an average estimate height of 0.18m according to the measurements within the study area. In between these two, the other tree species exhibited the following order of average height of the trees: *A. indica> A. lebbeck> F. exasperata> G. arborea>A. indica> V. paradoxa*.

### 4.4.3 Above-ground biomass of tree species

Based on allometric properties measured from the study area, the mean ± SE AGB of the tree are outlined in figure 4.4. Among the trees measured, *Azadirachta indica* had the highest gross biomass within the area with an estimated weight of about 2709.73kg±3242.68kg. The tree with the lowest gross weight average is *Carica papaya* with an average estimate gross weight of 79.01kg according to the measurements within the study area. In between these two, the other tree species exhibited the following order of gross biomass magnitude: *C. nucifera> F. exasperata> M. indica> G. arborea> A. lebbeck> V. paradoxa.* While the allometric measurements on the dry weight of the trees within the study area as outlined in figure 4.4 showed that, *Azadirachta indica* has the highest dry biomass within the area with an estimated weight of about 1964.56kg ± 2350.94kg. The tree with the lowest dry weight average is *Carica papaya* with an average estimate dry weight of 57.28kg according to the measurements within the study area. In between these two, the other tree species exhibited the following order of dry weight biomass magnitude: *C. nucifera> F. exasperata> M. indica> G. arborea> A. lebbeck> V. paradoxa*.

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### 4.4.4 Below-ground Biomass

Based on allometric properties measured from the study area and the calculation of belowground biomass as outlined in figure 4.5, *Azadirachta indica* had the highest biomass below ground within the area with an estimated weight of about 704.53kg±911. 60kg.The tree with the least biomass average is *Carica papaya* with an average estimate gross weight of 30.70kg according to the measurements within the study area. In between these two, the other tree species exhibited the following order of gross biomass magnitude: *C. nucifera*> *F. exasperata*> *M. indica*> *G. arborea*> *A. lebbeck*> *V. paradoxa.* While the allometric measurements on the dry weight of the trees within the study area

### 4.4.5 Total biomass

Based on allometric properties measured and calculation of AGB and BGB as shown in figure 4.6, the total biomass of the area based on the species sampled had *Gmelina arborea* highest biomass with about 1003321.66kg while the lowest is *Carica papaya* with a biomass of 2616.00kg.

## 4.5 Carbon content of the species

Based on allometric properties measured from the study area, the mean ± SE carbon content of the trees species are outlined in figure 4.8. Within the study area is estimated at about 29424.37kg while the average carbon by the tree is estimated at 490.41kg. Among the trees measured *Azadirachta indica* had the highest average carbon within the area with an estimated carbon of about 1237.67kg±838.28kg. The tree with the lowest average carbon is *Carica papaya* with an average carbon estimate of 36.08845kg according to the measurements within the study area.

## 4.6 Carbon Sequestration potentials

Based on allometric properties measured from the study area, the total carbon sequestration potentials of the trees within the study area as shown in figure 4.9 is estimated at about 107869.75tonne/ha while the average carbon sequestered by the tree is estimated at 1797.83ton/ha. Among the trees measured *Azadirachta indica* had the highest average carbon sequestered within the area with an estimated carbon of about 4537.30tonne/ha±5429.70tonne/ha. The tree with the lowest average carbon is *Carica papaya* with an average carbon sequestration potential estimate of 105.00 tonne/ha according to the measurements within the study area.

## 4.7 Physicochemical properties of soil

The results of the soil analysis showed that the percentage of sandy soil (90.9%) was found to be the highest, with the silt (7.4%) and clay soil (1.7%) obtained in a smaller quantity

The average compositions of organic carbon and nitrogen found in the soil sample were 1.9% and 0.2% respectively. The average compositions of soil nutrients found in the sampled soil are calcium (8.44Cmol/kg), mangnesium (3.31Cmol/kg), potassium (1.32Cmol/kg), sodium (1.16Cmol/kg), manganese (39.56Cmol/kg) and cupper (1.00Cmol/kg). Others are zinc and iron found in high concentrations with an average of 100.35mg/kg and 2.95mg/kg respectively.

### 4.7.1 Parametric parameters

Findings from one-way ANOVA and LSD post-hoc analysis as outlined in Table 4.5 revealed that there's is no significant difference in all the parameters examined except Ca and Fe. The soil pH of the forest was found to decrease with increasing gradient. Thus, proximal region was found to have the highest soil pH followed by intermediate and lastly, the inner region. The intermediate region was found to have the highest soil acidity followed by the inner region and lastly, the proximal region. Highest concentration of K was found in the proximal region and inner regions with intermediate having the least concentration. Mn concentration was found to decrease with increasing sloppiness from proximal to inner regions. Cu concentration was higher in the inner and proximal regions, with intermediate region having the least concentration. Significant difference was found in Ca and Fe. Based on LSD post-hoc analysis, it was discovered that there was significant difference between (intermediate and proximal) and there was significant difference between (intermediate and inner) regions in Ca concentration. Similarly, in Fe concentration there was significant difference between proximal and intermediate regions.

**Table 4-5: Concentrations (Mean ± 95% CI) of physicochemical parameters in the three regions of FFR**

| Parameters | Regions | | |
|---|---|---|---|
| | Proximal | Intermediate | Inner |
| Ph | 7.28 ± 0.10 [a] | 7.27 ± 0.09 [a] | 7.20 ± 0.16 [a] |
| Acidity (mol/kg) | 0.53 ± 0.30 [a] | 0.82 ± 0.28 [a] | 0.56 ± 0.16 [a] |
| Ca (mol/kg) | 6.89 ± 0.35 [a] | 11.33 ± 2.96 [b, c] | 7.11 ± 4.47 [a, d] |
| K (mol/kg) | 1.48 ± 0.38 [a] | 1.31 ± 0.16 [a] | 1.37 ± 0.24 [a] |
| Mn (mol/kg) | 45.75 ± 4.44 [a] | 38.30 ± 9.85 [a] | 34.63 ± 20.38 [a] |
| Cu (mol/kg) | 1.04 ± 0.40 [a] | 0.90 ± 0.25 [a] | 1.06 ± 0.65 [a] |
| Fe (mg/kg) | 91.63 ± 10.5 [a] | 108.17 ± 11.0 [b] | 101.25 ± 13.07 [a, b] |

Values with different superscripts in each row are significantly different at $p < 0.05$ (one-way ANOVA and LSD post-hoc)

### 4.7.2 Non-Parametric parameters

One-way Kruskal-Wallis ANOVA as outlined in Table 4.6 indicated that there was significant difference in all the parameters examined except for Zn where there was no significant difference observed. The intermediate region was found to have the highest concentration of P followed by inner region with the least being the proximal region. The concentration of TN decreases with increasing gradient from proximal down to inner regions. Proximal region was found to contain the least concentration of OC with inner region having the highest followed by the immediate region. Clay had higher concentration in intermediate, inner and proximal accordingly. The concentration of silt in the study area increases with increasing sloppiness. Thus, proximal region has the least concentration of silt while inner region has the highest concentration. On the contrary, the concentration of sand decreases with increasing sloppiness with proximal region having the highest concentration and inner region having the lowest concentration of sand. Intermediate region had the highest concentration of Mg followed by inner region with proximal region having the least concentration. There was no significant difference in concentration of zinc across the three regions of the study area.

**Table 4-6: Concentrations (Median, IQR) of physicochemical parameters in the three regions of FFR**

| Parameters | Regions | | |
|---|---|---|---|
| | Proximal | Intermediate | Inner |
| P (Mg/kg) | 9.78, 17.80 | 64.42, 2069 | 11.82, 35.98 |
| TN | 0.73, 0.48 | 0.28, 0.30 | 0.27, 0.34 |
| OC | 0.88, 0.98 | 2.27, 0.72 | 2.52, 4.4 |
| Clay | 1.0, 0.3 | 2.2, 0.8 | 1.5, 1.6 |
| Silt | 3.7, 1.7 | 3.9, 1.1 | 13.4,17.2 |
| Sand | 95.1, 1.5 | 93.7, 1.8 | 85.3, 15.7 |
| Mg (Mol/kg) | 1.53, 0.43 | 3.84, 2.61 | 3.79, 2.97 |
| Zn (Mg/kg) | 2.48, 2.23 | 1.71, 0.92 | 4.83, 5.41 |

$p < 0.05$ (one-way Kruskal-Wallis ANOVA)

# CHAPTER FIVE

# DISCUSSION, CONCLUSION AND RECOMMENDATION

## 5.1 Discussion

Tropical humid conditions favor the existence of forests. Hence, tracts of savanna ecosystems have the potential of developing into forests in the absence of disturbances such as herbivory, fire and anthropogenic activities (Dantas *et al*., 2016; Ondei *et al*., 2017). The finding of this study is consistent with this assertion having revealed that the study area is a repository to many deciduous species native to the savanna ecosystem. The estimated tree density of 508 stems $ha^{-1}$ is consistent with similar seasonal forests (Baithalu *et al*., 2013) and even higher than the 387 stems $ha^{-1}$ reported for Akure Forest Reserve, a strict nature reserve within the tropical rainforest (Adekunle *et al*., 2013). However, higher densities can be encountered in mangrove forests as evident in the 104 to 1,268 stems $ha^{-1}$ range reported by Sommeechai *et al*. (2018).

A key principle in designating a protected area is the potential of being a biodiversity hotspot that can be a reserve comprising representatives of as many species of its surrounding ecosystem as possible (Hunter and Gibbs, 2007). However, the eight tree species encountered do not provide a full account of expected tree species as a number of native species such as *Parkia biglobosa* that have been reported for proximal areas (Raji and Babalola, 2018) were absent.

The diversity of tree species within the study area (Shannon-Weiner, H = 1.58509) is higher than the mean of 1.19, but within the range of 0.30 – 2.11 reported by Nansen *et al*. (2001) for a dry forest reserve in Southern Benin. However, it appears lower than the value of 4.51 obtained by Sahu *et al*. (2007) for a tropical deciduous forest in India. An exotic species, *Gmelina arborea*, exhibited the highest dominance representing 51.6% of the trees in agreement with the report of Onyekwelu and Fuwape (1998) about Oluwa Forest Reserve. This may be related to the extensive establishment of plantations of this fast-growing species across the Nigerian savanna and rainforest ecoregions over three decades ago for the supply of pulpwood to pulp and paper mills (Adegbehin *et al*., 1988). The second most dominant tree species (*Azadirachta indica*) is also exotic and has been identified as an invasive species in the Nigerian National Biodiversity Strategy and Action plan (FGN, 2006). This also brings to the question, the reserve's true representativeness of the native vegetation, with exotic species accounting for 50% of the tree species encountered and also exhibiting a relatively higher dominance. The native species were observed to be disadvantaged in the study area which can make the reserve to be degraded, decrease in carbon capture and carbon sequestration. Rarity (species represented by ≤ 2 stems ha-1) was recorded for the native species, *Carica papaya*. Another native species, *Vitellaria paradoxa* is classified as a vulnerable species in the Red Data Book of the International Union for the Conservation of Nature (Makerere University Institute of Environment and Natural Resources, 1998). This may be due to the pressure on *V. paradoxa* in Kwara State as source of timber and energy (AbdulRahaman *et al.,* 2016).

The measurements of height and diameter at breast height of trees in Federal Forest Reserve Ilorin, were in conformity with a similar study conducted by Shamaki *et al*. (2016) in Nimbia Forest Reserve of Kaduna State within the Guinea Savanna ecoregion as well as the account of Aigbe and Omokhua (2015) in Oban Forest Reserve. The above-ground biomass of 29.42 tonnes ha$^{-1}$ in the study area is relatively lower than that reported by Timilsina *et al*. (2014) in a sub-tropical urban forest. The tree carbon sequestration potential of 1.8 tons C $ha^{-1}$ is similarly lower than that reported by Timilsina *et al*. (2014). This may be due to the presence of non-woody species such as *Cocos nucifera* and *Carica papaya* in the study area.

Physical property of a soil plays an important role in soil fertility because the amount and sizes of soil particles determine the porosity and bulk density which account for nutrients retention or leaching of nutrients (Brady *et al*, 2008). The physical properties of soil in the study area revealed that sand had the highest percentage (90%) composition followed by clay particle with 7.4%. The high water holding capacity of clay makes it more stable (1.7%) than other particles. It is that high stability that enables it to hold nutrient cations for nutrient exchange in the soil for plant uptake. It implies that the higher the clay content of a soil, the higher the cation exchange capacity and the higher the fertility of the soil. These findings are consistent with the result obtained by Peichl *et al*. (2012) on soil water and nutrient retention.

Soil nitrogen for the study area is 0.21%. This figure is in line with the 0.22% result obtained by Olabode (1997) for soil analysis conducted in Oluwa forest reserve, Ondo. The reason for this similarity is that both analyses were conducted in natural forest reserves. Nitrogen accounts for up to 3% of all plant compounds. The key to reducing nitrogen growing costs is to reduce nitrogen losses. The present nitrogen recommendations in most growing situations are based upon experience and are usually in excess of specific plant requirements. Nitrogen losses come about by reduced aeration and higher compaction in soil. Nitrates can be lost by being converted to gaseous nitrogen by anaerobic soil microorganisms in soils. The losses from gasification will be more on heavy soils than on light-textured soils. Leaching losses of nitrogen will be higher on light soils. Excess amounts of nitrogen can destroy soil humus and tilt. When excessive nitrogen is present in the soil, microorganisms will multiply by attacking the carbonaceous humus that is more accessible than randomly distributed crop residue. By breaking down humus for their carbon needs, soil microbes can deplete the humus reserve in soil.

Laboratory result showed that the average amount of phosphorous in the soil sample which is 7.25 mg/kg of soil supported the result (7.52mg/kg) obtained by Oriola *et al.* (2010) for a similar analysis conducted in Ilorin East Local Government Area of Kwara State. Most synthetic phosphate fertilizers, when added to the soil, undergo a degree of phosphate fixation with other soil elements. The degree of fixation depends upon the chemical nature of the soil. High sodium levels reduce phosphorus availability. Bioorganic phosphates are chelated in organic complexes and designed to favour microbiological activity that converts phosphorus to a more available form for crop use, thereby, preventing losses by fixation.

Plants contain an average of about 3% potassium as a part of plant tissue. Potassium is essential in the translocation of vital sugars in plant structures, strengthening plant stalks. Conventional fertilizers such as muriate of potash or potassium chloride are salts and contain chloride just as table salt (sodium chloride) does. Plants use potassium as the element $K^+$ ion and its availability depends upon its position within the soil and relationship to clay, humus and soil water. A clay particle is a strong magnet in comparison to sand, silt and humus. Clay soils hold potassium very tightly and resist leaching. This characteristic makes it more difficult to recover potassium from clay soils. Soil aeration and healthy, balanced aerobic microbial activity are essential for making potassium available to plant. Soil of the area in this study had 1.31 Cmol/kg potassium. This value falls within the range (0.26 – 1.53Cmol $kg^{-1}$) concentration range obtained by Ajiboye *et al.* (2015) for a similar research work conducted in Abeokuta.

Soil calcium level in the study area is 8.44 Cmol/kg. Calcium is often called the prince of nutrients because the soil colloid has to have a great saturation of calcium for plant uptake. It accounts for about 2% of plant tissue. Calcium is used to make calcium pectate, a sturdy building material component of cell walls. Calcium deficiency causes stunted roots and stress symptoms in new leaves and discoloration and distortion of plant growth. It may be the single most important soil and plant element. However, Eli and Agusomu (2015) reported a significant negative correlation between calcium and gum yield in soil of the northern guinea savanna of Nigeria. The concentration of calcium obtained is not consistent with 3.68Cmol/kg obtained by Eli and Agusomu (2015) for a similar study carried out in Otuoke. This inconsistency of result is due to the fact that Eli and Agusomu conducted their study where there were constant human activities such as farming and construction activities as well as possible climatic change.

Result indicated that the average percentage of organic carbon content of the sampled soil in the study area is 1.99. Soil organic carbon is directly related to soil fertility. This implies that the more the organic carbon contents of a soil, the more the nitrogen content of the soil, and the more fertile the soil will be. Plant growth, vigour and yield are dependent upon the availability of a number of essential nutrients.

## 5.2 Conclusion

The study of biomass and carbon sequestration of woody vegetation within Federal Forest Reserve, Ilorin concludes that the forest reserve has diverse tree species loosely distributed by their respective distance and therefore occur at widely spaced intervals. The study area is also found to be rich in various tree species. It is concluded that *Gmelina arborea* had the highest species occurrence making it the most ecologically important tree. *Azadrachta indica* was found to have the highest dry and moist biomass, carbon content and carbon sequestration potentials based on allometric properties measured among the tree species identified in the study area.

Furthermore, soil analysis conducted confirmed that the forest reserve is rich in soil mineral nutrients, this could be attributed to the high humus content from the decayed leaves and dead trees. Additionally, Manganese as an essential element in plant mineral nutrient, plays a key role in several physiological processes was found to be the highest mineral nutrient contained in the soil while calcium that plays a very important role in plant growth, nutrition, cell wall deposition, maintaining chemical balance in the soil, reduction of soil salinity and water penetration improvement was found to be on the high side, supporting the growth of trees in the forest reserve.

The study area was found to provide nutrient and habitat to organisms living in the soil; it also binds soil particles into aggregates and improves water holding capacity. This is however due to richness of the soil in organic carbon as obtained from the soil laboratory analysis. The high soil nitrogen content present in the forest reserve supports the development of proteins building block, nucleic acids and other cellular constituents which are essential for all forms of life revealed that the soil and therefore, healthy growth of trees.

## 5.3 Recommendation

To maintain ecological integrity and maintain natural vegetation, anthropogenic activities such as logging, grazing and encroachment should be prevented in government restricted areas. There is need for reforestation with native species in the Reserve and the planting of *V. Paradoxa* for preservation and conservation of the species as it was found to be going into extinction.

This research as baseline study has opened up for further research, hence the following is recommended on the identified species which are growth and age of the species.

Future researchers should also employ other models and methods of determining allometric properties, carbon sequestration, above and below ground biomass of trees in the forest reserve for the purpose of comparison.

## References

Abdullahi, M.B (2010). Phytosociological Studies and Community Rural Apppraisal Towards Biodiversity Conservation in Yankari Game Reserve, Bauchi State, Nigeria. An unpublished Ph.D Thesis. Abubakar Tafawa Balewa University, Bauchi, Nigeria, pp 99.

AbdulRahaman, A. A., Oladele, F. A., & Babalola, A. O. (2016). Conservation status of *Vitellaria paradoxa, Parkia biglobosa* and *Daniellia oliveri* in Ilorin Environ Kwara State Nigeria. *International Journal of Applied Sciences*, 1, 29-32.

Addo-Fordjour, P., Obeng, S., Anning, A. K., & Addo, M. G. (2009). Floristic composition, structure and natural regeneration in a moist semi-deciduous forest following anthropogenic disturbances and plant invasion. *International journal of biodiversity and conservation*, *1*(2), 021-037.

Adegbehin, J. O., Abayomi, J. O. And Nwaigbo, L. C. (1988). Gmelina Arborea in Nigeria. *The Commonwealth Forestry Review*, 67(2): 159-166.

Aigbe, H. I., & Omokhua, G. E. (2015). Tree species composition and diversity in Oban Forest Reserve, Nigeria. *Journal of agricultural Studies*, *3*(1), 10-24.

Ajiboye, A. G., Azeez, J. O., and Omotunde, A. J. (2015). Potassium forms and quantity–intensity relationships in some wetland soils of Abeokuta, Southwestern Nigeria. *Archives of Agronomy and Soil Science*, *61*(10), 1393-1408.

Ana C.G., (2018). Stand Structure Alterations in Forest Stands. Department of Rural Engineering, School of Science and Technology, Institute of Agrarian and Mediterranean Environmental Sciences (ICAAM), Institute of Advanced Research and Training, University of Évora, Portugal Review article. JOJ Hortic Arboric.

Appenzeller, T. (2000), ‘Plying a fabled waterway’, U.S. News Online, Available at: http://www.usnews.com/usnews/issue/000828/passage.html, (Date accessed: 24 April 2016).

Arbonnier, M.(2004). Trees, shrubs and lianas of west Africa dry zones CIRAD *Paris France.*

Azar, C., Holdaway, J. R., McNeill, S. J. (2006), ‘Carbon Capture and Storage from Fossil Fuels and Biomass – Costs and Potential Role in Stabilizing the Atmosphere’, Climatic Change, 74(1–3): 47–79.

Baccini, A., Laporte, N., Goetz, S. J., Sun, M., and Dong, H. (2008). A first map of tropical Africa’s above-ground biomass derived from satellite imagery. *Environmental Research Letters, 3*(4), 045011.

Baithalu, S., Anbarashan, M., & Parthasarathy, N. (2013). Two decadal changes in forest structure and tree diversity in a tropical dry evergreen forest on the Coromandel Coast of India. *Tropical Ecology,* 54(3), 395-401.

Barnhill, D. L., Sahotra, S., & Kalof, L. (2006). Deep ecology. *Berkshire Encyclopedia of Sustainability*, 132-35.

Barrantes, G., and Sandoval, L. (2009). Conceptual and statistical problems associated with the use of diversity indices in ecology. *Revista de biología tropical*.

Basiri, R. S., Tabatabaee, A., and Bina, H. (2011). Statistical Analysis of Spatial Distribution Pattern for Five Tree Species in Kurdestan Region.*World J. Sci. Tech*, *1*(50), 36-42.

Basuki, T. M., Van Laake, P. E., Skidmore, A. K., and Hussin, Y. A. (2009). Allometric equations for estimating the above-ground biomass in tropical lowland Dipterocarp forests. *Forest ecology and management*, *257*(8), 1684-1694.

BBC News., 2000. North Pole ice ‘turns to water’. BBC News Online. Available at: News.bbc.co.uk/english/world/americas/newsid _888000/888235.stm.

Bhatta, S. P. (2016). *Carbon Stock and Regeneration Status of Community Managed Sal (Shorea robusta Gaertn.) Forests in Dadeldhura District, Western Nepal* (Doctoral dissertation, Central Department of Botany Institute of Science and Technology Tribhuvan University Kirtipur, Kathmandu, Nepal).

Blanco, J. A., and Lo, Y. H. (2012). *Forest Ecosystems-More than Just Trees*.

Brady, N.C., & R.R. (2008). *The nature and properties of soil.* (Vol. 360). Upper saddle River: Pearson Prentice Hall.

Briggs, S.V., 1977. Estimates of biomass in a temperate mangrove community. Aust. J. Ecol. 2, 369–373.

Brower, J.E., Zar J.H., von Ende, C.N. (1998) *Field and Laboratory Methods for General Ecology* 4th Ed., WCB/Mcgraw-Hill. ISBN-13: 978-0-697-24358-4.

Brown, S. (1997). *Estimating biomass and biomass change of tropical forests: a primer* (Vol. 134). Food & Agriculture Org.

Cairns, M. A., Brown, S., Helmer, E. H., and Baumgardner, G. A. (1997). Root biomass allocation in the world's upland forests. *Oecologia*, *111*(1), 1-11.

Cermeño, P., Rodríguez-Ramos, T., Dornelas, M., Figueiras, F. G., Marañón, E., Teixeira, I. G., and Vallina, S. M. (2013). Species richness in marine phytoplankton communities is not correlated to ecosystem productivity. *Marine Ecology Progress Series*, *488*, 1-9.

Charles, R. B. & Richard J. C. (2016). Uncertainty in the modern era. Open textbook for Hong Kong project. Hong Kong Open University.

Chave, J., Condit, R., Lao, S., Caspersen, J. P., Foster, R. B., and Hubbell, S. P. (2003). Spatial and temporal variation of biomass in a tropical forest: results from a large census plot in Panama. *Journal of ecology*, *91*(2), 240-252.

Christensen, M., Heilmann-Clausen, J., Walleyn, R., and Adamcik, S. (2004) Wood-inhabiting Fungi as Indicators of Nature Value in.

Clark, D. A., Brown, S., Kicklighter, D. W., Chambers, J. Q., Thomlinson, J. R., and Ni, J. (2001). Measuring net primary production in forests: concepts and field methods.*Ecological applications*, *11*(2), 356-370.

Coto-Millán, P., Doménech Quesada, J. L., & Mateo Mantecón, I. (2008). Corporate ecological footprint: new conversion factors. *International Journal of Ecology*, 2008.

Dallmeier, F. (Ed.). (1992). Long-term monitoring of biological diversity in Tropical Digest 11. UNESCO, Paris.

Dantas, V. D. L., Hirota, M., Oliveira, R. S., & Pausas, J. G. (2016). Disturbance maintains alternative biome states. *Ecology Letters*, 19(1), 12-19.

DeFries, R. S., Rudel, T., Uriarte, M., & Hansen, M. (2010). Deforestation driven by urban population growth and agricultural trade in the twenty-first century. *Nature Geoscience*, 3(3), 178–181.

Dent, D. H., Bagchi, R., Robinson, D., Majalap-Lee, N., and Burslem, D. F. (2006). Nutrient fluxes via litterfall and leaf litter decomposition vary across a gradient of soil nutrient supply in a lowland tropical rain forest. *Plant and Soil*, *288*(1-2), 197-215.

Devagiri, G. M., Money, S., Sarnamsingh, V. K., Dadhawal, P. P., Khaple, A., Devakumar, A. S and Hubballi, S. (2013). Assessment of above-ground biomass and carbon pool in different vegetation types of south western part of Karnataka, India using spectral modeling Tropical Ecology 54(2): 149- 165, 2013

Eamus D., Mcguinness K. and Burrows W. (2000). Review of allometric relationships for estimating woody biomass for Queens land, the Northern Territory and Western Australia. The national carbon accounting system technical report: 5.

Eli, H.D., & Agusomu T.D. Physico-chemical Analysis of Otuoke soils

Eliasson, P., Svensson, M., Olsson, M., & Ågren, G. I. (2013). Forest carbon balances at the landscape scale investigated with the Q model and the Coup Model–Responses to intensified harvests. *Forest ecology and management*, *290*, 67-78.

FAO, (2004). Assessing carbon stocks and modelling win–win scenarios of carbon sequestration through land-use changes. Rome http://www.fao.org

FGN (2006). *Nigeria: National Biodiversity Strategy and Action Plan*. Federal Government of Nigeria [online], Available at http://www.cbd.int/doc/world/ng/ng-nbsap-01-en.pdf, Accessed 12 October 2018.

Gibbs, H. K., Brown, S., Niles, J. O., and Foley, J. A. (2007). Monitoring and estimating tropical forest carbon stocks: making REDD a reality. *Environmental Research Letters*, *2*(4), 045023.

Gilbert, B. & Luis, S. (2008). Conceptual and statistical problems associated with the use of diversity indices in ecology. Escuela de Biología, Universidad de Costa Rica, Ciudad Universitaria Rodrigo Facio, San José, Costa Rica.

Gimaret-Carpentier, C., Pélissier, R., Pascal, J. P., & Houllier, F. (1998). Sampling strategies for the assessment of tree species diversity. *Journal of Vegetation Science*, *9*(2), 161-172.

Glover, A. G., Smith, C. R., Paterson, G. L. J., Wilson, G. D. F., Hawkins, L., and Sheader, M. (2002). Polychaete species diversity in the central Pacific abyss: local and regional patterns, and relationships with productivity. *Marine Ecology Progress Series*, *240*, 157-170.

Google (2017).*Measure distances and areas in Google Earth* [online]. Available at https://support.google.com/earth/answer/9010337?co=GENIE.Platform%3DDesktopandhl=enandoco=0 (Accessed: 10 August 2017).

Gorte, W. R. (2009). Carbon Sequestration in Forests. Congressional Research Service, Natural Resources Policy, Report for Congress, 2-20.www.crs.govRL31432 Hall, A. (2012). Forests and Climate Change. The Social Dimensions of REDD in Latin America, 201- 213. Mason, N. W. H., and Carswell, F. E. (2014). Propagating Uncertainty in Plot-Based Estimates of Forest Carbon Stock and Carbon Stock Change. Ecosystems, 17, 627-640.

Hamburg, S.P., Harris, N., Jaeger, J., M., Santer, S., Schneider, S., Trenberth, K.E., Wigley, T.M.L., 1997. 'Common questions about climate change'. United Nations Environment Programme, World Meteorology Organization.

Harrison, I. Laverty, M. and Sterling, E. (2004). Species Diversity, *Connexions module: m12174*. Retrieved from http://cnx.org/content/m12174/latest on 05 August, 2011.

Hawthorne, W. D., & Jongkind, C. C. (2006). *Woody plants of Western African forests, A guide to the forest trees, shrubs and lianes from Senegal to Ghana*. Royal Botanic Gardens, Kew.

Heath, J., Ayres, E., Possell, M., Bardgett, R. D., Black, H. I., Grant, H., and Kerstiens, G. (2005). Rising atmospheric CO2 reduces sequestration of root-derived soil carbon. *Science*, *309*(5741), 1711-1713.

Hemery M, (2011) Estimating tree biomass of Sub-Saharan African forests: a review of available allometric equations. Silva Fenn 45: 477–569

Henderson, P. A., & Seaby, R. M. H. (2007). Community analysis package 4.0. *Pisces Conservation Ltd, Lymington, UK.*

Hill, M. O. (1973). Diversity and evenness: a unifying notation and its consequences. *Ecology*, *54*(2), 427-432.

Hofstad, O. (2005). Review of biomass and volume functions for individual trees and shrubs in Southeast Africa. *Journal of Tropical Forest Science*, 151-162.

Hogarth, P.J. 1999. The Biology of Mangroves. Oxford University Press inc., New York.

Houghton, R. A. (2005). Aboveground forest biomass and the global carbon balance. *Global Change Biology*, *11*(6), 945-958.

Hubalek, Z. (2000). Measures of species diversity in ecology: an evaluation. *FOLIA ZOOLOGICA-PRAHA-*, *49*(4), 241-260.

Hunter, M. L. and Gibbs, J. (2007). *Fundamentals of Conservation Biology*. 3rd Ed. Oxford: Blackwell.

Hurlbert, S. H. (1971). The nonconcept of species diversity: a critique and alternative parameters. *Ecology*, *52*(4), 577-586.

Ian, J. and Rebecca C. (2010) 'Trees for Carbon Sequestration '. Prime Facts for Profitable, Adaptive and Sustainable Primary Industries PRIMEFACT 981, pp.2.

IPCC (2006). Guidelines for National Greenhouse gas inventories. Vol. 4. Agriculture, forestry and other land use (AFLOLU), Institute for Global Environmental Strategies, Haryana, Japan, 2006.

IPCC (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report. Cambridge University Press, Cambridge.

Kaimowitz, D., & Angelsen, A. (1998). Economic models of tropical deforestation: A review. Bogor: Centre for International Forest Research.

Komiyama, A., Havanond, S., Srisawatt, w., Mochida, Y, Fujimoto, K., Ohnishi,l, Ishihara, S. and Miyagi, T. 2000. Top/root biomass ratio of a secondary mangrove (Ceriopstagal (Perr.) C.B. Rob.) Forest. *Forest Ecology and Management*, 139: 127-134

Kottè-Mapoko, E. F., Ngo-Massou, V. M., Essomè-Koum, L. G., Emane, J. M., Moussian, L. N., Tchoffo, R., and Din, N. (2017). Molluscs' composition and distribution in mangroves of the Cameroon central coast.*International Journal of Research Studies in Biosciences*, *5*(5), 4-13.

Kumar, J. N., Kumar, R. N., Bhoi, R. K., & Sajish, P. R. (2010). Tree species diversity and soil nutrient status in three sites of tropical dry deciduous forest of western India. *Tropical Ecology*, *51*(2), 273-279.

Laarmann, Diana, HennKorjus, Allan Sims, John A. Stanturf, Andres Kiviste, and KajarKöster. "Analysis of forest naturalness and tree mortality patterns in Estonia." *Forest Ecology and Management* 258 (2009): S187-S195.

Ladwig, L. M., Damschen, E. I., and Rogers, D. A. (2018). Sixty years of community change in the prairie–savanna–forest mosaic of Wisconsin. *Ecology and evolution*, *8*(16), 8458-8466.

Lal, R. 2011. Sequestering carbon in soils of agro-ecosystems. Food Policy 36: S33–S39.

Laura, M. L., Ellen, I. D. & David A. R. (2018). Sixty years of community change in the prairie–savanna–forest mosaic of Wisconsin. *Ecology and Evolution, 8(16)*, pp. 8458-8466.

Lesne, A. (2014). Shannon entropy: a rigorous notion at the crossroads between probability, information theory, dynamical systems and statistical physics. *Mathematical Structures in Computer Science*, *24*(3).

Litton, C. M., and Kauffman, B. J. (2008).Allometric models for predicting aboveground biomass in two widespread woody plants in Hawaii. *Biotropica*, *40*(3), 313-320.

Lu, D. (2005). Above-ground biomass estimation using lansat tm data in the Brazilian Amazon *International journal of remote sensing* 26.12:2509 – 2525

Magurran, A. 2004. Measuring Biological Diversity. Oxford, RU: Blackwell Publishing.

Makerere University Institute of Environment and Natural Resources (1998). *Vitellaria paradoxa*. The IUCN Red List of Threatened Species [online]. Available at https://www.iucnredlist.org/species/37083/10029534 (accessed: 24 May 2018).

Margalef, R. (1972). *Homage to Evelyn Hutchinson, or why there is an upper limit to diversity*. Connecticut Academy of Arts and Sciences.

Mather, A. S. (1991). Pressures on British forest policy: Prologue to the post-industrial forest? 23(3), 245–253.

Matthews H.D., Weaver A.J. (2010) 'Committed climate warming'. Nat Geosci 3(3):142–143; Matthews HD, CaldeiraK(2008) Stabilizing climate requires near-zero emissions. Geophys Res Lett 35(4): L04705.

McIntosh, R. P. (2007). An index of diversity and the relation of certain concepts to diversity.*Ecology*, Vol. 48, pp. 392-404.

Meinshausen M, Meinshausen N, Hare W, Raper SCB, Frieler K, Knutti R, Frame DJ, Allen MR (2009) Greenhouse-gas emission targets for limiting global warming to 2◦C. 458(7242):1158–1162.

Merganič, J., Merganičová, K., Marušák, R., & Audolenská, V. (2012). Plant diversity of forests. In *Forest ecosystems-more than just trees*. IntechOpen.

Michel, K., and Matzner, E. (2002). Nitrogen content of forest floor Oa layers affects carbon pathways and nitrogen mineralization. *Soil Biology and Biochemistry, 34*(11), 1807-1813.

Misra, R (1968). Ecology work Book.Oxford and IBH Publishing Co.Calcutta.244 pp.of grassland vegetation. *Journal of Range Management*.14:pp63-69

Mitchard, E. T., Saatchi, S. S., White, L., Abernethy, K., Jeffery, K. J., Lewis, S. L., ...and Meir, P. (2012). Mapping tropical forest biomass with radar and spaceborne LiDAR in Lopé National Park, Gabon: overcoming problems of high biomass and persistent cloud.*Biogeosciences*, *9*(1), 179-191.

Mohammed, A. H., Jahun, S. F. B., Mohammed, G. A., and Dangana, A. S. (2015). Herbaceous Species Diversity in Kanawa Forest Reserve 06-9108-1 (KFR) in Gombe State, Nigeria. *American Journal of Agriculture and Forestry*, *3*(4), 140-150.

Myers, N. (1988). Threatened biotas:'' Hot spots'' in tropical forests. Environmentalist, 8(3), 187–208.

Myers, S. (1991). Structure preservation and the strong domain hypothesis. Linguistic Inquiry, 22(2), 379–385.

Nansen, C., Tchabi, A., & Meikle, W. G. (2001). Successional sequence of forest types in a disturbed dry forest reserve in southern Benin, West Africa. *Journal of Tropical Ecology*, 17(04), 525–539.

Neumann, M., and Starlinger, F. (2001). The significance of different indices for stand structure and diversity in forests. *Forest ecology and Management*, *145*(1-2), 91-106.

Nowak, D.J., & Crane D.E.(2002). Carbon storage and sequestration by urban trees in the USA. *Environmental pollution.* 116(3), 381-389.

Ogunwale, J. A., and Isa, N. (2004).Characterization and classification of the soils of a toposequence at Gbagba, Kwara state, Nigeria.*Agrosearch*, *6*(1-2), 55-64.

Olabode, O. S. (1997). Comparison of the physical and chemical properties of soils under natural forest and Gmelina plantation.*Agrosearch*, *3*(1-2), 19-30.

Ondei, S., Prior, L. D., Vigilante, T., & Bowman, D. M. (2017). Fire and cattle disturbance affects vegetation structure and rain forest expansion into savanna in the Australian monsoon tropics. *Journal of biogeography*, 44(10), 2331-2342.

Onyekwelu, J. C. (2007). Growth, biomass yield and biomass functions for plantation-grown in the humid tropical rainforest zone of south-western Nigeria. *Bioresource Technology*, *98*(14), 2679-2687.

Onyekwelu, J.C., & Fuwape, J.A. (1998) site index equation for *Gmeline arborea* pulpwood plantation in Oluwa Forest Reserve Nigeria. *Journal of Tropical Forest Science,* 337-345.

Orimoogunje, O. O. I. (2014). The impact of land use dynamics on Oluwa Forest Reserve in Southwestern, Nigeria. *Journal of Landscape Ecology*, 7(2), 25–44.

Oriola, E. O., Ifabiyi, I. P., and Hammed, A. T. (2010).Impact of reforestation in a part of degrading natural ecological system of Ilorin, Kwara State, Nigeria. *African Journal of Agricultural Research*, *5*(20), 2811-2816.

Oyeyiola, G. P., and Agbaje, A. B. (2013). Physicochemical Analysis of a Soil near Microbiology Laboratory at The University of Ilorin, Main Campus.*Journal of Natural Sciences Research*, *3*(6), 78-81.

Parthasarathy, N. (2001). Changes in forest composition and structure in three sites of tropical evergreen forest around Sengaltheri, Western Ghats. *Current science*, 389-393.

Pedro, C., Tamara, R., Maria, D., Francisco, G. F., Emilio, M., Isabel, G. T. & Sergio, M. V. (2013). Species richness in marine phytoplankton communities is not correlated to ecosystem productivity. Centre for Biological Diversity, Scottish Oceans Institute, University of St Andrews, St Andrews, UK

Peichl, M., Leava, N. A., & Kiely, G. (2012). Above-and belowground ecosystem biomass, carbon and nitrogen allocation in recently afforested grassland and adjacent intensively managed grassland. *Plant and Soil*, *350*(1-2), 281-296.

Pelemo, O.J., Akintola, B.A., Temowo, O.O., Akande E.O., Akoun, M. (2011). Effects of landscape Change on Biodiversity in Nigeria: Remote Sensing and GIS Approach. Continental. *J. Environs. Design Manage.* 1 (2): 22-29.

Poorter, H & Nagel, O. (2004). The role of biomass allocation in the growth response of plant to different levels of light, $CO_2$ nutrients and water a quantitative review. *Functional Plant Biology* 27(12). Pp. 1191-1191.

Putz, F. E., Blate, G. M., Redford, K. H., Fimbel, R., & Robinson, J. (2001). Tropical forest management and conservation of biodiversity: An overview. *Conservation Biology*, 15(1), 7–20.

Raji, I.A., & Babalola, F.D. (2018). “Assessment of Tree Diversity and Abundance in university of Ilorin Campus: Towards Conservation”. In *proceedings of 6$^{th}$ NSCB Biodiversity Conference; uniuyo* (Vol. 443, p. 450pp).

Ravindranath, N.H and Ostwald, M (2008). Carbon Inventory Methods: Handbook for Greenhouse Gas Inventory, Carbon Mitigation and Roundwood Production Projects. Springer Science + Business Media B.V 113-14

Rey de Vinas, I.C and Ayanz, S.A (2000). Biomass of root and shoot systems of Quercus coccifera shrublands in Eastern Spain. Annals of Forest Science, 57:803-810.Retrieved from https://hal.archivesouvertes.fr/hal-00883436/documentandvet on 07/01/2016.

Richard, L. (2019). Project management made easy [online], available at https://www.climate-policy-watcher.org/carbon-stocks/methods-for-belowground-biomass.html (accessed on 18 March 2019)

Sabogal, C. (1992). Regeneration of tropical dry forests in Central America, with examples from Nicaragua. *Journal of Vegetation Science*

Sagar, R., and Sharma, G. P. (2012). Measurement of alpha diversity using Simpson index (1/Lamda): the jeopardy. *Environmental Skeptics and Critics*, *1*(1), 23.

Sahu, S.C., Dhal, N.K., & Mohanty, R.C. (2012). Tree species diversity, distribution and population structure in a tropical dry deciduous forest of Malyagiri hill ranges Eastern Ghats, India. *Tropical Ecology*, 53(2), 163-168.

Salmaca I.K. (2007). Estimation of Forest Biomass and its Error: A Case Study in Kalimantan, M.Sc. thesis, University of Twente, Faculty of geo-information science and earth observation, Enschede, the Netherlands Pp 74. Retrieved from http://www.gemmsc.org/Academic%2520output/Irvin% 2520Salmaca.pdf on 07/01/2016

Sandberg, G. (2013). Estimation of Forest Biomass and Faraday Rotation using Ultra High Frequency Synthetic Aperture Radar. Thesis for the Degree of Doctor of Philosophy. Department of Earth and Space Sciences Chalmers University of Technology Gothenburg, Sweden pp 52.

Sarkar, S. (2006). Ecological diversity and biodiversity as concepts for conservation planning: comments on Ricotta. *Actabiotheoretica*, *54*(2), 133-140.

Schneider, L. (2009). ‘Assessing the additionality of CDM projects: practical experiences and lessons learned’, *Climate Policy,* 9: 242–254.

Sedjo, R.A., (1989). Forests to offset the greenhouse effect. *Journal of Forestry* 87, 12–15.

Sedjo, Roger; Sohngen, Brent (2012)."Carbon Sequestration in Forests and Soils". Annual Review of Resource Economics (Annual Reviews) 4: 127 144.doi:10.1146/annurev-resource-083110-115941

Shamaki, S. B., Akindele, S. O., Isah, A. D., & Mohammed, I. (2016). Height-diameter relationship models for Teak (Tectona grandis) plantation in Nimbia Forest Reserve, Nigeria. *Asian Journal of Environment and Ecology*, *1*(1), 1-7.

Sheram, K. (1993). *The Environmental Data Book: A Guide to Statistics on the Environment and Development*. International Bank for Reconstruction and Development, The World Bank, 1818 H Street, NW, Washington, DC 20433..

Shrestha, S., and Adhikari, P. L. (2016). Investigating Temporal Variation of Water Quality and Benthic Macroinvertebrates in Taudaha Lake, Kathmandu, Nepal.*Journal of Water Resource and Protection*, *8*(13), 1283.

Sivakumar, M.V.K. (2007). Interactions between climate and desertification. *Agricultural and forest meteorology, 142*(2-4), 143-155.

Soares, P., and Tomé, M. (2003). GLOBTREE: an individual tree growth model for Eucalyptus globulus in Portugal. *Modelling forest systems. CAB International, Wallingford*, 97-110.

Sommeechai, M., Wachrinrat, C., Dell, B., Thangtam, N., & Srichaichana, J. (2018). Ecological Structure of a Tropical Urban Forest in the Bang Kachao Peninsula, Bangkok. *Forests*, 9(1), 36.

Stokland, J. N. (2003). *Forest biodiversity indicators in the Nordic countries: status based on national forest inventories*. Nordic Council of Ministers.

Stormer, F.A., & Valentine, G.L. (1981). Management of shelter for wildlife [USA]. *Publication Great Plains Agricultural council.*

Sundquist E, Burruss R, Faulkner S, Gleason R, Harden J, Kharaka Y, Tieszen L, Waldrop M. (2008). USGS Fact Sheet: 'Carbon Sequestration to Mitigate Climate Change'. *U.S. Geological Survey*. www.pubs.usgs.gov.

Tee,T.N.(2010). Practical Issues In Forest Products Marketing (Pp. 132- 152) In:Ijeomah, H.M. and Aiyeloja (eds.) .2010.*Practical Issues in Forest and WildlifeResources Management*.Green Canopy Consultants, Port Harcourt, Rivers State.

Thompson, J.A.,& Kolka, R.K., (2005).soil carbon storage estimation in a forested watershed usin quantitative soil-landescape modelling. *Soil science society of America journal*. 69(4). 1086-1093

Timilsina, N., Staudhammer, C. L., Escobedo, F. J., & Lawrence, A. (2014). Tree biomass, wood waste yield, and carbon storage changes in an urban forest. *Landscape and Urban Planning*, 127, 18–27.

Twilley, R.R., Chen, R.H., Hargis, T., 1992. Carbon sinks in mangroves and their implications to carbon budget of tropical coastal ecosystems. *Water Air Soil Pollution*. 64, 265–288.

UNFCCC (2014). *Key decisions relevant for reducing emissions from deforestation and forest degradation in developing countries (REDD+)*. United Nations Framework Convention on Climate Change [online]. Available at https://unfccc.int/files/land_use_and_climate_change/redd/application/pdf/compilation_redd_decision_booklet_v1.1.pdf (Accessed: 26 October 2018).

Van Kooten, G. C. and Bulte, E. H. (2000). *The economics of nature: managing biological assets*.Blackwells.

Vashum, K.T and Jayakumar, S (2012).Methods to Estimate Above-Ground Biomass and Carbon Stock in Natural Forests - A Review. J. Ecosyst. Ecogr.2:116. doi:10.4172/2157-7625.1000116.

Vejre, H., Callesen, I., Vesterdal, L., and Raulund-Rasmussen, K. (2003). Carbon and nitrogen in Danish forest soils—contents and distribution determined by soil order. *Soil Science Society of America Journal*, *67*(1), 335-343.

Wani, A.A., Joshi, P.K., Singh, O. and Pandey, R (2012). Carbon Inventory Methods in Indian Forests - A Review: International Journal of Agriculture and Forestry, 2(6): 315-323.

Wertz-Kanounnikoff, S., Verchot, L, V., Kanninen, M, and Murdiyarso, D. (2008). 'How can we monitor, report and verify carbon emissions from forests'. In: Angesen, A (ed) Moving ahead with RED: issues, options, and implications Bogor: CIFOR. Pp. 87-98.

Wilkie, D., Shaw, E., Rotberg, F., Morelli, G., & Auzel, P. (2000). Roads, development, and conservation in the Congo Basin. *Conservation Biology*, 14(6), 1614–1622.

World Bank.2015c. Agricultural methane emissions (% of total). Available at http://data.worldbank.org/indicator/EN.ATM.METH.AG.ZS/countries/1W?display=grap h (verified 1 October 2015)

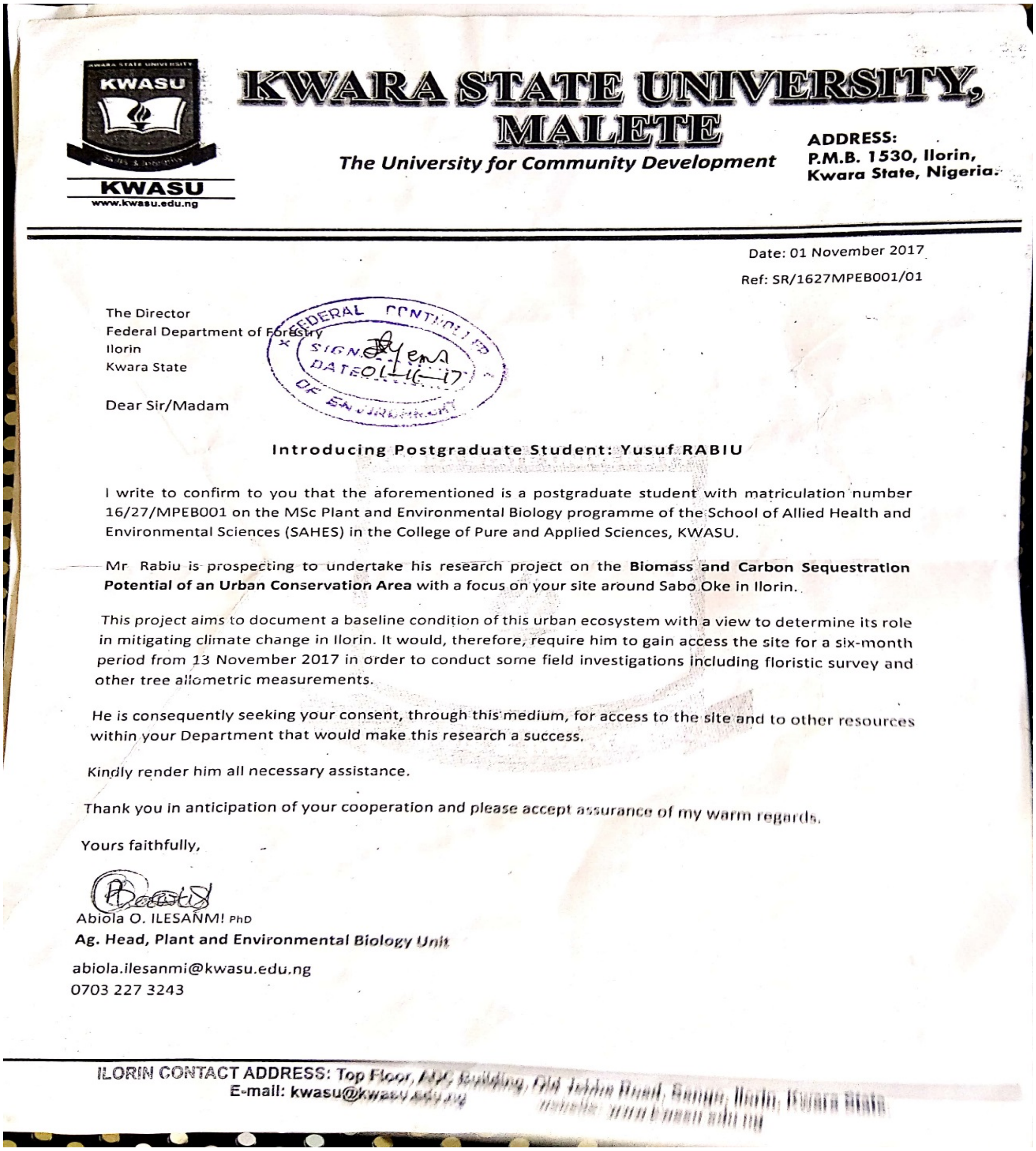
Yeboah, D. (2011). Variation in carbon content of tropical tree species from Ghana.

Yu, L., and Gong, P. (2012). Google Earth as a virtual globe tool for Earth science applications at the global scale: progress and perspectives. *International Journal of Remote Sensing*, 33(12), 3966-3986.

Zianis, D., Muukkonen, P., Mäkipää, R., and Mencuccini, M. (2005). *Biomass and stem volume equations for tree species in Europe*.FI.

# Appendix

## Appendix 1: letter of introduction to access Federal Forest Reserve, Ilorin.



**KWARA STATE UNIVERSITY, MALETE**

*The University for Community Development*

**ADDRESS:** **P.M.B. 1530, Ilorin, Kwara State, Nigeria.**

KWASU
www.kwasu.edu.ng

Date: 01 November 2017

Ref: SR/1627MPEB001/01

The Director
Federal Department of Forestry
Ilorin
Kwara State

Dear Sir/Madam

**Introducing Postgraduate Student: Yusuf RABIU**

I write to confirm to you that the aforementioned is a postgraduate student with matriculation number 16/27/MPEB001 on the MSc Plant and Environmental Biology programme of the School of Allied Health and Environmental Sciences (SAHES) in the College of Pure and Applied Sciences, KWASU.

Mr Rabiu is prospecting to undertake his research project on the **Biomass and Carbon Sequestration Potential of an Urban Conservation Area** with a focus on your site around Sabo Oke in Ilorin.

This project aims to document a baseline condition of this urban ecosystem with a view to determine its role in mitigating climate change in Ilorin. It would, therefore, require him to gain access the site for a six-month period from 13 November 2017 in order to conduct some field investigations including floristic survey and other tree allometric measurements.

He is consequently seeking your consent, through this medium, for access to the site and to other resources within your Department that would make this research a success.

Kindly render him all necessary assistance.

Thank you in anticipation of your cooperation and please accept assurance of my warm regards.

Yours faithfully,

Abiola O. ILESANMI PhD
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