SOIL SEED BANK, FLORA SPECTRUM AND CARBON STOCK IN A COPPICED TEAK (*Tectona grandis* LINN. F.) PLANTATION IN GAMBARI FOREST RESERVE, IBADAN, NIGERIA

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ABSTRACT

Teak, *Tectona grandis*, is an economic tree widely used for timber production, and its coppice shoot regrowth exploited for pole and firewood. Establishment of Teak Plantation (TP) is important to reduce the growing gap between the demand and supply of timber. Natural and anthropogenic factors like Soil Seed Bank (SSB), flora incursion and grazing could threaten the integrity of TP and its Carbon Stock (CS) capacity. However, there is dearth of information on how SSB, flora spectrum, and CS could help in determining the resilience of coppiced-TP in Gambari Forest Reserve (GFR), Ibadan, Nigeria. Therefore, SSB, flora spectrum and CS were investigated in a coppiced-TP in GFR.

Thirty 50m x 50m main-quadrats were randomly located for enumeration of tree species in wet and dry seasons. Within each main-quadrat, five 10m x 10m sub-quadrats and within each sub-quadrat, five 1m x1m sub-sub-quadrats were laid to enumerate shrubs/climbers and herbaceous species. Within each main-quadrat, soil samples were collected from five random spots at 0-5cm (Shallow Topsoil-ST) and 5-10cm (Deep Topsoil-DT); and were each bulked and air-dried in the laboratory. Soil (1kg) was taken from each bulked-soil, and spread in 20cm x 20cm x 3cm perforated plastic trays in three replicates in the screen house to monitor seedling sprouting for five months. In each main-quadrat, height and girth at breast height of teak plants (girth≥30cm) were measured. The Relative Importance Value (RIV) for each plant species in TP and SSB were determined using standard procedures. Community structure indices (Dominance-D, Shannon-Wiener-H′ and Jaccard-J) were evaluated. A non-destructive method and allometric equations were used to evaluate teak CS.

A total of 106 and 79 species belonging to 37 and 34 families were identified in the coppiced-TP during wet and dry seasons, respectively. The highest RIV in wet and dry seasons were obtained in *Tectona grandis* (43.5% and 43.8%; trees), *Carpolobia alba* (17.4% and 26.3%; shrubs), *Icacinia trichantha* (23.7% and 34.1%; climbers) and *Chromolaena odorata* (25.1% and 17.0%; herbs), respectively. The D and H′ were: 0.60 and 1.19 (trees), 0.24 and 1.91 (shrubs), 0.15 and 2.17 (climbers) and 0.09 and 2.68 (herbs populations), respectively. The vegetation in both seasons were perfectly similar for trees (J=100.0%), but less similar for shrubs (J=85.7%), climbers (J=55.6%) and herbs (J=46.7%). In SSB, 41 species belonging to 17 families, had 20 and 38 species in wet and dry seasons, respectively. *Chromolaena odorata* had the highest RIV in wet and dry seasons (ST-21.9% and 18.2%; DT-17.1% and 16.3%, respectively). Dominance in ST and DT were 0.10 and 0.13, while H′ was 2.67 and 2.48, respectively. Similarity was least (J=36.5%) between ST (wet season) and DT (dry season) and the highest (J=76.3%) between ST (dry season) and DT (dry season). Jaccard similarity range (SSB/TP) was 0.0-1.8%, 4.2-10.3%, 0.0-3.5% and 25.9-64.7% for SSB/trees, SSB/shrubs, SSB/climbers and SSB/herbs, respectively. Total CS for teak was 877.8 kg/ha.

There were incursions of *Carpolobia alba, Icacinia trichantha* and *Chromolaena odorata* in the coppiced teak plantation in Gambari Forest Reserve, Ibadan, which caused low teak carbon stock.

Key Words: Seedling sprouting, Jaccard Similarity index, Flora diversity, Tree monoculture.

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CERTIFICATION

We certify that this work was carried out by Bassirou IBRAHIMA DJIBO in the Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria.

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CHAPTER ONE

1.0 INTRODUCTION

To reconcile the increased demand for wood and timber products and environmental sustainability, forest plantations have increased worldwide, especially in tropical zones. These plantations are usually established by planting one or more selected species during afforestation or reforestation programmes. The species may be either exotic or indigenous, even-aged and regularly spaced (FAO, 2015). These plantations provide many social and environmental services, and can help reduce deforestation, restore degraded land, mitigate climate change and increased atmospheric carbon dioxide, and improve local livelihoods. They are sources of profits, such as timber, fire wood, food and fodder, medicinal products and employment thus contributing to national economies (FAO, 2010).

Tectona grandis Linn. F. (Teak) is one of the most important tropical hardwood species grown in forest plantations in Africa, particularly in Nigeria where it was introduced around 1902 (Oyebade and Anaba, 2018). It is a large deciduous tree with a rounded crown and could attain over 25 m in height under favourable conditions. The natural habitats of teak are usually moist and dry deciduous mixed forests with altitude below 1,000 meters. The species grows best in localities with 1,250 to 3,750 mm annual rainfall, temperatures between 13ºC and 43ºC as well as deep and well-drained soils (FAO, 2015). The natural distribution area of Teak includes south Asian countries such as India, Myanmar, Lao People Democratic Republic and Thailand, but it has naturalized in Java since its introduction six to eight hundred years ago (Pachas *et al.*, 2019).

Teak offers consistent socio-economic and environmental benefits such as high-quality wood and timber production, high biomass and carbon stock acumulation (N'Gbala *et al.*, 2017). At the global level, it is estimated that deforestation contribute up to 15% of the greenhouse gas emissions. Tree monoculture is one of the most important reforestation strategies which could help to capture and sequester a large amount of carbon dioxide emitted into the atmosphere. Therefore, teak has great potential to transform a low biomass area into a great stand with high carbon stock accumulation and it performs well in various silvicultural options (James *et al.*, 2016).

Teak thrives in monocultural plantation as well as when mixed with other species, although it may require some specific silvicultural practices. For these reasons, the species has been widely established in plantations in many countries outside its natural distribution area over the last centuries (Ounban *et al.*, 2016). Africa is the second continent with large area of teak plantations (10%) after Asia (80%), and Nigeria is one of most important teak producers in tropical Africa (FAO, 2015). Since its first introduction in tropical African countries in the 1900s, various silvicultural systems have been gradually adopted for teak production (Chukwu and Olajuyigbe, 2017; N'Gbala *et al.*, 2017). Coppice teak plantations are widely used specifically in African countries to enhance the productivity in old plantations where the regrowth from seedlings may witness competition from the wildings of others plant species (Yevide *et al.*, 2014).

As a pioneer species, teak is light demanding and susceptible to competition from other plant species, most specifically during its younger development stage (FAO, 2015). Although the coppiced teak plants grow faster than seedlings, coppiced teak plantations are more likely to have a diversified flora spectrum because of the opening of the canopy (Pachas *et al.*, 2019). The establishment of other trees across the plantation may reduce the capacity of the coppice shoots to grow thus impacting negatively the resilience and productivity of the plantation.

In plant communities, one of the most important means of new species wildings recruitment, establishment and propagation within the ecosystem is the soil seed bank (Buisson *et al.*, 2018). The soil seed bank is the stock of all viable seeds in the soil profile, including those in the litter of an ecosystem (Tiebel *et al.*, 2018). The soil seed bank is a key component of the ecosystem and reflects, to some extent, the vegetation that has existed in the past in a given locality and/or the surrounding ecosystems (Douh *et al.*, 2014). Soil seed banks are potential sources of regrowth after disturbances and highly contribute to the establishment and succession of future plant communities in an environment (Gioria *et al.*, 2014). They are often more tolerant to unfavourable conditions than the above ground vegetation. Hence, the soil seed bank is critical in linking past, present and future plant communities' structures and dynamics. Seed banks are also of considerable importance for the ecological resilience of ecosystems through the natural life cycle and the spontaneous reappearance of certain species seemingly disappeared for less or long lengths of time (Akinyemi and Oke, 2013; Török *et al.*, 2018). Soil seed bank thus, play main functions in the maintenance, succession, and evolution of biodiversity in natural habitats and explain the high resilience capacity of some ecosystems (Gomaa, 2012). The absence or inhibition of seed banks slows down the reappearance of species in the vegetation and consequently limit the stimulation of the process of species replacement in the community. Whereas a well-furnished seed bank supports the maintenance of the species. In fact, the ability of the certain species to produce an abundant stock of persisting seed bank enhances their recruitment and propagation in the community (Oladipo and Oke, 2007; Takim *et al.*, 2013; Stradic *et al.*, 2018).

Studying the soil seed bank has practical importance in agriculture, forestry, and biodiversity conservation. Agricultural sciences are strongly interested in weed seed banks, considered as undesirable due to their negative economic impacts on agriculture. Weed seed bank could help understand the successes or failures in the implementation of weed management interventions in cropping systems (Takim *et al.*, 2013). In plant ecology, the soil seed bank is of major interest because of their significant role in the persistence of invasive species in an ecosystem, including in plantation zones where invasive pioneers can assert themselves to the detriment of the crop plant (Jiang *et al.*, 2013). The soil seed bank is a key component to consider in forest plantations because understanding its structure and dynamics may help detect the frequently occurring species and provide an idea of the potential strength of resilience of the plantation and/or its invasion by other plants. Alien species invasion may drastically affect the structure of the plantation and have long-term implications on productivity of the plantation depending on the persistence of the invaders and on the resilience capacity of the crop plant (Gaertner *et al.*, 2009; Gioria *et al.*, 2012).

The importance of evaluating the seed banks when developing sustainable strategies for controlling the spread of invasive species and in assessing the restoration potential of ecosystems, had been postulated (Fourie, 2008; Gaertner *et al.*, 2009). Although controversial conclusions have been drawn from studies on the relationship between the seed bank and the above ground vegetation. Nevertheless, the exploration of the soil seed bank will help increase our understanding of the vegetation dynamics in forest plantations and thus enhance the efficiency and efficacy of decision making (Wang *et al.*, 2013). For instance, many studies in Nigeria had examined forest resource dynamics, regeneration and restoration potentials from the soil seed bank (Akinyemi and Oke, 2013), the impact of invasive species on vegetation and the seed banks dynamics

(Oke *et al.*, 2009), the impact of monoculture on the vegetation and its soil seed bank (Oke *et al.*, 2007; Chima *et al.*, 2013; Chima and Alex, 2017) , and the functional role of the soil seed bank in the community's resilience after an industrial disturbance (Olatunji *et al.*, 2015). However, there is dearth of information on the relationships between the soil seed bank, the flora spectrum, and carbon stock in teak plantations. Examining the link between the above ground vegetation, the soil seed bans as well as the actual carbon stock could help in determining the resilience and productivity of coppiced teak plantations.

The aim of this work is to assess the soil seed bank composition and floristic composition of the coppiced Teak plantation in Gambari Forest Reserve with a particular view of establishing a possible threat to its continued productivity.

Specific objectives are:

i. to assess the vegetation trend within the study area over the last three decades;
ii. to assess the floristic composition of the above ground vegetation in Teak plantation;
iii. to determine the composition of the soil seed bank and its relationship with soil depth and season;
iv. to compare the floristic composition of the above ground vegetation with the soil seed bank over the wet and dry seasons;
v. to estimate the carbon stock of coppiced Teak species in the plantation.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Forest plantations and their social and environmental benefits

Plantation forests are cropping system consisting of the cultivation of one or more tree species cultivated within a certain land area. These plantations could be either for economic purposes or for the conservation of a specific species (FAO, 2015). These forests provide many services provided by natural forests and could assist in biodiversity conservation. The global land area under plantation forests continue to grow as the demand for good services provided by these forests increase (Akpan-ebe, 2017). It is estimated that plantation forest' area had significantly increased from 124 million hectares in 1995 to 184 million hectares in 2000. Recent estimations suggest that the actual land covered by forest plantations is 277 million hectares of which Africa accounts for only about four percent (FAO, 2015). These forests contribute significantly to local economies, provide numerous social and environmental benefits. These include the significant carbon pools due to continuous carbon sequestration from the atmosphere. Consequently, many valuable and fast growing tropical forest species such as teak are being planted at high rate around the globe (Basuki *et al.*, 2009).

2.2 Teak plantation forests

2.2.1 Systematic, description and distribution of Teak

Teak (*Tectona grandis* Linn.F.) is an important commercial hardwood grown in plantation forests across the world. The species belongs to the Verbenaceae family. It is a large and deciduous tree with a rounded crown. The tree grows up to 25 meters in height under favourable soil and nutrient conditions. The natural habitats of teak are in moist and dry deciduous mixed forest ecosystems with altitude below 1,000 meters. The species grows best in localities with 1,250 to 3,750 mm annual rainfall, and temperatures between 13ºC and 43ºC (FAO, 2015).

Teak natural geographical distribution zone lies between 9^o to 26^o latitude North, and 73^o to 104^o longitude Est. it grows and prospers on undulating terrain of basalt, granite, gneiss, charnockite, schist, limestone and sandstone. It attains its high productivity on well-drained and deep alluvium soils. Below is the systematic classification of teak.

Kingdom	Plantae
Division	Magnoliophyte
Class	Magnoliopsida
Subclass	Asteroidea
Order	Lamiales
Family	Verbenaceae
Genus	*Tectona*
Species	*grandis*
Authority	Linn. F.

2.2.2 Teak plantations

The first documented teak plantations were established in India in 1902. Early introductions of teak outside Asia were made in Nigeria. Teak plantation establishment in Ghana started around 1905 on a small land area (Kollert and Cherubini, 2012; Kollert and Kleine, 2017; Pachas *et al.*, 2019).

Teak was introduced in many countries of Tropical Africa because of its excellent wood quantity and timber production. Plantations of teak and other tree species in tropical nations gradually accelerated between the 1950-1960s and lop 1970 was estimated to be 0.891 million hectares (Kollert and Kleine, 2017; Smith *et al.*, 2017). Furthermore, the pace of planting teak in plantations accelerated in the late 1970s with the economic aid provided by exterior donor agencies. By 1980 the total region of teak plantation expanded to 1.72 million ha and 2.2 million ha by 1990. More than 90% of these plantations were situated in Asia. Nowadays it figures among the most planted forest species in tropical Africa where it contribute to about 8% of the plantation forests area (FAO, 2015).

2.2.3 Carbon stock in teak plantation

Teak plantations present considerable social and environmental concerns and would be put in contribution to combating the global carbon dioxide rate in the atmosphere. They are areas with important density of stems per hectare and dense canopy coverage thus highly contributing to the global carbon sequestration (James *et al.*, 2016). Carbon sequestration is the transfer of atmospheric carbon dioxide into long term pools such that it is not re-emitted into the environment in the near future (Basuki *et al.*, 2009; Djomo *et al.*, 2010; N'Gbala *et al.*, 2017). Teak plantations have been reported to have a greater carbon storage capacity, than undisturbed tropical forest (N'Gbala *et al.*, 2017). There is a positive correlation between carbon storage by teak and the age of the plantation. However, the suitability of the site may present an important influence on stand biomass productivity (Chukwu and Olajuyigbe, 2017; N'Gbala *et al.*, 2017). The annual volume increment has been reported to vary from 2 to 18 m^3 per hectare per year depending on the site quality (James *et al.*, 2016).

2.3 Flora spectrum and community structure investigation

The flora spectrum provides an insight into the vegetation status of a particular ecosystem. It mainly refers to the species composition of the site and the various interactions among individuals species in the community (Souley *et al.*, 2018). Researchers use various procedures in examining the flora spectrum one of which is the inventory.

2.3.1 Land use, land cover and change detection using remote sensing

Mapping land use land cover and change detection using remote sensing and geographic information systems has received increasing attention in building ecological databases over the last decades. Vegetation mapping is one of the basic approaches of land use and change detection which helps to understand how much land is used were and how within an ecosystem (Mengistu and Salami, 2007). Understanding the dynamics of forest ecosystem is critical for the planning and protection of biodiversity. Hence, land use and land cover analysis are an important tool in decision making in management of an ecosystem. Change detection is a mean to characterise an ecosystem dynamic, the chronological vegetation trends. It also inform preservation needs, helps evaluate the effectiveness of management strategies (Adedeji *et al.*, 2015).

Land cover changes may be originated either by natural or anthropologic disturbances. Recent advances have proven the feasibility of using high resolution spatial satellite imagery to assess forest and plantation areas over different length of time. Land cover dynamic a function of the climate, ecosystem processes, biogeochemical cycles, biodiversity and human activities. land cover and land cover change detection require maps that reflect the status of area undeerstudy at different times. Change detection is centred on identifying the biotic and abiotic components of the special and temporal changes that happen in the ecosystems (Houghton *et al.*, 2012; Adedeji *et al.*, 2015).

2.3.2 Flora inventory

To understand the structure of plant communities, scientists conduct field surveys of the plant species occurring in a given environment using various sampling strategies. Those sampling strategies allow them to identify the species and count their various densities (Barbour *et al.*, 1999). The sampling method could be random, systematic or a combination of the two. A major tool used for the listing of the flora, is the quadrat. This method consist of laying a quadrat of determined dimensions and enumerating all the species occurring within the quadrat and their respective densities using a species data matrices (Idrissa *et al.*, 2017).

2.3.3 Species distribution and importance estimation

These are the ecological parameters used to assess how the plant species are distributed across the area under study. There are several indicators developed to analyse the flora (Barbour *et al.*, 1999). Some of these indicators are expressed below.

2.3.3.1 Species richness and evenness

This is the total count of species enumerated per unit area in the sampling environment. It provide an accurate idea of how rich the ecosystem is but does not provide any idea on their distribution patterns (Idrissa *et al.*, 2017). It provides the complete list of species within the area, however its accuracy depends on the sampling effort (Barbour *et al.*, 1999).

Species richness is the number of different species in an ecosystem, greater species richness may cause ecosystems to function more efficiently and enhance productivity (Barbour *et al.*, 1999). The species evenness expresses the variation of individual densities per species within the community. When there is a large disparity between the densities of the different species in the community the evenness is low and when their densities are fairly similar throughout the community the evenness is high (Mahamane, 2005).

2.3.3.2 Abundance

The species abundance is a good estimate of how abundant a particular species is across the area of study. It gives more information on the total number of individuals of the species across the community. Abundance is important in detecting the characteristic indicator species within the ecosystem (Souley *et al.*, 2018).

2.3.3.3 Dominance and relative dominance

The concept of dominance in ecological communities is yet not clearly defined despite the consistent effort made by several authorities. According to Margherita and Osborne (2009) productivity is the most appropriate measurement parameter of dominance in a community. However, the collection of appropriate and reliable data of such parameter, where it is possible, is very tedious and may not be easily applicable especially in large scales studies (Akinyemi and Oke, 2013; Buisson *et al.*, 2018).

This led many authors to develop methods based on the species richness and or their densities to express dominance. Those methods equally weigh all the species encountered in the ecosystem under study. Although these methods may be limited by the richness, evenness, and size of the species, they are used by a relatively large number of authors due to their simplicity and adaptability to large scale studies (Zaghloul, 2008). The species dominance can be measured in several ways using species variables such as density, cover, or biomass. When the dominance is measured within the same taxonomic or ecological group the biases in the measurement could be smaller (Barbour *et al.*, 1999; Perera, 2005; Hopfensperger, 2007; Awodoyin *et al.*, 2013). This parameter examines how a particular or few species are dominating the others within the site. Like the abundance, it is a characteristic indicator of the community behaviour (Olubode *et al.*, 2011). It is expressed as the relative dominance, which is the dominance of a particular species as a percentage of the total dominance (Lawal and Salami, 2018).

2.3.3.4 Frequency and relative frequency

The frequency of a species is a measure of the number of times a species is encountered per unit area across the area under investigation. It is very informative parameter of the community as is helps to understand the precise distribution patterns of the different species (Barbour *et al.*, 1999). The relative frequency is the frequency of a particular species as a percent of the total frequency of all species (Lawal and Salami, 2018).

2.3.3.5 Relative importance value

The relative importance value is an important ecological parameter. It provide an integration of both the densities and spatial distributions of the species within the ecosystem. It is obtained by computing the mean of the relative dominance and relative frequency. The relative importance thus express qualitatively how a particular species is abundant or not in the ecosystem (Awodoyin *et al.*, 2013).

2.3.4 Community structure indices

In community ecology, species diversity refers to two principal ecological patterns which are the species richness, a measurement of how diverse the community is in terms of the total number of species and the species evenness which gives precise information on how the species are distributed within the ecosystem (Batista *et al.*, 2016).

2.3.4.1 Simpson Diversity Index

Simpson's Diversity Index is one of the conventional diversity measurement tools widely used in plant ecology. It is often used to quantify the biodiversity of habitats because it takes into account both the species richness and the individual abundance (Onyekwelu *et al.*, 2008). The index is a dominance index because it gives more weight to common or dominant species in the community under investigation. The index values range from 0 to 1 with greater values accounting for greater population diversity (Mahamane, 2005).

2.3.4.2 Shannon-Wiener diversity index

This is another conventional and widely used diversity index. It is an information statistic index based on the species richness and evenness within the community being investigated, with the assumption that the species in the community belong to one taxonomic group and that all the species are equal (Pielou, 1966). The index is computed by summing up all data for each species enumerated, after relating the importance of the data of each species to its own density. Although the first assumption of the index is generally satisfied in diversity analysis, some authors are reticent in considering all the species being equal because the basis of the species identification is that they are different from each other (Souley *et al.*, 2018). The greater the value of the index, the greater the population diversity (Idrissa *et al.*, 2017).

2.3.4.3 Equitability

The species equitability indices generally intend to segregate the diversity component which is the species richness and the species evenness into two independent components of the community. The concept is based on the assumption that the index would partition the total diversity into an effect of the species richness and an effect of variations in species relative abundance (Magurran, 2004). The equitability indices are useful because they permit considerable refinement in diversity studies.

Species diversity is the number of different species in a community weighed by some measure of abundance such as the area covered by each species, the species biomass, the density or relative abundance (Egberongbe *et al.*, 2017). The species evenness or equitability concept is a measurement of the relative abundance of each species in the ecosystem (Bossuyt and Honnay, 2008). When all the species of an ecosystem are represented with identical number of individuals, the species evenness is high. On the other hand, when some species are represented by huge number of individuals and the other species are represented with very few individuals within the ecosystem, the species evenness will be low (Mahamane, 2005).

2.3.4.4 Similarity index

A similarity index is an ecological comparison tool which helps to analyse how identical are two or more vegetation samples. It is a single variable which is a characteristic of the rankings resulting from the comparison of the species attributes in one pattern against the identical attribute in a second sample. These are useful indices in communities ecology however, they must not be used as test statistics in the assessment of sample' origins (Bossuyt and Honnay, 2008).

A similarity index based totally on the two samples is calculated in the hope that it will point out the diploma of resemblance between the two ecological populations represented by means of the samples. If the resemblance is "high" the samples may also be judged to come from the identical population. If it is "low" the populations may additionally be judged to be different. If the judgment is "different " some may say that the two communities (under a restricted, greater ecological definition of the community) are unique (Yan *et al.*, 2010).

2.4 Soil seed bank

Soil seed banks resemble other biological reservoirs and vary in accordance to seed proximity, seed persistence and physiological state (Saatkamp *et al.*, 2014). Stradic *et al.* (2018) described soil seed banks as an aggregation of un-germinated seeds potentially capable of replacing the standing vegetation. This includes all dwelling seeds in a soil profile, together with those on the soil surface, other vegetative propagules and related litter that are in a position to recompose natural vegetation (Akinyemi and Oke, 2013). Seeds in the soil seed bank may appear in or on the soil, but in many situations, there is a continuity between seeds at the surface, partly buried and completely buried ones (Gaertner *et al.*, 2009). In their study Douh *et al.* (2014) defined soil seed banks as the amount of conceivable seeds that are on the soil floor and or buried in the first 20 cm soil layer, though soil seed banks are additionally composed of different dispersal units. These are fruits surrounded by structures serving for dispersal and other plant parts such as bracts.

2.4.1 Classification of soil seed banks

Plant species present many differences in their abilities to constitute a stock of viable seeds and in the period of time, their seeds can remain in the soil. To understand the seasonality and the duration of soil seed banks, Thompson and Grime (1979) carried out a study on the flora of Central England and suggested a classification of the plant species based on their soil seed bank types. Based on the longevity, they identified four types of seed banks which can be mainly classified as, (a) transient seed banks for species that have viable seeds present for less than one year (Type; I and II), and (b) persistent seed banks for species with viable seeds that remain for more than one year (Type; III and IV). Their classification has been widely adopted by other researchers.

Transient soil seed banks are those with seeds that persist in the soil for less than one year. They are adapted to make the most of the gaps created through seasonally-predictable injury and mortality in the vegetation (Arruda *et al.*, 2018). Persistent soil seed banks are those with seeds that persist in the soil for more than one year. They showcase spatial and temporal variations, reflecting their preliminary dispersal onto the soil and subsequent motion (Trabaud *et al.*, 1997). Persistent seed banks can be both momentarily chronic with seeds that persist in the soil for greater than one year, however less than 5 years or long-term seeds that persist in the soil for more than five years (Buisson *et al.*, 2018).

2.4.2 Soil Seed Bank in Plant Communities

Soil seed banks would be understood as a reserve of seeds in the soil or on its floor produced in the most recent reproductive duration or over preceding years. They represent a kind of memory of the past and recent vegetation that is capable of regenerating the community (Akinyemi and Oke, 2013).

Soil seed banks perform critical functions in an ecosystem. They are an essential thing of the lifestyles cycle of sexually reproducing species and a necessary source of plant variety (Chesson *et al.*, 2004; Fenner and Thompson, 2005). Moreover, seed banks may also facilitate the coexistence of doubtlessly competing species while mitigating the results of inter and intraspecific competition. Soil seed banks represent a shape of dispersal in space and time, allowing the colonization of new localities (Chesson *et al.*, 2004). This is particularly important for the survival of rare, or endangered or endemic species.

2.4.3 Soil seed bank investigation methods

The estimates of seeds per unit area vary significantly according to the plant community under study, the method applied, the financial limiting aspect of research institutions, the volume of soil that can be sampled and the dimension and variety of the sampling devices (Tiebel *et al.*, 2018). Douh *et al.* (2014) suggested that focus must be on the key attributes of seed banks such as species diversity and density. In most studies, the method and sample size that were chosen were dictated by the factors mentioned. The two commonly used methods to estimate the soil seed bank characteristics are seed extraction and seedling emergence (Buisson *et al.*, 2018).

Studies have shown that the two methods give divergent results, with seed extraction detecting higher seed densities and richness. The seed extraction method includes apparently healthy but non-viable seeds although a viability test can be conducted after extraction (Price *et al.*, 2010). The seedling emergence, on the other hand, will only detect the fraction of ready to germinate seeds and may fail to detect those with specific germination requirements. The seedling emergence approach detects a larger proportion of small-seeded species, while the seed extraction method detects those with large seeds (Price *et al.*, 2010).

2.4.3.1 Seed extraction

In the seed extraction method, the seeds and soil particles are separated based on sizes and densities. The most common techniques are seed flotation in oversaturated salt solutions and pattern sieving (Gaertner *et al.*, 2009). The extracted seeds are then identified under a binocular microscope. This method is effective for detecting large-seeded species. However, they are very laborious and time-consuming, particularly in massive scale research. They sometimes fail to discover the smallest seeded species due to the fact that seeds are misplaced during the pattern processing (Price *et al.*, 2010).

2.4.3.2 Seedling emergence

In the seedling emergence method, the soil samples are spread on trays and kept under suitable conditions to promote the germination of as many individuals as possible. Thereafter, the emerging seedlings are identified and counted (Gaertner *et al.*, 2009).

The method requires space in a greenhouse and long-time seed germination monitoring (Buisson *et al.*, 2018). This method may be limited by physiological properties such as seed dormancy and germination requirements. Hence, seedling emergence may not provide a complete assessment of the seed flora (Stradic *et al.*, 2018). Also, the emerging seedlings are often correctly identified. Nevertheless, it is the most used applied method because it is less laborious, useful for large-scale studies and more suitable for assessing the persistent seed bank (Akinyemi and Oke, 2013).

2.5 Forest carbon stock

Carbon sequestration is the process of capturing and accumulating the atmospheric carbon dioxide in the ecosystem through biological processes such as photosynthesis that transform the carbon dioxide into stackable products. Once sequestrated the carbon is stored in the living plant biomass, soil and litter and constitute the ecosystem carbon stock. The carbon stock thus is the amount of carbon that has been sequestrated from the atmospheric carbon dioxide and is now stored in the ecosystem. The carbon stock is the natural reservoir that accumulates and stores carbon in the ecosystem (Henry *et al.*, 2010).

It is dynamic and can increase or decrease through some natural and anthropological factors such as photosynthesis, forest plantation, agroforestry, bush fires and deforestation. The carbon stock is quantified by estimating the accumulation of carbon sequestration by living biomass, soils and litter in the ecosystem. Various estimation methods, which could be grouped into two main groups were used by researches in this attempt (N’Gbala *et al.*, 2017).

2.6 Forest carbon stock estimation methods

Carbon stock evaluation in forests and plantations forests has been receiving exciting attention from scientists worldwide because of the capital role they play in the sequestration of atmospheric carbon dioxide (N’Gbala *et al.*, 2017). In the attempt to perform accurate estimations, several methods have been developed for such studies but the most commonly used method is the determination of tree biomass from which allometric equations and then used to estimate land area carbon stock (Chukwu and Olajuyigbe, 2017). Tree biomass is a crucial estimator of productivity and carbon storage in forests species. The determination of biomass accumulation in trees could be done either directly (destructive methods) or indirectly (non-destructive methods) (Rutishauser *et al.*, 2013).

2.6.1 Direct methods for biomass estimation

These methods consist of measuring the biomass by weighing the tree directly in the field. They are the most accurate technique for determining biomass, but they require the cutting of the plant and subsequent measurements of the plants parameters such as the total height, stem diameter at various positions along the bole and the number and length of the branches (N'Gbala *et al.*, 2017). These methods include the determination of the wet and dry tree biomass by the development and use of allometric formulae in to estimate total biomass and then estimation of carbon stock as half of total biomass (Chukwu and Olajuyigbe, 2017). This method is time consuming, requires intensive labour and is difficult to apply when studying at a large scale and or when big tree individuals are involved (Rutishauser *et al.*, 2013).

2.6.2 Indirect methods of biomass assessment

The non-destructive biomass accumulation and carbon stock evaluation methods involve the estimation of complex parameters from simple and easy to measure tree parameters (Rutishauser *et al.*, 2013). The measurements are indirect and usually consist of estimating the whole or partial plant biomass (above and below ground biomass) from easy to measure tree parameters such as the diameter at breast height and total height of the tree. The total plant biomass and carbon stock can then be inferred from those parameters without felling the tree using allometric equations (N'Gbala *et al.*, 2017). The non-destructive methods are widely used because they are eco-friendly, time efficient and easily applicable to large scale studies. These methods are also applicable to large species and make it more easy to evaluate the biomass and carbon stock of the entire communities (N'Gbala *et al.*, 2017).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study site

3.1.1 Field Location

Gambari Forest Reserve was established in 1899 as Ibadan Forest Reserve. Four years later, additional land area was added to the reserve and it was renamed after Onigambari, a nearby village. The forest reserve is located in Oluyole Local Government, Ibadan, Oyo-State, Nigeria. It lies between latitude 7˚25' and 7˚55' North and longitude 3˚53' and 3˚9' East and is bounded by Ona and Awon rivers (Figure 3.1) (Adedeji *et al.*, 2015). The topography of the reserve is generally undulating with an altitude lying between 120 and 150 m above the sea level. With 13,932.18 hectares total land area, the forest reserve covers five local communities: Mamu, Onigambari, Busogboro, Odo-Ona/Onipe, and Olonde, which constitute the five main zones of the reserve (Larinde and Olasupo, 2011). Plantation of forest species such as *Tectona grandis*, *Khaya ivorensis*, *Gmelina arborea*, and agro-sylvicultural plantations such as Cocoa and Cassava farming are found within the zones. The Busogboro zone is predominantly made of coppiced teak plantation which undergoes anthropogenic pressures such intense fuel wood exploitation, grazing, burning and plantation of other economic trees. The coppiced plantation also experiences competition from other plant species, which establish themselves within the plantation through various ways of propagation (Salami *et al.*, 2016).

3.1.2 Climate of the area

The forest reserve lies in the tropical area with two main seasonal variations, a wet season from March to October and a dry season from November to March with a brief spell of harmattan from December to January (Larinde and Olasupo, 2011). The annual rainfall is within the range of 1,200 mm to 1,500 mm. Temperatures are high throughout the year with mean annual values ranging from 21.1^{o}C to 31.1^{o}C while the relative humidity is low during the dry season.

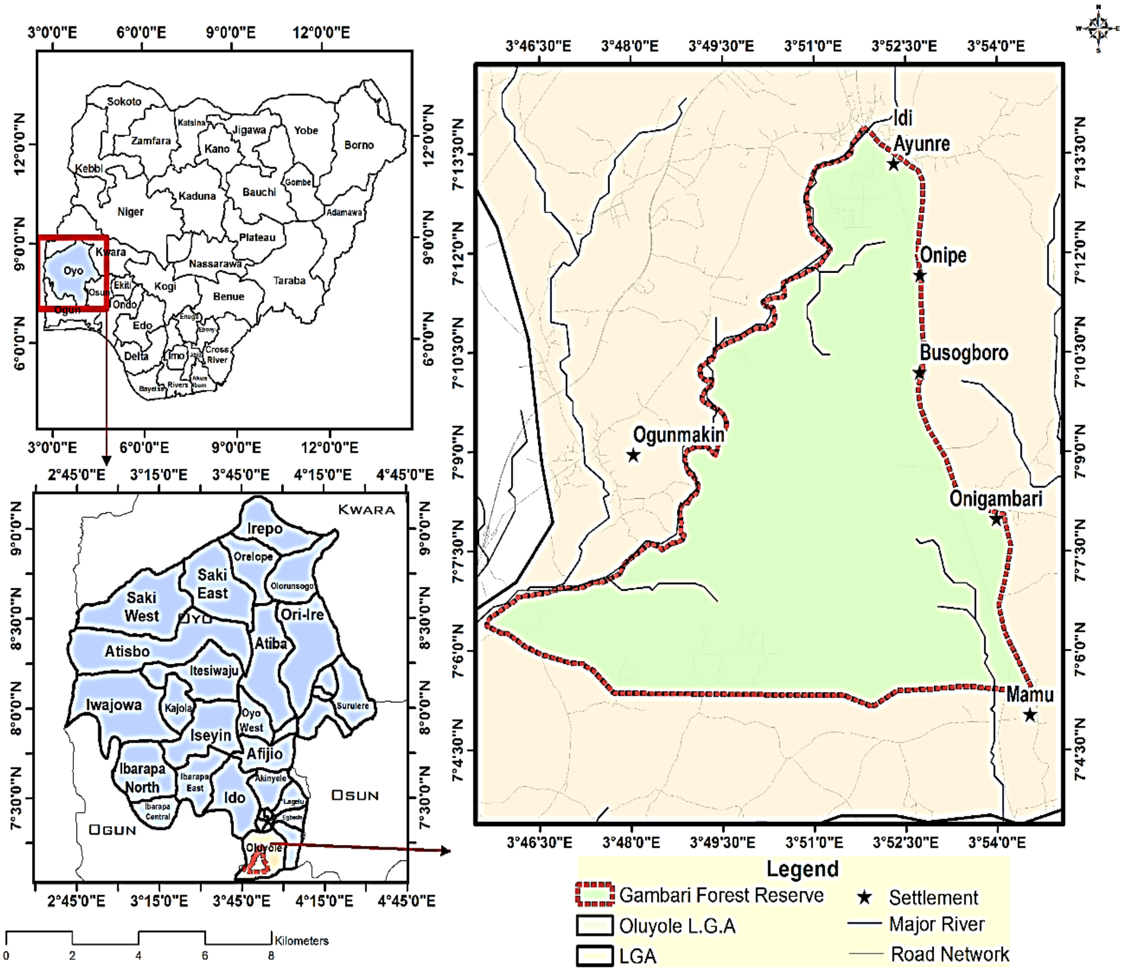

Figure 3.1 Map of Gambari Forest Reserve, Oluyole, Ibadan, Nigeria

The first rainy period spans March to July and the second spans September to November, having their peaks in July and September respectively and a short dry period in August. The monthly relative humidity is more than 80% in the morning, and fluctuates between 60 and 80% in the afternoon, except during January and February when it drops below 60% (Faleyimu and Agbeja, 2004).

3.1.3 Soils of the study site

The soils are derived from dissected Precambrian basement and complex of metamorphic and granite rocks with intrusions of quartzite, schists, gneisses and iron concretions. They are commonly brown, sandy loam, with up to 45 cm depth and in some cases about 1.21 m deep. The soils are rich of clay and ironstone gravel which justifies their classification into the Alfisols group (Adedeji *et al.*, 2015; Ige and Akinyemi, 2015). The clay mineral is kaolinite. The pH ranges between 6.5 and 7.0 but it tends to rise with the litter accumulation (Akinsoji, 2013).

3.1.4 Vegetation of the study area

The forest reserve was a high forest from which many forest products were derived but it has witnessed a series of transformations over the years. It used to be part of the lowland rainforest, but has become more of a derived savanna zone (Fasola, 2007). Nowadays, a large part of the reserve which was a good biodiversity repository for indigenous species such as *Terminalia* spp, *Triplochiton scleroxylon*, *Irvingia gabonensis*, and *Treculia africana* among others, have been converted to agriculture and the establishment of commercial monoculture plantations of tree species such as *Tectona grandis* and *Gmelina arborea* (Ige and Akinyemi, 2015).

Considering the land use type, the forest reserve is divided into Natural Forest and Plantations. The Busogboro zone, which covers our sampling area (Figure 3.) is predominantly made of coppiced *Tectona grandis* plantation. The plantation however, undergoes the incursion of other species from the surrounding vegetation (Ige and Akinyemi, 2015). Plates 3.1 and 3.2 offer a view of Teak plantation stands in the rainy and dry seasons respectively. Bush fire are frequent in the Teak plantation during the dry season. For instance, as sown in plate 3.3, most of our sampling units were burnt during the dry season survey. The forest resources are also used in various ways as shown in Plate 3.4.

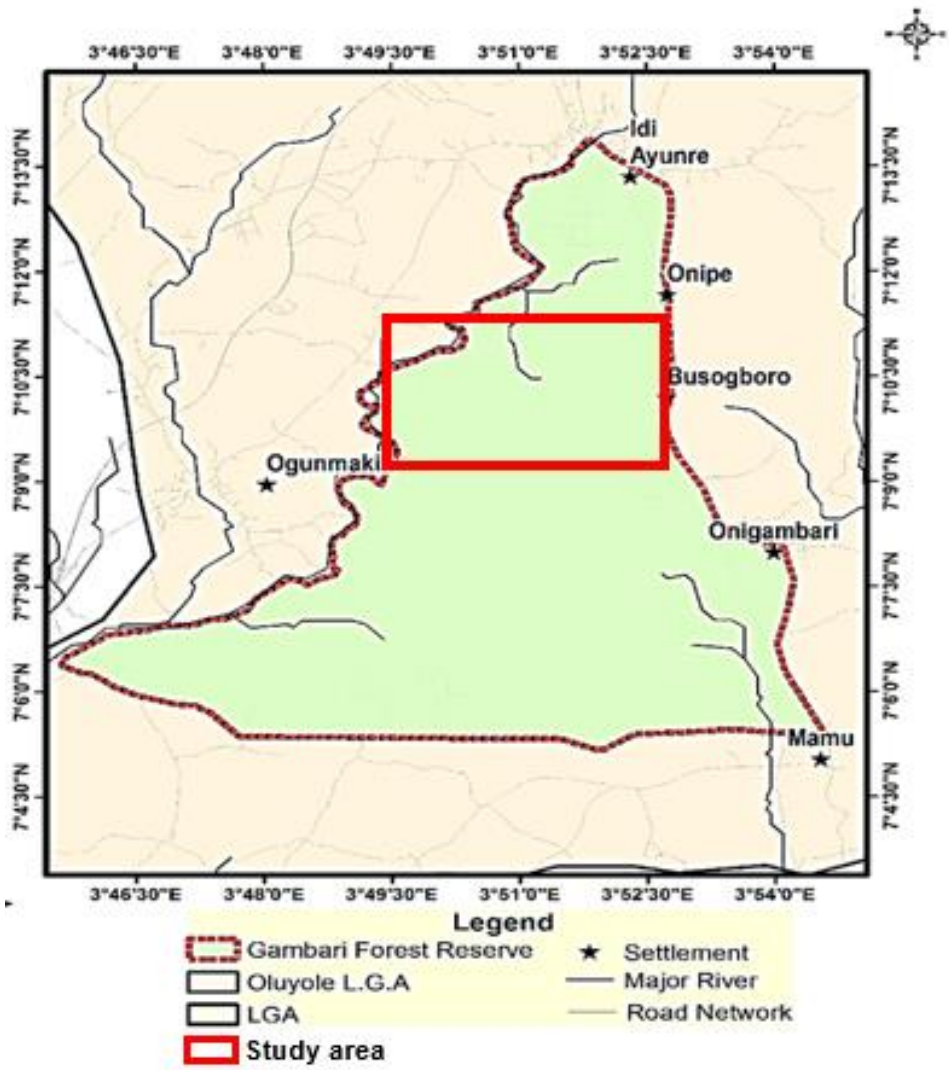

Figure 3.2. Map of Gambari Forest Reserve showing the study area in 2018

Plate 3.1. View of the Teak plantation stand at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria during the rainy season.

Plate 3.2. View of the Teak plantation stand at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria during the rainy season dry season.

Plate 3.3. Bush fire occurrence in Teak plantation stand at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria during the dry season.

A. Fire wood

B. Hardwood

Plate 3.4. Wood exploitation in the Teak plantation at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

3.2 Soil analysis

Five random soil cores (0-15 cm depth) were collected from each main quadrat (50 m x 50 m) for soil physicochemical analysis. The soil samples were bulked and mixed properly to form one composite soil sample for each sampling unit. From the composite soil sample of each unit, one Kg soil was obtained and air-dried at room temperature before being crushed in a mortar, sieved through two mm and 0.5 mm mechanical sieves and subjected to various analyses following the methods used by Egberongbe *et al.* (2017). These helped to understand the variations in the soil properties within the sampling environment and to point out eventual linkages between the soil properties and the vegetation structure. The soil physical and chemical properties analysed were as follows:

3.2.1 Soil pH

The pH was determined in a 1:1 ratio mixture of soil and distilled water (Mclean, 1982). The soils were air-dried then ten grams of each soil was weighed and sieved with a 2 mm sieve. Ten millilitres of distilled water were added and the combination be stirred with a glass rod for 5 minutes in a 50 ml beaker. A glass-electrode pH meter was then inserted into the suspension to measure the pH.

3.2.2 Soil Organic Carbon content

The soil organic carbon was determined using the Walkley-Black wet-oxidation method (Nelson and Sommers, 1982). Half gram of each air-dried soil sample was weighed and sieved (using a 0.5 mm sieve) into a 250 mL conical flask. Ten mL of 1N $K_2Cr_2O_7$ was added to the soil and swirled to mix. Twenty millilitres of concentrated H_2SO_4 were added rapidly and the mixture was left to cool. One hundred millilitres of distilled water were prepared without soil. Three drops of ferroin indicator were added to blank and sample, respectively before titrating with 0.5 N ferrous sulphate until it changed to wine colour.

3.2.3 Soil Total Nitrogen

Total nitrogen was determined using the micro-jeddah digestion-distillation apparatus (Bremner and Mulvaney, 1982). Half gram of 0.5 mm sieved soil was weighed into a 250 mL conical flask. Five millilitres of concentrated H_2SO_4 were added before swirling for 5 minutes and allowed to stand. One tablet of selenium was added as the catalyst. This was digested until a clear substance was attained. The clear substance in the beaker was rinsed and 5 mL of distilled water was added. This was left to settle before pouring into the micro-jeddah apparatus. It was distilled by adding 5 mL of boric acid and NaOH, into the Erlenmeyer flask of the distillation apparatus. The nitrogen content in the distillate was determined by titrating with 0.01 M standard HCl until the colour changed at the end-point from green to pink.

3.2.4 Soil Available Phosphorus

Available phosphorus was determined following the method of Bray and Kurtz (1945). Colorimetric determination of phosphorus in water and soil extracts as described by Olsen and Sommers (1982) was done by weighing two g of soil into a reaction cup. Five millilitres of Melich 3 were added before extracting through Whatman filter paper. Five millilitres of Murphy and Riley colour reagent were added before the addition of 15 mL of distilled water. Phosphorus absorbance was read using the spectrophotometer.

3.2.5 Soil Exchangeable Acidity

This was determined using the KCl extraction method (Smith and Li, 1993). Two grams of air-dry soil was weighed into a 150 mL plastic bottle. Twenty millilitres of 1 N KCl was added and shaken for an hour. This was later filtered through the Whatman N^{o}1 filter paper into a conical flask. Three drops of phenolphthalein indicator were added and it was titrated against 0.01 N NaOH until the colourless solution turned pink.

3.2.6 Soil Exchangeable Bases

The exchangeable bases were determined from 5 g of air-dried soil using 100 mL neutral ammonium acetate as the extractant (Rhoades, 1982a). Five grams of air-dried soil was weighed into a plastic bottle and 100 mL of neutral 1 M ammonium acetate was added. The mixture was mechanically shaken for 10 minutes and filtered through Whatman N^{o}1 filter paper into a 100 mL volumetric flask. This was later made up to mark with acetate. Calcium and magnesium were determined from the extract by 0.01 M EDTA titration method, while sodium and potassium were determined using the flame photometer (Evans, 1982).

3.2.7 Soil Micronutrients

The soil Iron, Copper, Manganese, and Zinc contents were determined using the hydrochloric acid procedure (Rhoades, 1982b). Ten grams of soil was measured into a plastic bottle and 100 mL of 0.1 M HCl was added before a stopper was inserted. This was shaking for 10 minutes before filtering through Whatman filter paper No. 42. The nutrients were determined using the atomic absorption spectrophotometer (Evans, 1982).

3.2.8 Soil Particle size Distribution

The particle size analysis followed Bouyoucous hydrometric method (Bouyoucos, 1951; Gee and Bauder, 1986). Fifty grams of air-dried soil was weighed into a dispersion cup. Twenty millilitres of 25% sodium hexametaphosphate (Calgon) was added as the dispersant. Two hundred and fifty millilitres of water were added and the mixture was subjected to the mechanical stirrer for 10 minutes. After stirring, the suspension was decanted into a sedimentation cylinder through a 210-micron sieve. The coarse fraction collected in the sieve was oven-dried in a moisture can at 105°C and weighed. The suspension in the sedimentation cylinder was topped to the 1 L mark by adding distilled water. The temperature and density of the suspension were taken with the aid of a thermometer and the Bouyoucos hydrometer, respectively at 1 minute (silt and clay concentration) and 2 hours (clay concentration).

3.3 Analysis of the vegetation trend in the last three decades

Geographic Information System (GIS) and Remote Sensing procedures were used to assess the trend of changes in the vegetation structure over the last thirty years. Three Landsat images (1984, 2000 and 2018) of the Forest Reserve area are obtained. Table 3.1 gives detailed information on the images collected. The images which cover Landsat Band 7, Band 3 and Band 4 were subjected to Geospatial analysis using ArcGIS 10.3 software to create composite imagery for each year. The study area selected was then cropped out from the composite imagery and classified into five classes: built-up area, the water body, bare soil, forest vegetation, and grassland.

3.4 Determination of the floristic composition of the study area

3.4.1 Sampling techniques

The enumeration of the plant species was conducted in July and August, 2018 for the wet season survey and in January and February, 2019 for the dry season survey. A random sampling technique was adopted to layout 30 sampling quadrats of 50 m x 50 m (Main quadrat) surface within the plantation zone (Figure 3.3). The geographical coordinates of the centre of each main plot (50 m x 50 m) were recorded with a GPS device (Garmin GPS Map78s). The coordinates of the main sampling quadrat are shown in Table 3.2.

Table 3-1 LandSat images used to analyse the land cover and vegetation in Gambari Forest Reserve over the last three decades.

Satellite	Sensor	Band	Spectral Range	Pixel Resolution	Year
L1-4	MSS Multi-spectral	1,2,3,4,7	0.5-1.1µm	30 meters	1984
L 4-5	TM Multi-spectral	1,2,3,4,7	0.45-2.35 µm	30 meters	2000
L7&8	ETM+ Multi-spectral	1,2,3,4,7	0.45-2.35 µm	15 meters	2018

Source : NASA Program, Landsat ETM+ Scene, USGS, Soux Falls.

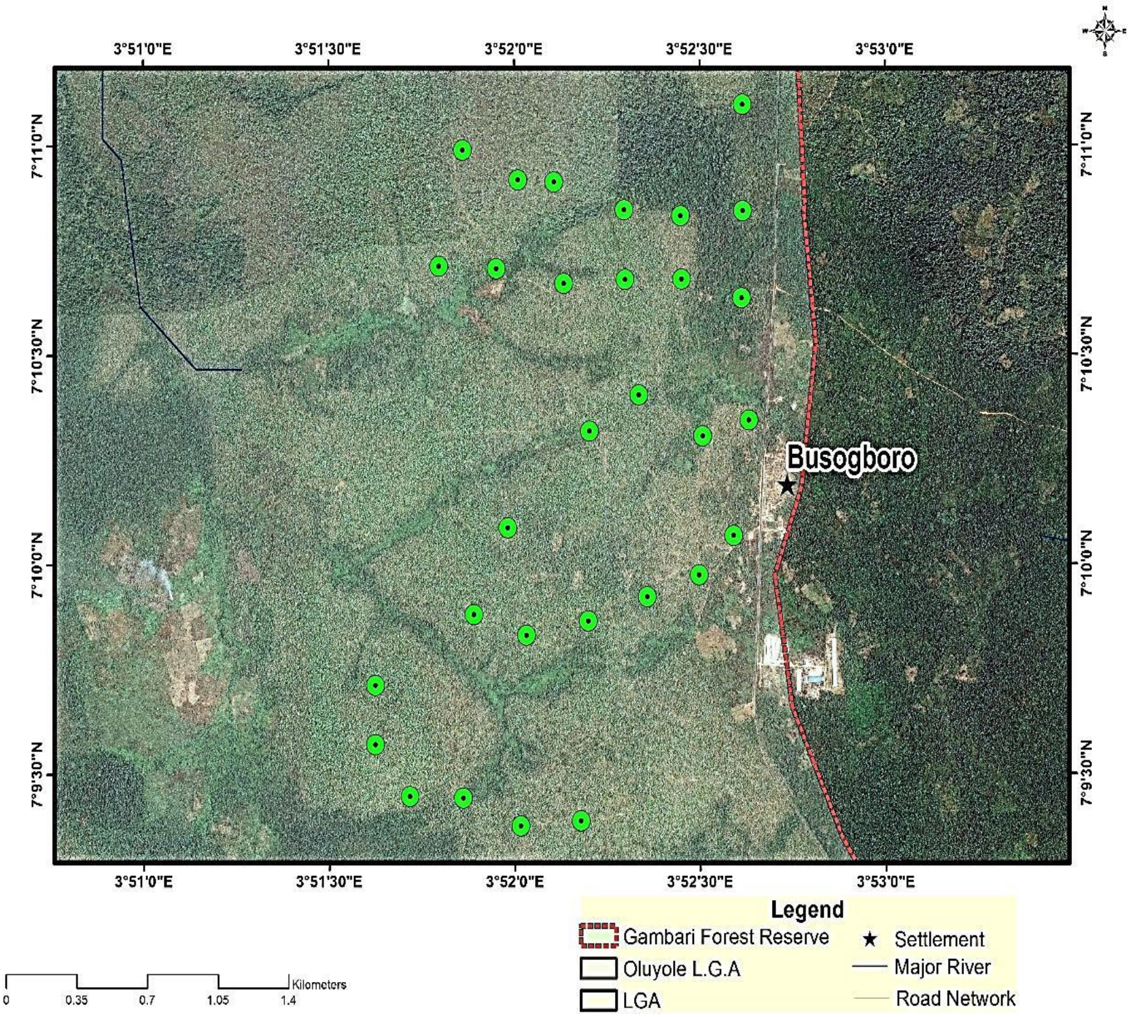

Figure 3.3 Location of the sampling units in the Teak plantation at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

Table 3.2 GPS coordinates of the sampled locations in the Teak plantation at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

Quadrats	Latitude	Longitude	Elevation
Quadrat 1	N 07°11.097'	E 003°52.597'	162 m
Quadrat 2	N 07°10.843'	E 003°52.614'	157 m
Quadrat 3	N 07°10.831'	E 003°52.447'	155 m
Quadrat 4	N 07°10.846'	E 003°52.295'	140 m
Quadrat 5	N 07°10.917'	E 003°52.008'	164 m
Quadrat 6	N 07°10.989'	E 003°51.859'	158 m
Quadrat 7	N 07°10.635'	E 003°52.611'	152 m
Quadrat 8	N 07°10.680'	E 003°52.449'	153 m
Quadrat 9	N 07°10.679'	E 003°52.297'	153 m
Quadrat 10	N 07°10.670'	E 003°52.132'	145 m
Quadrat 11	N 07°10.706'	E 003°51.950'	137 m
Quadrat 12	N 07°10.712'	E 003°51.795'	143 m
Quadrat 13	N 07°10.343'	E 003°52.630'	153 m
Quadrat 14	N 07°10.306'	E 003°52.506'	148 m
Quadrat 15	N 07°10.404'	E 003°52.334'	150 m
Quadrat 16	N 07°10.318'	E 003°52.200'	157 m
Quadrat 17	N 07°10.198'	E 003°52.105'	166 m
Quadrat 18	N 07°10.087'	E 003°51.980'	158 m
Quadrat 19	N 07°10.068'	E 003°52.589'	155 m
Quadrat 20	N 07°09.974'	E 003°52.496'	150 m
Quadrat 21	N 07°09.922'	E 003°52.356'	165 m
Quadrat 22	N 07°09.864'	E 003°52.197'	168 m
Quadrat 23	N 07°09.831'	E 003°52.030'	154 m
Quadrat 24	N 07°09.880'	E 003°51.889'	155 m
Quadrat 25	N 07°09.388'	E 003°52.177'	162 m
Quadrat 26	N 07°09.376'	E 003°52.014'	162 m
Quadrat 27	N 07°09.442'	E 003°51.859'	161 m
Quadrat 28	N 07°09.446'	E 003°51.716'	157 m
Quadrat 29	N 07°09.570'	E 003°51.623'	171 m
Quadrat 30	N 07°09.712'	E 003°51.623'	153 m

3.4.2 Data collection

The 50 m x 50 m square quadrats (Figure 3.4) were used in the first instance to enumerate all tree species. Then five sub-quadrats (10 m x 10 m) were laid one at each corner and at the centre of the main quadrat to assess understory plants (shrubs and climbers) species (Awodoyin *et al.*, 2013). Within each 10 m x 10 m sub-quadrat five 1 m x 1 m sub-sub-quadrats, one at each corner and one at the centre were laid out for the assessment of the herbaceous plant species. The total number of quadrats per plant life forms are given in Table 3.3. All the species occurring in the quadrats and their respective numbers were recorded with species raw data matrices. Dendrometry parameters such as the diameter at breast height (DBH; 1.3 m), and the total plant height were also recorded for the main tree species during the rainy season survey using a meter tape and a Haga Altimeter respectively.

3.4.3 Data analysis

The species composition and population structure were analysed using Microsoft Excel spreadsheets. The Paleontological statistics (PAST) software was used to perform the calculation the community structure indices, as follows:

3.4.3.1 Abundance

The species abundance was calculated using the formula:

$$\text{Abundance} = \frac{Total\ number\ of\ individuals\ of\ a\ species\ in\ all\ quadrats}{Total\ number\ of\ quadrats\ in\ which\ the\ species\ occurred} \quad (1)$$

3.4.3.2 Density and relative density

The species density represents the number of a species per unit area.

Density (D) and Relative Dominance (RD) were calculated as:

$$\text{Density} = \frac{Total\ number\ of\ individuals\ of\ a\ species\ in\ all\ quadrats}{Total\ number\ of\ quadrats} \quad (2)$$

$$\text{Relative density } (RD)\% = \frac{Density\ of\ a\ species}{Total\ density\ of\ all\ species}\ x\ 100 \quad (3)$$

3.4.3.3 Frequency and relative frequency

The species frequency is a measure of the degree of uniformity with which individuals of a species are distributed in an area. It was calculated as:

$$\text{Frequency (F)}\% = \frac{Number\ of\ quadrats\ in\ which\ the\ species\ occurred}{Total\ number\ of\ quadrats}\ x\ 100 \quad (4)$$

$$\text{Relative frequency (RF)}\% = \frac{Frequency\ of\ a\ species}{Total\ frequency\ of\ all\ species}\ x\ 100 \quad (5)$$

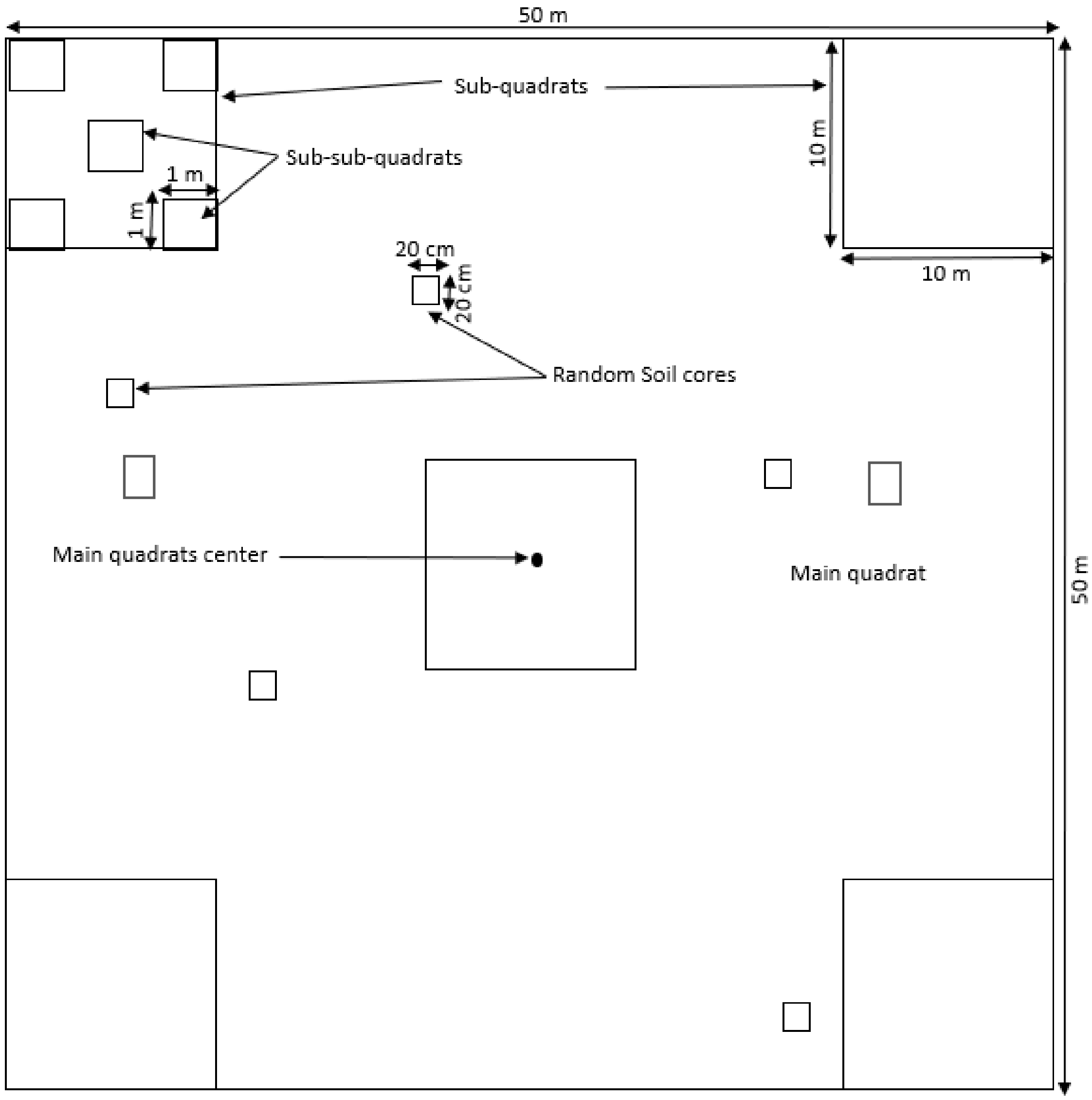

Figure 3.4 Layout of the sampling units for the standing vegetation plant species enumeration and soil sample collection in the Teak plantation stand at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

Table 3.3 Number of Quadrats based on the plant life forms in the Teak plantation at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

Life form	Number of quadrats
Trees 50 x 50 m	30
Under-story 10 x 10 m	150
Herbaceous1 x 1 m	750
Seed bank 0-5 cm depth Soil cores	30
Seed bank 5-10 cm depth Soil cores	30

3.4.3.4 Relative Importance Value (RIV)

The species relative importance value (RIV) was computed with the formula:

$$\text{RIV \%} = \frac{Relative\ Density + Relative\ Frequency}{2}\ x\ 100 \quad (6)$$

3.4.3.5 Community structure

It was estimated by the Shannon Wiener index of diversity (H') calculated using the formula:

$$\text{H}' = -\sum_{i=0}^{S} pi\ Lnpi \quad (7)$$

Where H′ is the Shannon diversity index, S is the total number of species in the community, pi is the proportion of a species to the total number of plants in the community and Ln is the natural logarithm (Awodoyin *et al.*, 2013; Lawal and Salami, 2018).

The dominance D and the Simpson diversity index were calculated by:

$$\text{Dominance D } = \frac{\sum_{i=1}^{p} ni(\text{ni}-1)}{N(N-1)} \quad (8)$$

Where N= total number of individuals of all the species, in total induvial of the i^{th} species, p = number of different species enumerated.

Simpson index of diversity was calculated by

$$\text{Simpson index} = (1 - D) \quad (9)$$

Where D = dominance.

The mode of distribution and evenness of species was calculated by equitability index (J):

$$\text{J } = \frac{H'}{Ln(S)} \quad (10)$$

Where J is the equitability index, H′ is the Shannon diversity index, S is the total number of species in each community, and Ln is the natural logarithm (Awodoyin *et al.*, 2013; Lawal and Salami, 2018).

3.5 Determination of the floristic composition of the soil seed bank

3.5.1 Collection of soil samples

Composite soil samples were collected from each sampling unit during the wet and dry season to assess the spatial and temporal heterogeneity of the soil seed bank. In each main quadrat, five soil cores (each 20 cm x 20 cm) were randomly collected for the purpose of seed bank study. The soil samples were collected at two different levels 0-5 cm, 5-10 cm depths. The soil samples from each depth were mixed and bulked properly to get one composite soil sample for the seedling emergence experiment. The bulking of soil samples was to ensure the integration of the spatial heterogeneity of soil seed bank distribution (Chima *et al.*, 2013). In total, 30 soil cores per depth category for soil seed bank seedling enumeration (Table 3.3).

3.5.2 Monitoring of the seedling sprouting

The monitoring of the seedling sprouting from the soil seed bank was carried out for five months for each season soil cores. The experiment was carried out in the screen house of the Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria. The soil samples were cleaned by removing the roots and debris then air-dried at room temperature (Plate 3.5). From each soil sample of each sampling unit, 1 kg of soil was spread in a plastic tray (20 cm x 20 cm surface area x 3 cm depth) and replicated 3 times, making a total of 90 germination trays per depth category and 180 germination trays for each season (Table 3.4). The germination trays were watered regularly all along the survey process. Excess water drained out through the perforation laid at the base of each plastic tray. The layout of the seedling pots in the screen house is shown in Plate 3.6. Emerging seedlings that were easily identifiable were counted, recorded and discarded on a two weeks basis process for a duration of five months for each sample. Seedlings that were difficult to identify were counted, labelled, transplanted and grown separately until they could be identified. For each sample category, the species composition and diversity parameters were assessed.

3.5.3 Data analysis

The species composition and population structure were made through the Microsoft Excel spreadsheet. The Paleontological statistics (PAST) software was used to perform the calculation the community structure indices. Data of plant species were analysed following the formulae in section **3.4.3.**

Table 3.4 Number of seedling germination trays per season and soil depth level laid out in the screen house.

Season	Wet Season	Dry Season	Total
0-5 cm	90	90	180
5-10 cm	90	90	180
Total	180	180	360

Plate 3.5. Soil samples air dried at room temperature.

A. Wet season

B. Dry season

Plate 3.6. Layout of the seedling germination pots in the screen house.

3.6 Similarity between the vegetation and soil seed bank

Jaccard similarity index was used to analyse the similarity between the standing vegetation and the soil seed bank based on their species composition. The similarity index was computed using the formula:

$$J_{SI} = \frac{a}{(a+b-c)} \qquad (11)$$

Where: **a** is the total number of species in the first sample, **b** is the total number of species in the second sample, c is the number of species common to the two sets of samples and $\boldsymbol{J_{SI}}$ is the the Jaccard similarity index.

3.7 Teak carbon stock estimation

Non-destructive and allometric procedure were adopted to assess the amount of carbon stock of the Teak stands. We used an allometric equations based on the diameter at breast height (DBH) and were used to estimate the above ground tree biomass and we later inferred the below ground (root biomass) tree biomass from the above ground biomass. In each 50 m x 50 m quadrat, the diameter at breast height (DBH) of all Teak individuals with a minimum DBH of 30 cm was measured at 1.30 m from the ground surface (Li *et al.*, 2011; N'Gbala *et al.*, 2017)

The total tree biomass was calculated using the equation:

$$Total\ Biomass = Aboveground + Belowground\ Biomass \qquad (12)$$

The Above ground biomass was estimated using the allometric equation below recommended by IPCC (2003) and used by N'Gbala *et al.* (2017) in Cote d'Ivoire to estimate carbon stock in Teak plantation stands:

$$ABG = 0.153DBH^{2.382} \qquad (13)$$

Where ABG = above ground biomass, DBH = diameter at breast hight.

The below ground biomass was inferred from the above ground following the method of N'Gbala *et al.* (2017). The formula below was used for that purpose:

$$BGB = e^{(-1.0587+0.8836\ln(ABG))} \qquad (14)$$

Where BGB = below ground biomass and ABG = above ground biomass.

The total tree carbon stock was then estimated from the tree total biomass by multiplying the later by 0.5 as recommended by IPCC (2003).

CHAPTER FOUR

4.0 RESULTS

4.1 Soil physicochemical characteristics in Teak plantation at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria

The soil was mainly Sandy Loam. The pH is key to plant nutrients availability in the soil as it control the chemical forms of the different nutrients and influence their reactions. The pH of our stand tends to be acidic but fall in the optimum pH range for most plants with a mean of 6.24 ± 0.030. The soil organic matter and soil organic carbon content are related to the productivity of a soil and its ability to sustain the plant communities of the site. The soil organic carbone was 1.950% (± 0.120); the organic matter was 3.368 % (± 0.209) while the total nitrogen was 0.192% (± 0.027) across the plantation. On the other hand, the nutrient content was suitable across the plantation area. The Sodium content was 1.152 Cmol/kg (± 0.024); the calcium was 15.347 Cmol/kg (± 0.973); the magnesium was 1.959 Cmol/kg (± 0.149) the potassium was 0.464 Cmol/kg (± 0.027) and the iron was 1672.666 mg/kg (± 123.730). Detailed information of the means (± standard errors) of the physical and chemical characteristics of the soil across the plantation are presented in Table 4.1.

4.2 The vegetation trend over the last three decades

The land cover classification done on three different images revealed a change of the vegetation from 1984 (Figure 4.1) to 2000 (Figure 4.2) and 2018 (4.3). Although the built-up areas and grassland continue to increase in the forest reserve reflecting the continuous degradation of the forest vegetation and an increasing opening of the vegetation across the reserve, there was an increase in the forest plantation in the study site. Land cover dynamic was dominated by a considerable increase of forest plantation and other agricultural use. For instance, bare soil which occupied more than a half of the area was the most extensive land cover class in 1984. Along the time the bare soil was increasingly replaced by tree plantations which cover around half of site in 2018. On the other hand, the natural and secondary forest have drastically reduced between 1984 and 2018 indicating rapid deforestation and land degradation in the forest reserve overtime.

Table 4.1 Mean (± standard error) of the soil physicochemical properties in Teak plantation stand at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

Soil properties	Mean ± SE
pH(H_2O)	6.235 ± 0.029
O.C %	1.950 ± 0.120
O.M %	3.368 ± 0.209
TN %	0.192 ± 0.027
Na Cmol/kg	1.152 ± 0.024
Ca Cmol/kg	15.347 ± 0.973
Mg Cmol/kg	1.959 ± 0.149
K Cmol/kg	0.464 ± 0.027
Fe mg/kg	1672.666 ± 123.730
Cu mg/kg	3.87 ± 0.304
Mn mg/kg	571.9 ± 49.490
Zn mg/kg	118.133 ± 11.197
P mg/kg	160.611 ± 17.854
% Sand	78.106 ± 1.009
% Clay	11.833 ± 0.536
% Silt	10.06 ± 0.894

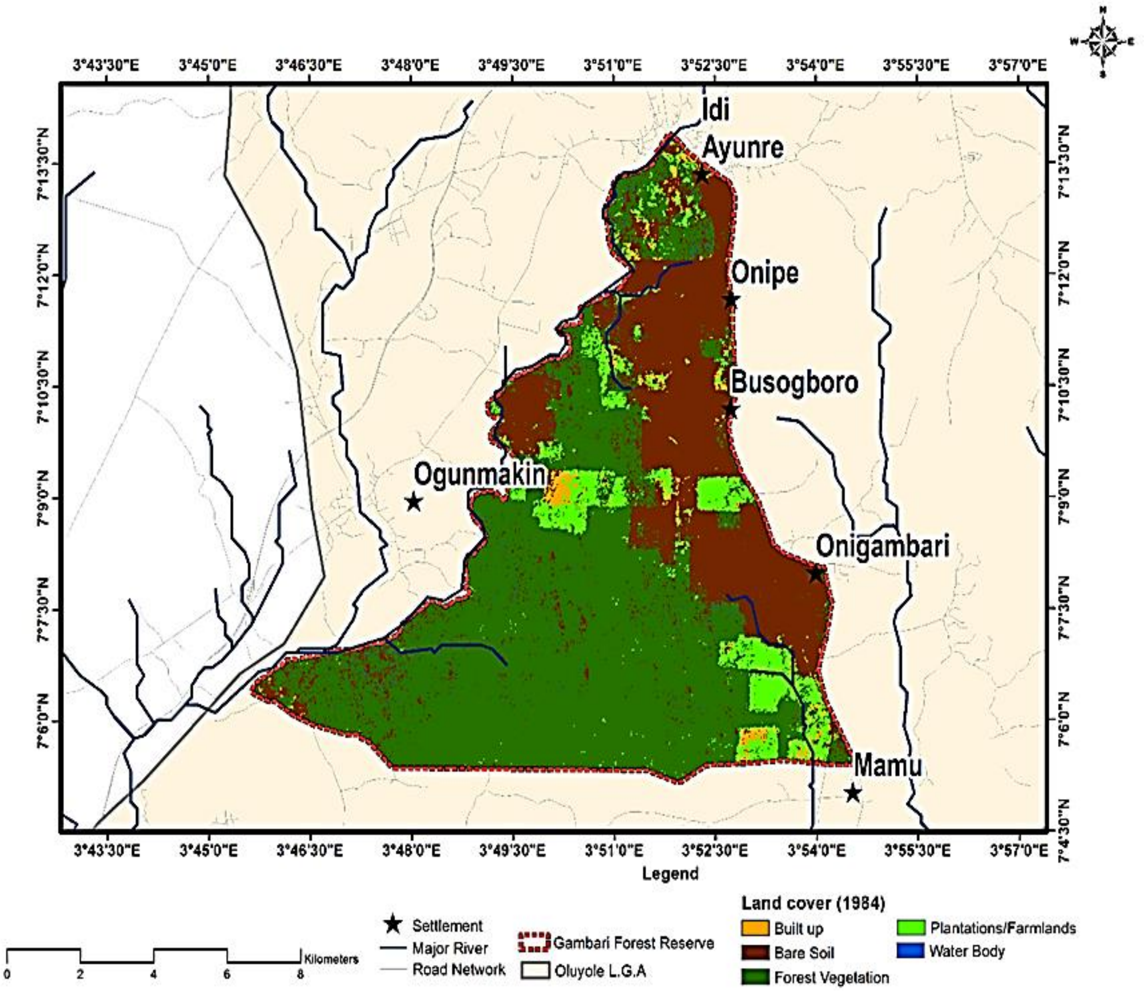

Figure 4.1 State of the vegetation of Gambari Forest Reserve, Ibadan, Nigeria in 1984.

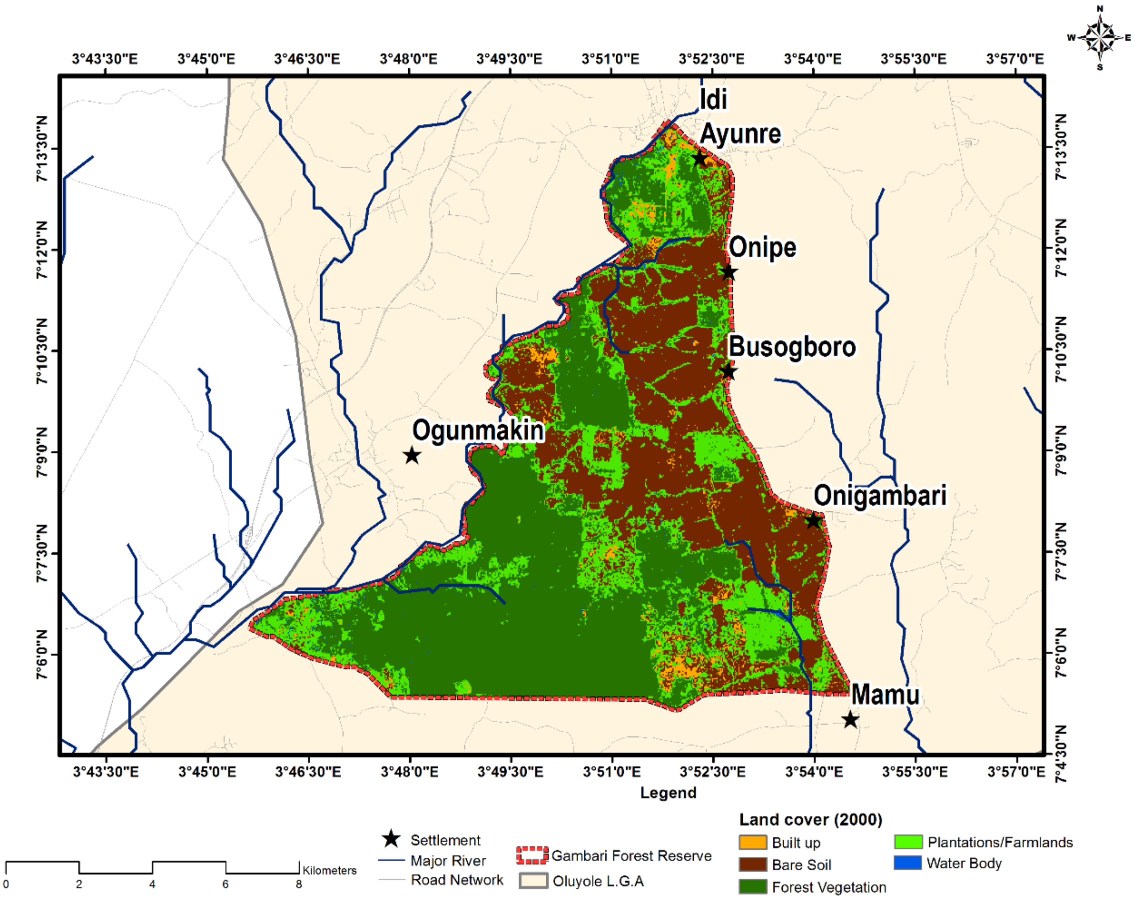

Figure 4.2 State of the vegetation of Gambari Forest Reserve, Ibadan, Nigeria in 2000

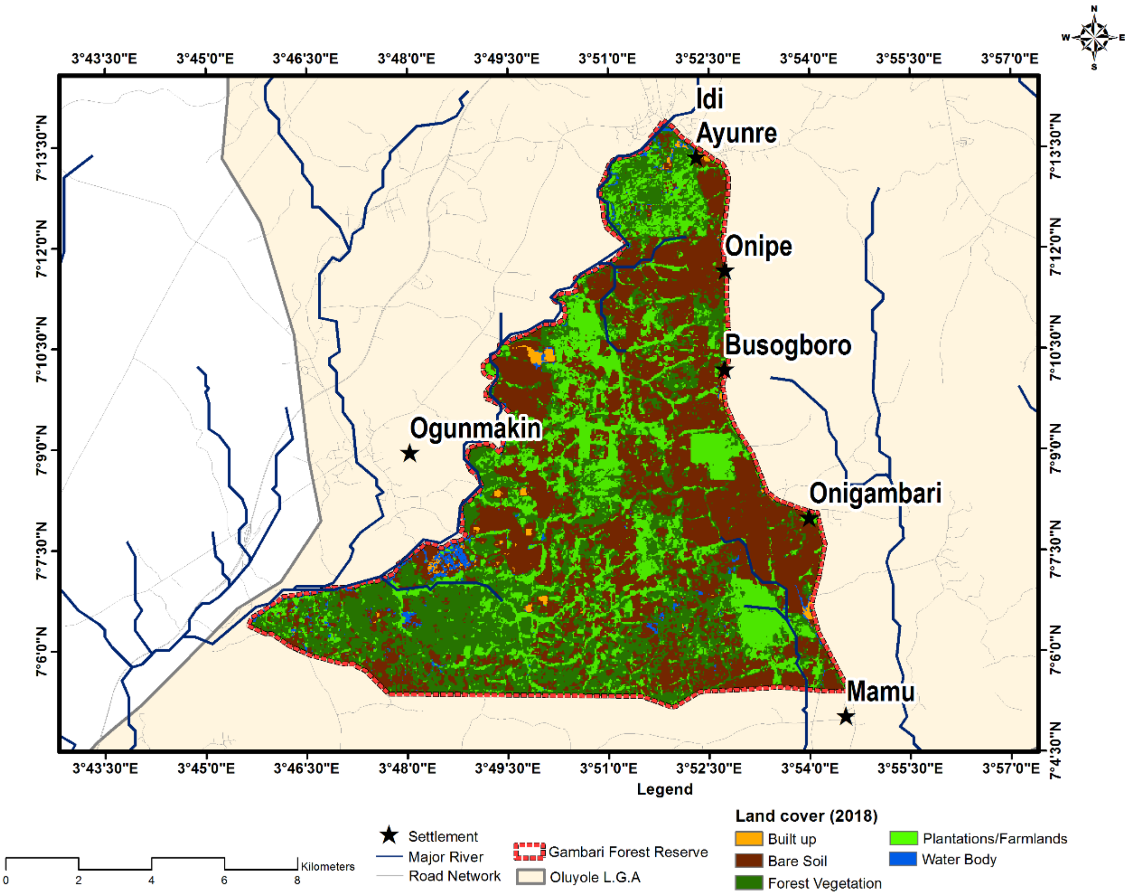

Figure 4.3 State of the vegetation of Gambari Forest Reserve, Ibadan, Nigeria in 2018

4.3 Floristic composition and taxonomic diversity

The taxonomic composition, habit and area of origin of the recorded flora both in the seed bank and the aboveground vegetation is shown in Table 4.2. A total of 126 species belonging to 112 genera and 41 families were recorded. Among these species, 106 were found in the standing vegetation while 41 species were recorded in the seed bank. There was a wide gap between the overall seed bank composition and the overall above ground plant species composition because only 21 species were commonly recorded both in the seed bank and aboveground vegetation while 85 species were found only in the above ground flora and 20 other species belonged to the seed bank only. Trees were dominant in the vegetation (34.91%) followed by the shrubs and herbs 19.81% and 17.92% respectively. The soil seed bank species richness was dominated by the herbs (60.98%). The grass and shrubs species were co-dominant in the soil seed bank each representing 14.63% of the species emerged. Despite the exotic species monocropping system of the plantation stand, native species were well represented both in the standing vegetation and soil where they account for 77.36% and 68.29% of the flora respectively. The family with the highest number of species was Fabaceae with 16 species followed by Poaceae with 13 species, Malvaceae with 9 species and Apocynaceae with 7 species. However, most of the families have 3 or less species density. Detailed information of the species densities per families and per genera are presented in Table 4.3. The larger values of the diversity indices were found in the soil seed bank where the Shannon-Wiener (H') was up to 3.01 in the 0 to 5 cm soil depth of the dry season seed bank while the Simpson index which follows the same trend was 0.92 in the same layer in the dry season (Table 4.4).

4.4 The above ground vegetation

The above ground flora was rich with a total of 106 species encountered in the different plant life forms. All the species recorded during the dry season survey were also present during the wet season record. The 24 main tree species were recorded both in the wet season and the dry seasons. However, the number of individuals has decreased. The shrubs and herbaceous flora decreased both in their species richness and density during the dry season survey.

Although the number of the main tree species has remained constant (24 species) for the trees with their girth at 1.30 m, one tree species recorded in the younger layer

Table 4-2 list of species recorded in the vegetation and soil seed bank of a coppiced teak plantation in Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

No	Family	Genera	Species	Habit	Origin	vegetation	Seed bank
1	Acanthaceae	Phaulopsis	*Phaulopsis ciliata* (Willd.) Hepper	Herb	Native	+	+
2	Alzoaceae	Trianthema	*Trianthema portulacrastrum* Linn.				+
3	Amaranthaceae	Alternanthera	*Alternanthera sessilis* (L.) R. Br. Ex DC.	Herb	Exotic	+	+
4		Amaranthus	*Amaranthus spinosus* Linn.				+
5		Celosia	*Celosia leptostachya* Benth.	Herb	Native	+	+
6			*Celosia trigyna* Linn.				+
7		Cyathula	*Cyathula prostrata* (L.) Blume	Herb	Native	+	+
8		Gomphrena	*Gomphrena celosiodes* Mart.				+
9	Annonaceae	Annona	*Annona senegalensis* Pers.	Tree	Native	+	
10		Cleistopholis	*Cleistopholis patens* (Benth.) Engl. & Diels	Tree	Native	+	
11	Apocynaceae	Alstonia	*Alstonia boonei* De Wild	Tree	Native	+	
12			*Alstonia congensis* Engl.	Tree	Native	+	

Table 4-2 cont'd. list of species recorded in the vegetation and soil seed bank of a coppiced teak plantation in Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

No	Family	Genera	Species	Habit	Origin	vegetation	Seed bank
13		Ancylobotrys	*Ancylobotrys amoena* Hua	Liane	Native	+	
14		Funtumia	*Funtumia africana* (Benth.) Stapf	Tree	Native	+	
15			*Funtumia elastica* (P. Preuss) Stapf	Tree	Native	+	
16		Parquetina	*Parquetina nigrescens* (Afzel.) Bullock.	Vine	Native	+	
17		Rauvolfia	*Rauvolfia vomitora* Afzel.	Shrub	Native	+	
18		Secamone	*Secamone afzelli* (Schulfes) K. Schum.	Vine	Native	+	
19	Arecaceae	Elaeis	*Elaeis guineensis* Jacq.	Tree	Native	+	
20		Laccosperma	*Laccosperma secundiflora* (P. Beauv.) Kuntze	Rattan	Native	+	
21	Asteraceae	Ageratum	*Ageratum conyzoides* Linn.	Herb	Native	+	
22		Chromolaena	*Chromolaena odorata* (Linn.) R. King & H. Robinson	Shrub	Exotic	+	+
23		Crassocephalum	*Crassocephalum crepidoides* (Benth.) S. Moore.	Herb	Native	+	

Table 4-2 Cont'd. list of species recorded in the vegetation and soil seed bank of a coppiced teak plantation in Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

No	Family	Genera	Species	Habit	Origin	vegetation	Seed bank
24		Melanthera	*Melanthera scadens* (Schum. & Thonn.) Roberty				+
25		Synedrella	*Synedrella nodiflora* (Linn.) Gaert.	Herb	Exotic	+	
26		Tithonia	*Tithonia diversifolia* (Helmsl.) A. Gray	Shrub	Exotic	+	+
27	Bignoniaceae	Kigelia	*Kigelia africana* (Lam.) Benth.	Tree	Native	+	
28		Markhamia	*Markhamia tomentosa* (Benth.) K. Shum. Ex Engl.	Tree	Native	+	
29		Newbouldia	*Newbouldia laevis* Seem. Ex Bureau	Tree	Native	+	
30	Boraginaceae	Cordia	*Cordia auriantiaca* Baker	Tree	Native	+	
31			*Cordia millenii* Baker	Tree	Native	+	
32		Heliotropium	*Heliotropium indicum* Linn.	Herb	Native	+	
33	Cannabaceae (Ulmaceae)	Celtis	*Celtis adolfi-friderici* Engl.	Tree	Native	+	
34			*Celtis integrifolia* Lam.	Tree	Native	+	

Table 4-2 Cont'd. list of species recorded in the vegetation and soil seed bank of a coppiced teak plantation in Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

No	Family	Genera	Species	Habit	Origin	vegetation	Seed bank
35	Clusiaceae	Harungana	*Harungana madagascariensis* Lam. Ex Poir.	Shrub	Native	+	
36	Commelinaceae	Commelina	*Commelina benghalensis* Linn.	Herb	Native	+	+
37			*Commelina erecta* Linn.	Herb	Native	+	+
38		Palisota	*Palisota hirsuta* (Thunb.) K. Schum.	Herb	Native	+	
39	Cyperaceae	Cyperus	*Cyperus esculentus* Linn.	Sedge	Cosmopolitan	+	
40		Mariscus	*Mariscus alternifolius* Vahl.	Sedge	Native	+	+
41	Dioscoreaceae	Dioscorea	*Dioscorea dumetorum* (Kunth) Pax	Vine	Native	+	
42			*Dioscorea Praehensilis* Benth.	Vine	Native	+	
43	Euphorbiaceae	Acalypha	*Acalypha ciliata* Forsk.				+
44		Alchorneae	*Alchorneae laxiflora* (Benth.) Pax & K. Hoffim.	Shrub	Native	+	
45		Croton	*Croton lobatus* Linn.				+

Table 4-2 Cont'd. list of species recorded in the vegetation and soil seed bank of a coppiced teak plantation in Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

No	Family	Genera	Species	Habit	Origin	vegetation	Seed bank
46			*Croton zambesicus* Muell. Arg.	Tree	Native	+	
47		Euphorbia	*Euphorbia hirta* Linn.				+
48		Macaranga	*Macaranga barteri* Muell. Arg.	Shrub	Native	+	
49		Phylathus	*Phylathus amrus* Schum. & Thonn.				+
50	Leguminoseae	Abrus	*Abrus precatorius* Linn.	Vine	Native	+	
51		Acacia	*Acacia ataxacantha* DC.	Shrub	Native	+	
52		Albizia	*Albizia zygia* (DC.) J. F. Macbr.	Tree	Native	+	
53		Amphimas	*Amphimas pterocarpoides* Harms	Tree	Native	+	
54		Calopogonium	*Calopogonium mucunoides* Desv.				+
55		Desmodium	*Desmodium velutinum* (Willd.) DC.	Herb	Cosmopoli tan	+	
56		Dialium	*Dialium guineense* Willd.	Tree	Native	+	

Table 4-2 Cont'd. list of species recorded in the vegetation and soil seed bank of a coppiced teak plantation in Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

No	Family	Genera	Species	Habit	Origin	vegetation	Seed bank
57		Eurythrophleum	*Eurythrophleum guineensis* G. Don.	Tree	Native	+	
58		Gliricidia	*Gliricidia sepium* (Jacq.) Kunth ex Walp.	Shrub	Exotic	+	
59		Leptoderris	*Leptoderris micrantha* Dunn	Vine	Native	+	
60		Milletia	*Milletia thonningii* (Schumach. & Thonn.) Baker	Shrub	Native	+	
61		Mimosa	*Mimosa pudica* Linn.	Herb	Exotic	+	+
62		Mucuna	*Mucuna flagellipes* Hook. F.	Vine	Native	+	
63			*Mucuna sloanei* Fawc. & Rendle	Vine	Native	+	
64		Phaseolus	*Phaseolus lunatus* Linn.	Vine	Exotic	+	+
65		Piptadeniastrum	*Piptadeniastrum africanum* (Hook. f.) Brenan	Tree	Native	+	
66	Icacinaceae	Icacina	*Icacina trichantha* Olii.	Liane	Native	+	
67	Irvingiaceae	Irvingia	*Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill.	Tree	Native	+	
68	Lecythidaceae	Napoleonaea	*Napoleonaea vogelii* Hook & Planch	Shrub	Native	+	

Table 4-2 Cont'd. list of species recorded in the vegetation and soil seed bank of a coppiced teak plantation in Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

No	Family	Genera	Species	Habit	Origin	vegetation	Seed bank
69	Loganiaceae	Spigelia	*Spigelia anthelmia* Linn.				+
70	Loranthaceae	Phragmanthera	*Phragmanthera capitata* (Spreng.) Balle	Shrub	Native	+	
71	Lythraceae	Lawsonia	*Lawsonia inermis* Linn.	Shrub	Native	+	
72	Malvaceae	Bombax	*Bombax buonopozense* P. Beauv.	Tree	Native	+	
73		Ceiba	*Ceiba pentandra* (Linn.) Gaertn.	Tree	Native	+	
74		Cola	*Cola gigantea* A. Chev.	Tree	Native	+	
75		Dombeya	*Dombeya buettneri* K. Schum.	Shrub	Native	+	
76		Grewia	*Grewia carpinifolia* Juss.	Shrub	Native	+	
77		Sida	*Sida acuta* Burm. F.	Shrub	Pantropical	+	+
78			*Sida garckeana* Polak.				+
79		Triplochiton	*Triplochiton scleroxylon* K. Schum.	Tree	Native	+	
80		Waltheria	*Waltheria indica* Linn.	Herb	Exotic	+	+
81	Meliaceae	Cedrela	*Cedrela odorata* Linn.	Tree	Exotic	+	

Table 4-2 Cont'd. list of species recorded in the vegetation and soil seed bank of a coppiced teak plantation in Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

No	Family	Genera	Species	Habit	Origin	vegetation	Seed bank
82	Menispermaceae	Chasmanthera	*Chasmanthera dependens* Hochst.	Vine	Native	+	
83		Rhigiocarya	*Rhigiocarya racemifera* Miers	Liane	Exotic	+	
84	Moraceae	Ficus	*Ficus exasperata* Vahl.	Tree	Native	+	
85			*Ficus tonningii* Blume	Tree	Native	+	
86	Moraceae	Milicia	*Milicia excelsa* (Welw.) C. C. Berg	Tree	Native	+	
87	Myristicaceae	Pycanthus	*Pycanthus angolensis* (Welw.) Warb.	Tree	Native	+	
88	Nyctaginaceae	Boerhavia	*Boerhavia diffusa* Linn.	Herb	Native	+	+
89			*Boerhavia erecta* Linn.				+
90	Pandaceae	Microdesmis	*Microdesmis puberula* Hook. F. ex Planch	Shrub	Native	+	
91	Phyllanthaceae	Bridelia	*Bridelia micrantha* (Hochst.) Baill.	Shrub	Native	+	
92		Phyllanthus	*Phyllanthus muellerianus* (Kuntze) Exell	Shrub	Native	+	
93	Poaceae	Andropogon	*Andropogon tectorum* Schumach & Thonn.	Grass	Native	+	
94		Axonopus	*Axonopus compresus* (Sw.) P. Beauv.	Grass	Exotic	+	+

Table 4-2 Cont'd. list of species recorded in the vegetation and soil seed bank of a coppiced teak plantation in Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

No	Family	Genera	Species	Habit	Origin	vegetation	Seed bank
95		Bambusa	*Bambusa vulgaris* Schrad. Ex J. C. Wendl.	Grass	Exotic	+	
96		Cymbopogon	*Cymbopogon citratus* (DC.) Stapf	Herb	Exotic	+	+
97		Cynodon	*Cynodon dactylon* (Linn.) Pers.	Grass	Native	+	+
98		Dactylotenium	*Dactylotenium aegyptium* (Linn.) P. Beauv.				+
99		Digitaria	*Digitaria horizontalis* Willd.	Grass	Native	+	
100			*Digitaria longiflora* (Ret.) Pers.				+
101		Eleusine	*Eleusine indica* (Linn.) Gaetn.	Grass	Cosmopolitan	+	+
102		Oplismenus	*Oplismenus burmannii* (Retz.) P. Beauv.	Grass	Native	+	+
103		Panicum	*Panicum brevifolium* Linn.	Grass	Native	+	
104			*Panicum laxum* Sw.	Grass	Native	+	

Table 4-2 Cont'd. list of species recorded in the vegetation and soil seed bank of a coppiced teak plantation in Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

No	Family	Genera	Species	Habit	Origin	vegetation	Seed bank
105		Sporobolus	*Sporobolus pyramidalis* P. Beauv.	Grass	Cosmopolitan	+	
106	Polygalaceae	Carpolobia	*Carpolobia alba* G. Don	Shrub	Native	+	
107	Rubiaceae	Mitragyna	*Mitragyna stipulosa* (DC.) Kuntze	Tree	Native	+	
108		Morinda	*Morinda lucida* Benth.	Tree	Native	+	
109		Oldenlandia	*Oldenlandia corymboza* Linn.				+
110		Rytigyna	*Rytigyna nigerica* (S. Moore) Robyns	Shrub	Native	+	
111	Rutaceae	Afraegle	*Afraegle paniculata* (Shum.) Engl.	Tree	Native	+	
112		Zanthoxylum	*Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler	Tree	Native	+	
113	Sapindaceae	Lecaniodiscus	*Lecaniodiscus cupanioides* Planch. Ex Benth.	Tree	Native	+	
114		Paullinia	*Paullinia pinnata* Linn.	Vine	Native	+	

Table 4-2 Cont'd. list of species recorded in the vegetation and soil seed bank of a coppiced teak plantation in Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

No	Family	Genera	Species	Habit	Origin	vegetation	Seed bank
115	Sapotaceae	Synsepalum	*Synsepalum dulcificum* (Schumach. & Tonn.) Baill.	Vine	Native	+	
116	Solanaceae	Nicotiana	*Nicotiana rustica* Linn.	Herb	Exotic	+	
117		Schwenckia	*Schwenckia americana* Linn.	Herb	Exotic	+	
118		Solanum	*Solanum americanum* Mill.	Herb	Exotic	+	+
119	Tiliaceae	Corchorus	*Corchorus olitorius* Linn.				+
120		Triumfetta	*Triumfetta rhomboidea* Jacq.				+
121	Urticaceae	Laportea	*Laportea aestuans* (Linn.) Chew.				+
122		Pouzolzia	*Pouzolzia guineensis* Benth.				+
123	Verbenaceae	Gmelina	*Gmelina arborea* Roxb.	Tree	Exotic	+	+
124		Stachytarpheta	*Stachytarpheta jamaicensis* (Linn.) Vahl.	Shrub	Exotic	+	
125		Tectona	*Tectona grandis* Linn. f.	Tree	Exotic	+	
126	Vitaceae	Cissus	*Cissus populnea* Guill. & Perr.	Vine	Native	+	
Total	**41**	**112**	**126**			**106**	**41**

Table 4.3. Number of genera and species recorded per family in the vegetation and seed bank of a coppiced teak plantation in Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

No	Families	No. of Genera	No. of Species
1	Acanthaceae	1	1
2	Alzoaceae	1	1
3	Amaranthaceae	5	6
4	Annonaceae	2	2
5	Apocynaceae	6	8
6	Arecaceae	2	2
7	Asteraceae	6	6
8	Bignoniaceae	3	3
9	Boraginaceae	2	3
10	Cannabaceae (Ulmaceae)	1	2
11	Clusiaceae	1	1
12	Commelinaceae	2	3
13	Cyperaceae	2	2
14	Dioscoreaceae	1	2
15	Euphorbiaceae	7	7
16	Fabaceae	15	16
17	Icacinaceae	1	1
18	Irvingiaceae	1	1
19	Lecythidaceae	1	1
20	Loganiaceae	1	1
21	Loranthaceae	1	1
22	Lythraceae	1	1
23	Malvaceae	9	9

24	Meliaceae	1	1
25	Menispermaceae	2	2
26	Moraceae	2	3
27	Myristicaceae	1	1
28	Nyctaginaceae	1	2
29	Pandaceae	1	1
30	Phyllanthaceae	2	2
31	Poaceae	11	13
32	Polygalaceae	1	1
33	Rubiaceae	4	4
34	Rutaceae	2	2
35	Sapindaceae	2	2
36	Sapotaceae	1	1
37	Solanaceae	3	3
38	Tiliaceae	2	2
39	Urticaceae	2	2
40	Verbenaceae	3	3
41	Vitaceae	1	1
Total		114	126

Table 4.4. Diversity indices of the vegetation per plant life form in the Wet and Dry season in a coppiced teak plantation in Gambari Forest Reserve, Ibadan, Nigeria.

Layers	Taxa _S	Individuals	Dominance D	Simpson 1-D	Shannon H	Equitability J
Climbers Dry	10	199	0.20	0.80	1.88	0.82
Climbers Wet	18	705	0.11	0.89	2.47	0.85
Monocots Herbaceous Dry	5	3497	0.29	0.71	1.37	0.85
Dicots Herbaceous Dry	13	7067	0.17	0.83	2.06	0.80
Monocots Herbaceous Wet	11	6210	0.18	0.83	1.96	0.82
Dicots Herbaceous Wet	24	9153	0.18	0.88	2.49	0.79
Shrubs Dry	18	1464	0.24	0.76	1.88	0.65
Shrubs Wet	21	1639	0.24	0.76	1.94	0.64
Trees Dry	37	7134	0.61	0.39	1.17	0.32
Trees Wet	37	8399	0.59	0.41	1.21	0.33

during the wet was absent in the dry season survey record. Other under-story herbaceous species richness and densities have also dropped during the dry season. Pictures of some plant species recorded in the standing vegetation of Teak plantation stand are shown in Plate 4.1. Although the above ground species richness was important in the shrub and vine flora, tree species dominate the standing vegetation regardless the survey season. The rate of exotic species was also high in all the different plant habits regardless of the sampling season. Detailed information of the species presence and absence in the standing vegetation per plant forms and seasons is provided in Table 4.5 and the number of species per family are presented in table 4.6.

4.4.1 Flora distribution of the main tree species (girth >30 cm) in the standing vegetation.

The species distribution of the main tree species layer are presented in Table 4.7 for the dry season survey and in Table 4.8 for the wet season survey. *Tectona grandis* presented an RIV of 55.28 % and 55.19 % in the wet and dry season record respectively. Apart from *T. grandis,* the other dominant tree species were *Gmelina arborea, Albizzia zygia, Funtumia africana* and *Triplochiton scleroxylon* according to their importance values. The relative importance values were larger during the wet season survey irrespective of the species.

About 41% of the species were poorly represented with their relative importance values less than 1%. *Bombax buonopozense, Morinda lucida, Zanthoxylum zanthoxyloides* were the least represented among the main tree species, both during the wet and dry season surveys.

4.4.2 The understorey flora of the stand vegetation

Table 4.9 and Table 4.10 summarize the distribution of the climbing and rattan plant species density of the wet and dry seasons respectively. While Table 4.11 and Table 4.12 summarize the distribution of the shrub species for the wet and dry season surveys respectively. The trees were dominant in the understorey with a total of 34 and 33 species in the wet and dry season respectively, followed by the shrubs and vine. The trees in the understory were dominated by *Tectona grandis* with an RIV of 46.18% and 48.15% in the wet and dry season record respectively. It had important number of seedlings both during the wet and dry seasons. Plate 4.2 shows different kind of *T. grandis* seedlings in the plantation.

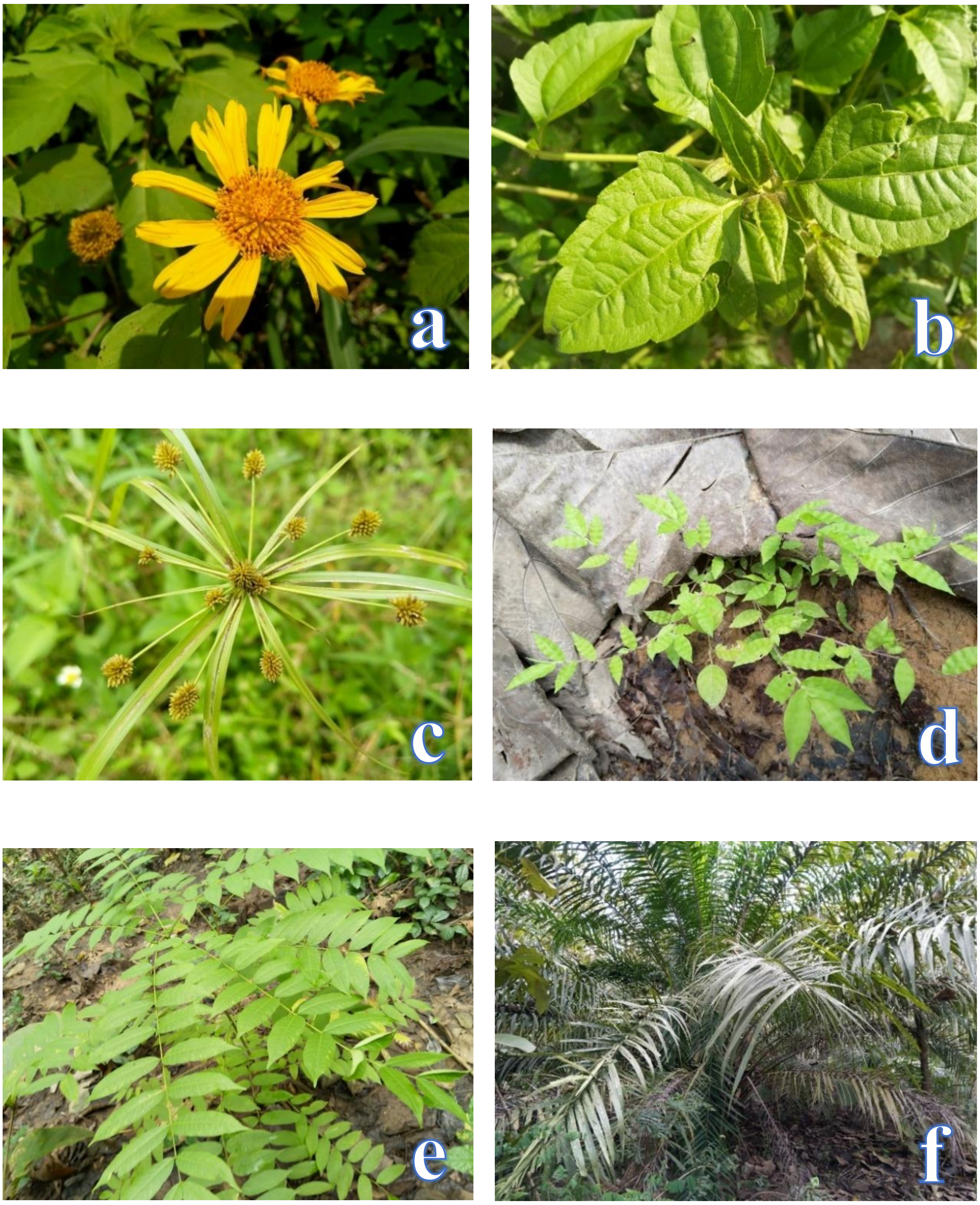

Plate 4.1. Some plant species recorded in the standing vegetation of the Teak plantation stand at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria: a: *Tithonia diversifolia;* b*: Chromolaena odorata;* c*: Mariscus alternifolius;* d: *Oplismenus burmannii;* e: *Cedrela odorata;* f: *Elaesis guinensis*.

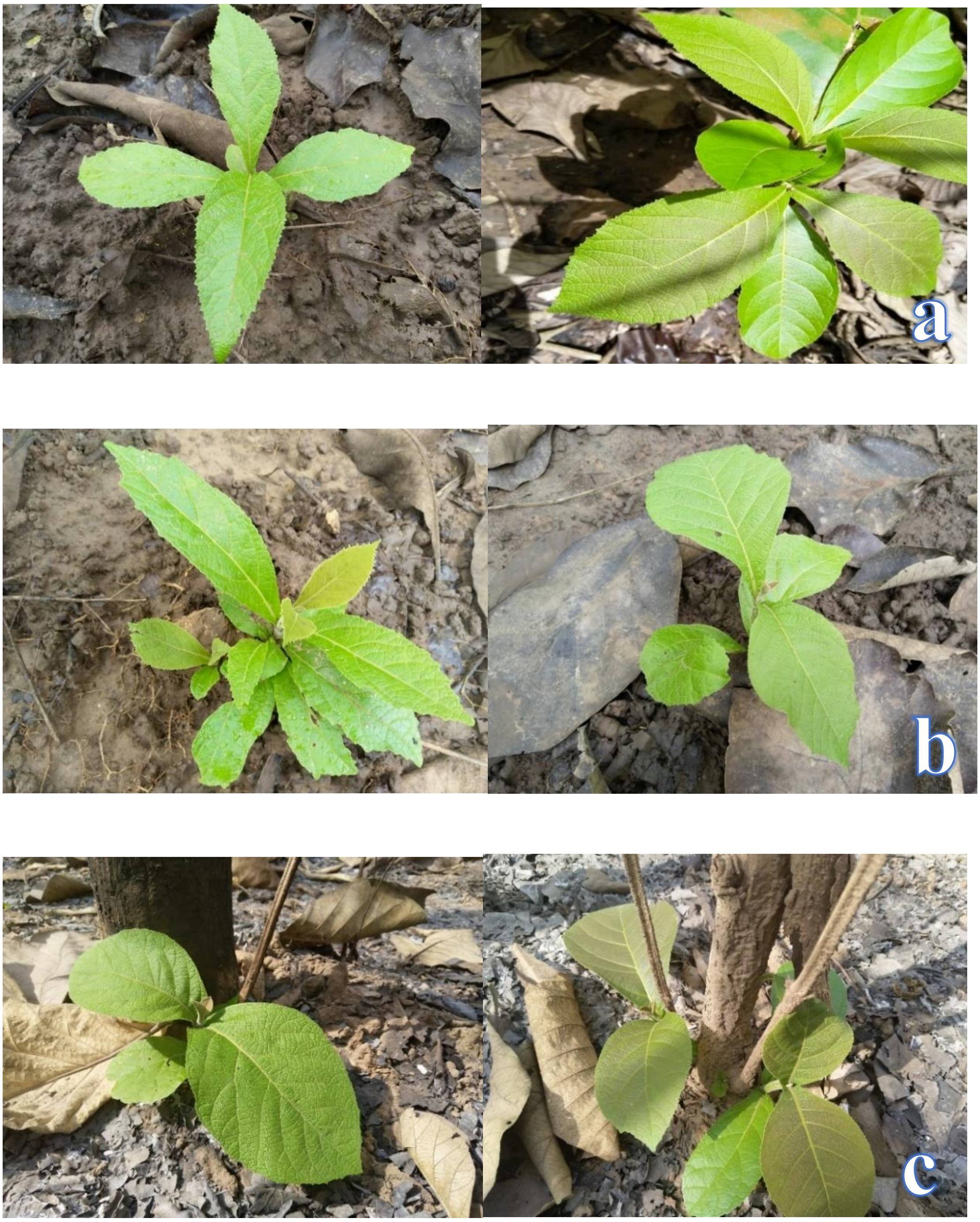

Plate 4.2. Teak seedlings and coppices in the Teak plantation stand at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria: a: Wet season; b: Dry season seedlings in unburnt stands and c: Dry season coppices in burnt stands.

Table 4.5. Plant species enumerated per plant life form in the Wet season and Dry season in the standing vegetation in the Teak plantation at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

No	Family	Species	Habit
1	Acanthaceae	*Phaulopsis ciliata* (Willd.) Hepper	Herb
2	Amaranthaceae	*Alternanthera sessilis* (L.) R. Br. Ex DC.	Herb
3		*Celosia leptostachya* Benth.	Herb
4		*Cyathula prostrata* (L.) Blume	Herb
5	Annonaceae	*Annona senegalensis* Pers.	Tree
6		*Cleistopholis patens* (Benth.) Engl. & Diels	Tree
7	Apocynaceae	*Alstonia boonei* De Wild	Tree
8		*Alstonia congensis* Engl.	Tree
9		*Ancylobotrys amoena* Hua	Liane
10		*Funtumia africana* (Benth.) Stapf	Tree
11		*Funtumia elastica* (P. Preuss) Stapf	Tree
12		*Parquetina nigrescens* (Afzel.) Bullock.	Vine
13		*Rauvolfia vomitora* Afzel.	Shrub
14		*Secamone afzelli* (Schulfes) K. Schum.	Vine
15	Arecaceae	*Elaeis guineensis* Jacq.	Tree
16		*Laccosperma secundiflora* (P. Beauv.) Kuntze	Rattan
17	Asteraceae	*Ageratum conyzoides* Linn.	Herb
18		*Chromolaena odorata* (Linn.) R. King & H. Robinson	Shrub
19		*Crassocephalum crepidoides* (Benth.) S. Moore.	Herb
20		*Synedrella nodiflora* (Linn.) Gaert.	Herb
21		*Tithonia diversifolia* (Helmsl.) A. Gray	Shrub
22	Bignoniaceae	*Kigelia africana* (Lam.) Benth.	Tree
23		*Markhamia tomentosa* (Benth.) K. Shum. Ex Engl.	Tree
24		*Newbouldia laevis* Seem. Ex Bureau	Tree
25	Boraginaceae	*Cordia auriantiaca* Baker	Tree
26		*Cordia millenii* Baker	Tree
27		*Heliotropium indicum* Linn.	Herb
28	Cannabaceae (Ulmaceae)	*Celtis adolfi-friderici* Engl.	Tree

Table 4.5. Cont'd. Plant species enumerated per plant life form in the Wet season and Dry season in the standing vegetation in the Teak plantation at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

No	Family	Species	Habit
29		*Celtis integrifolia* Lam.	Tree
30	Clusiaceae	*Harungana madagascariensis* Lam. Ex Poir.	Shrub
31	Commelinaceae	*Commelina benghalensis* Linn.	Herb
32		*Commelina erecta* Linn.	Herb
33		*Palisota hirsuta* (Thunb.) K. Schum.	Herb
34	Cyperaceae	*Cyperus esculentus* Linn.	Sedge
35		*Mariscus alternifolius* Vahl.	Sedge
36	Dioscoreaceae	*Dioscorea dumetorum* (Kunth) Pax	Vine
37		*Dioscorea praehensilis* Benth.	Vine
38	Euphorbiaceae	*Alchornea laxiflora* (Benth.) Pax & K. Hoffim.	Shrub
39		*Croton zambesicus* Muell. Arg.	Tree
40		*Macaranga barteri* Muell. Arg.	Shrub
41	Fabaceae	*Abrus precatorius* Linn.	Vine
42		*Acacia ataxacantha* DC.	Shrub
43		*Albizia zygia* (DC.) J. F. Macbr.	Tree
44		*Amphimas pterocarpoides* Harms	Tree
45		*Desmodium velutinum* (Willd.) DC.	Herb
46		*Dialium guineense* Willd.	Tree
47		*Eurythrophleum guineensis* G. Don.	Tree
48		*Gliricidia sepium* (Jacq.) Kunth ex Walp.	Shrub
49		*Leptoderris micrantha* Dunn	Vine
50		*Milletia thonningii* (Schumach. & Thonn.) Baker	Shrub
51		*Mimosa pudica* Linn.	Herb
52		*Mucuna flagellipes* Hook. F.	Vine
53		*Mucuna sloanei* Fawc. & Rendle	Vine
54		*Phaseolus lunatus* Linn.	Vine
55		*Piptadeniastrum africanum* (Hook. f.) Brenan	Tree
56	Icacinaceae	*Icacina trichantha* Olii.	Liane
57	Irvingiaceae	*Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill.	Tree

Table 4.5. Cont'd. Plant species enumerated per plant life form in the Wet season and Dry season in the standing vegetation in the Teak plantation at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

No	Family	Species	Habit
58	Lecythidaceae	*Napoleonaea vogelii* Hook & Planch	Shrub
59	Loranthaceae	*Phragmanthera capitata* (Spreng.) Balle	Shrub
60	Lythraceae	*Lawsonia inermis* Linn.	Shrub
61	Malvaceae	*Bombax buonopozense* P. Beauv.	Tree
62		*Ceiba pentandra* (Linn.) Gaertn.	Tree
63		*Cola gigantea* A. Chev.	Tree
64		*Dombeya buettneri* K. Schum.	Shrub
65		*Grewia carpinifolia* Juss.	Shrub
66		*Sida acuta* Burm. F.	Shrub
67		*Triplochiton scleroxylon* K. Schum.	Tree
68		*Waltheria indica* Linn.	Herb
69	Meliaceae	*Cedrela odorata* Linn.	Tree
70	Menispermaceae	*Chasmanthera dependens* Hochst.	Vine
71		*Rhigiocarya racemifera* Miers	Liane
72	Moraceae	*Ficus exasperata* Vahl.	Tree
73		*Ficus tonningii* Blume	Tree
74		*Milicia excelsa* (Welw.) C. C. Berg	Tree
75	Myristicaceae	*Pycanthus angolensis* (Welw.) Warb.	Tree
76	Nyctaginaceae	*Boerhavia diffusa* Linn.	Herb
77	Pandaceae	*Microdesmis puberula* Hook. F. ex Planch	Shrub
78	Phyllanthaceae	*Bridelia micrantha* (Hochst.) Baill.	Shrub
79		*Phyllanthus muellerianus* (Kuntze) Exell	Shrub
80	Poaceae	*Andropogon tectorum* Schumach & Thonn.	Grass
81		*Axonopus compresus* (Sw.) P. Beauv.	Grass
82		*Bambusa vulgaris* Schrad. Ex J. C. Wendl.	Grass
83		*Cymbopogon citratus* (DC.) Stapf	Herb
84		*Cynodon dactylon* (Linn.) Pers.	Grass
85		*Digitaria horizontalis* Willd.	Grass
86		*Eleusine indica* (Linn.) Gaetn.	Grass
87		*Oplismenus burmannii* (Retz.) P. Beauv.	Grass

Table 4.5. Cont'd. Plant species enumerated per plant life form in the Wet season and Dry season in the standing vegetation in the Teak plantation at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

No	Family	Species	Habit
88		*Panicum brevifolium* Linn.	Grass
89		*Panicum laxum* Sw.	Grass
90		*Sporobolus pyramidalis* P. Beauv.	Grass
91	Polygalaceae	*Carpolobia alba* G. Don	Shrub
92	Rubiaceae	*Mitragyna stipulosa* (DC.) Kuntze	Tree
93		*Morinda lucida* Benth.	Tree
94		*Rytigyna nigerica* (S. Moore) Robyns	Shrub
95	Rutaceae	*Afraegle paniculata* (Shum.) Engl.	Tree
96		*Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler	Tree
97	Sapindaceae	*Lecaniodiscus cupanioides* Planch. Ex Benth.	Tree
98		*Paullinia pinnata* Linn.	Vine
99	Sapotaceae	*Synsepalum dulcificum* (Schumach. & Tonn.) Baill.	Vine
100	Solanaceae	*Nicotiana rustica* Linn.	Herb
101		*Schwenckia americana* Linn.	Herb
102		*Solanum americanum* Mill.	Herb
103	Verbenaceae	*Gmelina arborea* Roxb.	Tree
104		*Stachytarpheta jamaicensis* (Linn.) Vahl.	Shrub
105		*Tectona grandis* Linn. f.	Tree
106	Vitaceae	*Cissus populnea* Guill. & Perr.	Vine

Table 4.6. Number of species enumerated per families in the vegetation

N0	Family	Number of Species
1	Acanthaceae	1
2	Amaranthaceae	3
3	Annonaceae	2
4	Apocynaceae	8
5	Arecaceae	2
6	Asteraceae	5
7	Bignoniaceae	3
8	Boraginaceae	3
9	Cannabaceae (Ulmaceae)	2
10	Clusiaceae	1
11	Commelinaceae	3
12	Cyperaceae	2
13	Dioscoreaceae	2
14	Euphorbiaceae	3
15	Fabaceae	15
16	Icacinaceae	1
17	Irvingiaceae	1
18	Lecythidaceae	1
19	Loranthaceae	1
20	Lythraceae	1
21	Malvaceae	8
22	Meliaceae	1
23	Menispermaceae	2
24	Moraceae	3
25	Myristicaceae	1
26	Nyctaginaceae	1
27	Pandaceae	1
28	Phyllanthaceae	2
29	Poaceae	11
30	Polygalaceae	1
31	Rubiaceae	3

Table 4.6. Cont'd. Number of species enumerated per families in the vegetation

N0	Family	Number of Species
32	Rutaceae	2
33	Sapindaceae	2
34	Sapotaceae	1
35	Solanaceae	3
36	Verbenaceae	3
37	Vitaceae	1

Table 4.7. Density, Relative Density, Frequency, Relative Frequency and Relative Importance (RIV) values of tree species enumerated in the standing vegetation in the Wet season at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
1	*Tectona grandis*	213.87	76.39	100.00	9.93	43.16
2	*Gmelina arborea*	14.90	5.32	76.67	7.62	6.47
3	*Albizia zygia*	9.43	3.37	63.33	6.29	4.83
4	*Triplochiton scleroxylon*	3.77	1.35	56.67	5.63	3.49
5	*Markhamia tomentosa*	4.83	1.73	50.00	4.97	3.35
6	*Elaeis guineensis*	4.77	1.70	50.00	4.97	3.33
7	*Lecaniodiscus cupanioides*	4.33	1.55	46.67	4.64	3.09
8	*Cordia millenii*	2.20	0.79	50.00	4.97	2.88
9	*Cordia auriantiaca*	2.13	0.76	40.00	3.97	2.37
10	*Funtumia africana*	2.00	0.71	36.67	3.64	2.18
11	*Cola gigantea*	2.63	0.94	30.00	2.98	1.96
12	*Ceiba pentandra*	2.00	0.71	23.33	2.32	1.52
13	*Pycanthus angolensis*	1.00	0.36	26.67	2.65	1.50
14	*Newbouldia laevis*	0.90	0.32	26.67	2.65	1.49
15	*Morinda lucida*	0.73	0.26	26.67	2.65	1.46
16	*Amphimas pterocarpoides*	0.50	0.18	23.33	2.32	1.25
17	*Mitragyna stipulosa*	0.43	0.15	23.33	2.32	1.24
18	*Alstonia boonei*	0.57	0.20	20.00	1.99	1.09
19	*Cedrela odorata*	2.33	0.83	13.33	1.32	1.08
20	*Ficus tonningii*	0.40	0.14	20.00	1.99	1.06
21	*Funtumia elastica*	0.37	0.13	20.00	1.99	1.06
22	*Eurythrophleum guineensis*	1.07	0.38	16.67	1.66	1.02
23	*Ficus exasperata*	0.73	0.26	16.67	1.66	0.96
24	*Annona senegalensis*	0.50	0.18	16.67	1.66	0.92
25	*Alstonia congensis*	0.40	0.14	16.67	1.66	0.90
26	*Milicia excelsa*	0.60	0.21	13.33	1.32	0.77
27	*Zanthoxylum zanthoxyloides*	0.37	0.13	13.33	1.32	0.73
28	*Celtis integrifolia*	0.23	0.08	13.33	1.32	0.70
29	*Irvingia gabonensis*	0.50	0.18	10.00	0.99	0.59

Table 4.7. Cont'd. Density, Relative Density, Frequency, Relative Frequency and Relative Importance (RIV) values of tree species enumerated in the standing vegetation in the Wet season at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
30	*Croton zambesicus*	0.23	0.08	10.00	0.99	0.54
31	*Kigelia africana*	0.23	0.08	10.00	0.99	0.54
32	*Celtis adolfi-friderici*	0.20	0.07	10.00	0.99	0.53
33	*Cleistopholis patens*	0.20	0.07	10.00	0.99	0.53
34	*Dialium guineense*	0.20	0.07	10.00	0.99	0.53
35	*Piptadeniastrum africanum*	0.20	0.07	6.67	0.66	0.37
36	*Afraegle paniculata*	0.13	0.05	6.67	0.66	0.35
37	*Bombax buonopozense*	0.07	0.02	3.33	0.33	0.18
Total		279.97	100.00	1006.67	100.00	100.00

Key: D = Density; RD = Relative Density; F= Frequency; RF = Relative Frequency; RIV = Relative Importance Value.

Table 4.8. Density, Relative Density, Frequency, Relative Frequency and Relative Importance values (RIV) of tree species enumerated in the vegetation in the Dry season at Gambari Forest Reserve, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
1	*Tectona grandis*	184.23	77.47	100.00	10.14	43.80
2	*Gmelina arborea*	12.27	5.16	60.00	6.08	5.62
3	*Albizia zygia*	7.23	3.04	76.67	7.77	5.41
4	*Triplochiton scleroxylon*	3.33	1.40	60.00	6.08	3.74
5	*Lecaniodiscus cupanioides*	4.07	1.71	53.33	5.41	3.56
6	*Markhamia tomentosa*	3.80	1.60	50.00	5.07	3.33
7	*Cordia auriantiaca*	2.83	1.19	53.33	5.41	3.30
8	*Cordia millenii*	1.53	0.64	43.33	4.39	2.52
9	*Funtumia africana*	1.90	0.80	33.33	3.38	2.09
10	*Cola gigantea*	2.30	0.97	26.67	2.70	1.83
11	*Amphimas pterocarpoides*	0.67	0.28	30.00	3.04	1.66
12	*Newbouldia laevis*	1.03	0.43	26.67	2.70	1.57
13	*Ceiba pentandra*	1.73	0.73	23.33	2.36	1.55
14	*Morinda lucida*	0.60	0.25	26.67	2.70	1.48
15	*Cedrela odorata*	2.20	0.93	20.00	2.03	1.48
16	*Pycanthus angolensis*	1.07	0.45	23.33	2.36	1.41
17	*Mitragyna stipulosa*	0.47	0.20	23.33	2.36	1.28
18	*Annona senegalensis*	0.57	0.24	20.00	2.03	1.13
19	*Alstonia boonei*	0.53	0.22	20.00	2.03	1.13
20	*Alstonia congensis*	0.37	0.15	20.00	2.03	1.09
21	*Funtumia elastica*	0.37	0.15	20.00	2.03	1.09
22	*Ficus exasperata*	0.47	0.20	16.67	1.69	0.94
23	*Milicia excelsa*	0.43	0.18	16.67	1.69	0.94
24	*Celtis adolfi-friderici*	0.33	0.14	16.67	1.69	0.91
25	*Croton zambesicus*	0.33	0.14	16.67	1.69	0.91
26	*Eurythrophleum guineensis*	0.80	0.34	13.33	1.35	0.84
27	*Ficus tonningii*	0.17	0.07	13.33	1.35	0.71
28	*Irvingia gabonensis*	0.43	0.18	10.00	1.01	0.60
29	*Elaeis guineensis*	0.33	0.14	10.00	1.01	0.58

Table 4.8. Cont'd. Density, Relative Density, Frequency, Relative Frequency and Relative Importance values (RIV) of tree species enumerated in the vegetation in the Dry season at Gambari Forest Reserve, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
30	*Celtis integrifolia*	0.27	0.11	10.00	1.01	0.56
31	*Kigelia africana*	0.27	0.11	10.00	1.01	0.56
32	*Dialium guineense*	0.20	0.08	10.00	1.01	0.55
33	*Cleistopholis patens*	0.17	0.07	10.00	1.01	0.54
34	*Zanthoxylum zanthoxyloides*	0.20	0.08	6.67	0.68	0.38
35	*Piptadeniastrum africanum*	0.17	0.07	6.67	0.68	0.37
36	*Afraegle paniculata*	0.10	0.04	6.67	0.68	0.36
37	*Bombax buonopozense*	0.03	0.01	3.33	0.34	0.18
Total		237.80	100.00	986.67	100.00	100.00

Key: D = Density; RD = Relative Density; F= Frequency; RF = Relative Frequency; RIV = Relative Importance Value.

Table 4.9. Density, Relative Density, Frequency, Relative Frequency and Relative Importance values (RIV) of climbers enumerated in the vegetation in the Wet season in Gambari Forest Reserve, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
1	*Icacina trichantha*	1.01	21.56	42.00	25.51	23.53
2	*Secamone afzelli*	0.77	16.31	29.33	17.81	17.06
3	*Parquetina nigrescens*	0.67	14.18	16.67	10.12	12.15
4	*Laccosperma secundiflora*	0.43	9.08	10.67	6.48	7.78
5	*Mucuna sloanei*	0.28	5.96	9.33	5.67	5.81
6	*Mucuna flagellipes*	0.20	4.26	9.33	5.67	4.96
7	*Dioscorea Praehensilis*	0.20	4.26	5.33	3.24	3.75
8	*Cissus populnea*	0.16	3.40	5.33	3.24	3.32
9	*Paullinia pinnata*	0.16	3.40	5.33	3.24	3.32
10	*Ancylobotrys amoena*	0.11	2.27	6.67	4.05	3.16
11	*Dioscorea dumetorum*	0.15	3.12	2.67	1.62	2.37
12	*Synsepalum dulcificum*	0.12	2.55	2.67	1.62	2.09
13	*Leptoderris micrantha*	0.08	1.70	4.00	2.43	2.07
14	*Chasmanthera dependens*	0.11	2.27	2.67	1.62	1.94
15	*Abrus precatorius*	0.07	1.42	4.00	2.43	1.92
16	*Bambusa vulgaris*	0.05	1.13	4.00	2.43	1.78
17	*Phaseolus lunatus*	0.05	1.13	3.33	2.02	1.58
18	*Rhigiocarya racemifera*	0.09	1.99	1.33	0.81	1.40
Total		4.70	100.00	164.67	100.00	100.00

Key: D = Density; RD = Relative Density; F= Frequency; RF = Relative Frequency; RIV = Relative Importance Value.

Table 4.10. Density, Relative Density, Frequency, Relative Frequency and Relative Importance values (RIV) of climbers enumerated in the vegetation in the Dry season in Gambari Forest Reserve, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
1	*Icacina trichantha*	0.41	30.65	22.00	37.50	34.08
2	*Parquetina nigrescens*	0.35	26.63	10.00	17.05	21.84
3	*Phaseolus lunatus*	0.15	11.56	8.67	14.77	13.17
4	*Mucuna flagellipes*	0.11	8.04	5.33	9.09	8.57
5	*Cissus populnea*	0.11	8.54	4.67	7.95	8.25
6	*Paullinia pinnata*	0.05	4.02	2.00	3.41	3.71
7	*Chasmanthera dependens*	0.05	4.02	1.33	2.27	3.15
8	*Bambusa vulgaris*	0.03	2.51	2.00	3.41	2.96
9	*Synsepalum dulcificum*	0.03	2.51	1.33	2.27	2.39
10	*Ancylobotrys amoena*	0.02	1.51	1.33	2.27	1.89
Total		1.33	100.00	58.67	100.00	100.00

Key: D = Density; RD = Relative Density; F= Frequency; RF = Relative Frequency; RIV = Relative Importance Value.

Table 4.11. Density, Relative Density, Frequency, Relative Frequency and Relative Importance values (RIV) of the shrub plant species enumerated in the vegetation in the Wet season in Gambari Forest Reserve, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
1	*Carpolobia alba*	2.84	17.69	38.00	17.18	17.43
2	*Alchorneae laxiflora*	2.62	15.67	22.00	18.78	17.23
3	*Tithonia diversifolia*	0.35	13.17	18.67	17.45	16.31
4	*Phragmanthera capitata*	0.37	3.36	11.33	4.52	13.94
5	*Rytigyna nigerica*	0.33	3.05	11.33	4.52	13.99
6	*Grewia carpinifolia*	0.17	1.59	7.33	2.93	6.26
7	*Dombeya buettneri*	0.10	0.92	5.33	2.13	2.94
8	*Harungana madagascariensis*	0.12	1.10	4.67	1.86	1.78
9	*Napoleonaea vogelii*	0.11	0.98	4.67	1.86	1.42
10	*Gliricidia sepium*	0.13	1.22	4.00	1.60	1.41
11	*Phyllanthus muellerianus*	0.12	1.10	4.00	1.60	1.35
12	*Microdesmis puberula*	0.16	1.46	2.67	1.06	1.26
13	*Milletia thonningii*	0.05	0.49	3.33	1.33	0.91
14	*Bridelia micrantha*	0.11	0.98	2.00	0.80	0.89
15	*Rauvolfia vomitora*	0.03	0.31	2.67	1.06	0.68
16	*Stachytarpheta jamaicensis*	0.05	0.43	2.00	0.80	0.61
17	*Acacia ataxacantha*	0.04	0.37	2.00	0.80	0.58
18	*Macaranga barteri*	0.04	0.37	2.00	0.80	0.58
19	*Lawsonia inermis*	0.03	0.31	1.33	0.53	0.42
Total		10.93	100.00	250.67	100.00	100.00

Key: D = Density; RD = Relative Density; F= Frequency; RF = Relative Frequency; RIV = Relative Importance Value.

Table 4.12. Density, Relative Density, Frequency, Relative Frequency and Relative Importance values (RIV) of the shrub plant species enumerated in the vegetation in the Dry season in Gambari Forest Reserve, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
1	*Carpolobia alba*	2.61	26.22	15.33	26.32	26.27
2	*Alchorneae laxiflora*	2.47	24.78	18.67	25.69	26.24
3	*Tithonia diversifolia*	2.42	24.30	19.33	25.97	26.14
4	*Rytigyna nigerica*	1.38	5.89	11.33	4.67	5.28
5	*Phragmanthera capitata*	1.02	3.28	11.33	4.67	3.91
6	*Grewia carpinifolia*	0.13	1.37	5.33	2.20	1.71
7	*Harungana madagascariensis*	0.11	1.09	5.33	2.20	1.65
8	*Phyllanthus muellerianus*	0.09	0.89	4.00	1.65	1.27
9	*Gliricidia sepium*	0.11	1.09	3.33	1.37	1.23
10	*Milletia thonningii*	0.07	0.75	4.00	1.65	1.2
11	*Bridelia micrantha*	0.11	1.16	2.67	1.10	1.13
12	*Dombeya buettneri*	0.08	0.82	3.33	1.37	1.1
13	*Microdesmis puberula*	0.11	1.09	2.00	0.82	0.96
14	*Acacia ataxacantha*	0.05	0.48	2.00	0.82	0.65
15	*Lawsonia inermis*	0.05	0.48	2.00	0.82	0.65
16	*Macaranga barteri*	0.04	0.41	2.00	0.82	0.62
Total		9.76	100.00	242.67	100.00	100.01

Key: D = Density; RD = Relative Density; F= Frequency; RF = Relative Frequency; RIV = Relative Importance Value.

T. grandis was followed by during the wet season *Albizia zygia* (RIV of 10.26% and 9.20% in the wet and dry season respectively) and *Gmelina arborea* (RIV of 7.03% and 7.30% in the wet and dry season respectively). Other species with RIV values over 3% of the understorey tree species were *Lecaniodiscus cupanioides, Triplochiton scleroxylon* and *Markhamia tomentosa*. Many trees in this layer have less than 1% RIV.

The climbing and rattan plant species were dominated by *Icacina trichantha, Secamone afzelli* and *Parquetina nigrescens* with 23.53%, 17.06% and 12.15 RIV respectively in the wet season while *Icacina trichantha*, *Parquetina nigrescens* and *Phaseolus lunatus* had the greater RIV of 34.08%, 21.84% and 13.17% respectively during the dry season. Species such as *Ancylobotrys amoena, Phaseolus lunatus* and *Rhigiocarya racemifera* were poorly represented in both seasons.

The shrub species were more dominated by *Carpolobia alba* and *Alchorneae* l*axiflora*, regardless of the sampling period. The two species had respective RIV of 17.43% and 26.27% during the wet season and 17.23% and 26.23% during the dry season. Species such as *Dombeya buettneri, Stachytarpheta jamaicensis, Acacia ataxacantha, Microdesmis puberula, Lawsonia inermis* and *Macaranga barteri* had less than 1% RIV.

4.4.3 Distribution of the herbaceous plant species in the vegetation

The herbaceous species were more dominated by *Chromolaena odorata* and *Sida acuta,* both exotic species, regardless of the sampling period. Table 4.13 and Table 4.14 provided detailed information on the species distribution in herbaceous layer. Species of the Poaceae family such as *Digitaria horizontalis, Cynodon dactylon* and *Oplismenus burmannii* have dominated this plant layer in the wet season survey with 10.75%, 9.16% and 8.58% RIV respectively. However, herbs such as *Alternanthera sessilis* and *Ageratum conyzoides* were also well represented in standing flora with 8.58% and 8.30% RIV respectively. The other important herbaceous species were, *Andropogon tectorum, Celosia leptostachya, Crassocephalum crepidoides, Cyperus esculentus, Desmodium velutinum, Eleusine indica,* and *Heliotropium indicum.* The Poaceae family still dominated the herbaceous flora of the standing vegetation with *Cynodon dactylon* and *Oplismenus burmannii* which had RIV of 14.70% and 13.09% respectively. However, *Alternanthera sessilis* and *Mimosa pudica* were also important with 14.08% and 9.90% RIV respectively. *Boerhavia diffusa, Waltheria indica, Mariscus alternifolius* and *Solanum americanum* are the less abundant species during the dry season.

Table 4.13. Density, Relative Density, Frequency, Relative Frequency and Relative Importance values (RIV) of herbaceous plant species enumerated in the vegetation in the Wet season in Gambari Forest Reserve, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
1	*Chromolaena odorata*	4.37	24.02	56.67	25.6	25.12
2	*Sida acuta*	2.78	15.44	44.67	11.81	13.63
3	*Digitaria horizontalis*	2.22	14.62	22.80	6.88	9.75
4	*Cynodon dactylon*	1.67	10.99	24.27	7.32	9.16
5	*Oplismenus burmannii*	1.75	11.57	18.53	5.59	8.58
6	*Alternanthera sessilis*	1.06	6.98	33.73	10.18	7.58
7	*Ageratum conyzoides*	1.13	7.46	30.27	9.13	7.30
8	*Synedrella nodiflora*	0.65	4.30	24.27	7.32	4.81
9	*Mimosa pudica*	0.65	4.31	23.07	6.96	4.63
10	*Cymbopogon citratus*	0.70	4.64	14.00	4.22	4.43
11	*Axonopus compresus*	0.69	4.57	9.73	2.94	3.75
12	*Commelina benghalensis*	0.48	3.16	12.53	3.78	3.47
13	*Cyathula prostrata*	0.35	2.34	14.27	4.30	3.32
14	*Eleusine indica*	0.43	2.83	8.53	2.57	2.70
15	*Commelina erecta*	0.39	2.54	9.47	2.86	2.70
16	*Celosia leptostachya*	0.28	1.82	10.80	3.26	2.54
17	*Cyperus esculentus*	0.55	3.66	4.13	1.25	2.45
18	*Panicum brevifolium*	0.27	1.75	9.87	2.98	2.36
19	*Heliotropium indicum*	0.28	1.84	9.47	2.86	2.35
20	*Boerhavia diffusa*	0.31	2.03	8.67	2.61	2.32
21	*Mariscus alternifolius*	0.23	1.52	6.53	1.97	1.75
22	*Sporobolus pyramidalis*	0.34	2.22	3.60	1.09	1.66
23	*Waltheria indica*	0.23	1.50	5.60	1.69	1.60
24	*Phaulopsis ciliata*	0.11	0.71	6.27	1.89	1.30
25	*Panicum laxum*	0.11	0.74	4.80	1.45	1.09
26	*Crassocephalum crepidoides*	0.06	0.38	3.20	0.97	0.67
27	*Schwenckia americana*	0.06	0.40	2.93	0.88	0.64
28	*Solanum americanum*	0.04	0.26	2.67	0.80	0.53
29	*Nicotiana rustica*	0.03	0.21	2.40	0.72	0.47

Table 4.13. Cont'd. Density, Relative Density, Frequency, Relative Frequency and Relative Importance values (RIV) of herbaceous plant species enumerated in the vegetation in the Wet season in Gambari Forest Reserve, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
30	*Desmodium velutinum*	0.04	0.26	2.00	0.60	0.43
31	*Palisota hirsuta*	0.04	0.25	1.60	0.48	0.37
32	*Andropogon tectorum*	0.02	0.12	1.47	0.44	0.28
Total		15.17	99.98	331.48	99.99	100.01

Key: D = Density; RD = Relative Density; F= Frequency; RF = Relative Frequency; RIV = Relative Importance Value.

Table 4.14. Density, Relative Density, Frequency, Relative Frequency and Relative Importance values (RIV) of the herbaceous plant species enumerated in the vegetation in the Dry season in Gambari Forest Reserve, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
1	*Chromolaena odorata*	1.43	17.18	40.00	16.85	17.01
2	*Sida acuta*	1.19	15.72	33.67	14.00	14.86
3	*Cynodon dactylon*	1.20	6.55	26.67	.85	13.70
4	*Alternanthera sessilis*	0.88	12.10	33.33	11.07	13.08
5	*Oplismenus burmannii*	1.26	17.30	18.40	8.87	13.03
6	*Mimosa pudica*	0.60	8.30	23.87	11.50	9.90
7	*Cymbopogon citratus*	0.55	7.59	16.13	7.78	7.68
8	*Cyathula prostrata*	0.40	5.54	18.40	8.87	7.20
9	*Commelina benghalensis*	0.39	5.37	14.80	7.13	6.25
10	*Commelina erecta*	0.34	4.67	11.47	5.53	5.10
11	*Sporobolus pyramidalis*	0.51	7.02	5.87	2.83	4.92
12	*Axonopus compresus*	0.36	4.93	9.07	4.37	4.65
13	*Boerhavia diffusa*	0.24	3.30	10.00	4.82	4.06
14	*Waltheria indica*	0.27	3.70	8.00	3.86	3.78
15	*Mariscus alternifolius*	0.20	2.73	7.47	3.60	3.16
16	*Solanum americanum*	0.07	0.90	4.00	1.93	1.41
Total		7.27	100.00	207.48	100.01	99.98

Key: D = Density; RD = Relative Density; F= Frequency; RF = Relative Frequency; RIV = Relative Importance Value.

Species such as Nicotiana rustica, Palisota hirsuta, Panicum brevifolium, P. laxum, Phaulopsis ciliata, Schwenckia americana, Secamone afzelli and Synedrella nodiflora were only found in the wet season.

4.5 The soil seed bank flora

The seedlings began to emerge after the first two weeks of the experiment beginning in wet season for both the two-soil depth layer while it has commenced after one week during the dry season experiment. Plate 4.3 and Plate 4.4 showed the state of seedling germination after one and two weeks of experiment beginning respectively and some species enumerated in the soil seed bank are shown in Plate 4.5. The soil seed bank had a total of 41 species among which 38 species were identified in the dry season and 20 species during the wet season survey. The seed bank was quietly made of herbaceous and shrubs species (Table 4.15). Although the seedling densities of exotic species such as *Chromolaena odorata* and *Sida acuta* were important, the native species dominated the soil seed bank flora. The species diversity indices per season and soil depth layer of the soil seed bank flora are presented in Table 4.16. *Eleusine indica, Gmelina arborea* and *Solanum americanum* were only recorded during the wet season survey while 18 other species were only recorded during the dry season survey.

The seed bank of the 0-5 cm depth was shown in Table 4.17 for the wet season survey and Table 4.18 for the dry season survey respectively. The seed bank of this soil layer was dominated by *Chromolaena odorata*, *Sida acuta*, *Cynodon dactylon* and *Alternanthera sessilis* with 21.92%, 18.22%, 11.69% and 9.25% RIV in the wet season and 17.06%, 11.70%, 8.51% and 3.72% in the dry season surveys respectively. *Cyathula prostrata* and *Oplismenus burmannii* were also important in this layer while most of the species had less than 2% RIV, specifically during the dry season survey.

The distribution of the soil seed bank of the deeper top soil layer (5 to 10 cm depth) was summarized in Table 4.19 for the wet season seed bank and Table 4.20 for the dry season seed bank. It was also dominated by *Chromolaena odorata* 30.70% and 22.76% RIV and *Sida acuta* 24.42% and 14.88% RIV in the wet season and dry season respectively. However, *Cyathula prostrata* was also important in the wet season seed bank while *Mariscus alternifolius* and *Cynodon dactylis* were important in the dry season seed bank. The RIV values of most of the species recorded were relatively low.

A. Wet season

B. Dry season

Plate 4.3.. Emerging seedlings at one weeks after the beginning of the process.

A. Wet season

B. Dry season

Plate 4.4. Emerging seedlings at two weeks after the beginning of the process.

A. *Commelina benghalensis*

B. *Synedrella nodiflora*

C. *Chromolaena odorata*

D. *Acalypha ciliata*

E. *Phaulopsis ciliata*

F. *Amaranthus spinosus*

Plate 4.5. Some seedlings germinated from the soil seed bank

Table 4.15. Habit and area of origin of the plant species enumerated in the soil seed bank in Wet season and Dry season in Gambari Forest Reserve, Ibadan, Nigeria.

No	Family	Species	Habit
1	Acanthaceae	*Phaulopsis ciliata* (Willd.) Hepper	Herb
2	Aizoaceae	*Trianthema portulacrastrum* Linn.	Herb
3	Amaranthaceae	*Alternanthera sessilis* (L.) R. Br. Ex DC.	Herb
4		*Amaranthus spinosus* Linn.	Herb
5		*Celosia leptostachya* Benth.	Herb
6		*Celosia trigyna* Linn.	Herb
7		*Cyathula prostrata* (L.) Blume	Herb
8		*Gomphrena celosiodes* Mart.	Herb
9	Asteraceae	*Chromolaena odorata* (Linn.) R. King & H. Robinson	Shrub
10		*Melanthera scadens* (Schum. & Thonn.) Roberty	Herb
11		*Tithonia diversifolia* (Helmsl.) A. Gray	Shrub
12	Commelinaceae	*Commelina benghalensis* Linn.	Herb
13		*Commelina erecta* Linn.	Herb
14	Cyperaceae	*Mariscus alternifolius* Vahl.	Sedge
15	Euphorbiaceae	*Acalypha ciliata* Forsk.	Herb
16		*Croton lobatus* Linn.	Shrub
17		*Euphorbia hirta* Linn.	Herb
18		*Phylathus amarus* Schum. & Thonn.	Herb
19	Fabaceae	*Calopogonium mucunoides* Desv.	Vine
20		*Mimosa pudica* Linn.	Herb
21		*Phaseolus lunatus* Linn.	Vine
22	Loganiaceae	*Spigelia anthelmia* Linn.	Herb
23	Malvaceae	*Sida acuta Burm*. F.	Shrub
24		*Sida garckeana* Polak.	Herb
25		*Waltheria indica* Linn.	Herb
26	Nyctaginaceae	*Boerhavia diffusa* Linn.	Herb
27		*Boerhavia erecta* Linn.	Herb
28	Poaceae	*Axonopus compresus* (Sw.) P. Beauv.	Grass
29		*Cymbopogon citratus* (DC.) Stapf	Herb
30		*Cynodon dactylon* (Linn.) Pers.	Grass

Table 4.15. Cont'd. Habit and area of origin of the plant species enumerated in the soil seed bank in Wet season and Dry season in Gambari Forest Reserve, Ibadan, Nigeria.

No	Family	Species	Habit
31		*Dactylotenium aegyptium* (Linn.) P. Beauv.	Grass
32		*Digitaria longiflora* (Ret.) Pers.	Grass
33		*Eleusine indica* (Linn.) Gaetn.	Grass
34		*Oplismenus burmannii* (Retz.) P. Beauv.	Grass
35	Rubiaceae	*Oldenlandia corymboza* Linn.	Herb
36	Solanaceae	*Solanum americanum* Mill.	Herb
37	Tiliaceae	*Corchorus olitorius* Linn.	Herb
38		*Triumfetta rhomboidea* Jacq.	Shrub
39	Urticaceae	*Laportea aestuans* (Linn.) Chew.	Herb
40		*Pouzolzia guineensis* Benth.	Shrub
41	Verbenaceae	*Gmelina arborea* Roxb.	Tree

Table 4.16. Diversity indices of Plant species enumerated in the soil seed bank per soil depth in Wet season and Dry season in the Teak plantation at Gambari Forest Reserve, Ibadan, Nigeria.

Layers	Taxa S	Individuals	Dominance D	Simpson 1-D	Shannon H	Equitability J
SB 0-5 Dry	38	2703	0.08	0.92	3.01	0.83
SB 0-5 Wet	20	1338	0.13	0.87	2.38	0.79
SB 5-10 Dry	29	323	0.09	0.91	2.89	0.86
SB 5-10 Wet	14	218	0.17	0.83	2.07	0.78

Table 4.17. Density, Relative Density, Frequency, Relative Frequency and Relative Importance Values (RIV) of the plant species enumerated in the soil seed bank of the 0 to 5 cm soil depth in the Wet season in the Teak plantation at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
1	*Chromolaena odorata*	3.28	22.05	75.56	21.79	21.92
2	*Sida acuta*	2.84	19.13	60.00	17.31	18.22
3	*Oplismenus burmannii*	2.33	15.70	26.67	7.69	11.69
4	*Cynodon dactylon*	1.51	10.16	28.89	8.33	9.25
5	*Alternanthera sessilis*	0.79	5.31	21.11	6.09	5.70
6	*Cyathula prostrata*	0.43	2.91	18.89	5.45	4.18
7	*Boerhavia diffusa*	0.41	2.77	17.78	5.13	3.95
8	*Mimosa pudica*	0.42	2.84	16.67	4.81	3.82
9	*Mariscus alternifolius*	0.42	2.84	13.33	3.85	3.34
10	*Axonopus compresus*	0.60	4.04	6.67	1.92	2.98
11	*Commelina benghalensis*	0.36	2.39	10.00	2.88	2.64
12	*Cymbopogon citratus*	0.37	2.47	7.78	2.24	2.35
13	*Commelina erecta*	0.24	1.64	8.89	2.56	2.10
14	*Solanum americanum*	0.18	1.20	8.89	2.56	1.88
15	*Waltheria indica*	0.16	1.05	8.89	2.56	1.81
16	*Phaseolus lunatus*	0.22	1.49	4.44	1.28	1.39
17	*Tithonia diversifolia*	0.10	0.67	4.44	1.28	0.98
18	*Eleusine indica*	0.14	0.97	3.33	0.96	0.97
19	*Celosia leptostachya*	0.03	0.22	2.22	0.64	0.43
20	*Gmelina arborea*	0.02	0.15	2.22	0.64	0.40
Total		14.85	100.00	346.67	99.97	100.00

Key: D = Density; RD = Relative Density; F= Frequency; RF = Relative Frequency; RIV = Relative Importance Value.

Table 4.18. Density, Relative Density, Frequency, Relative Frequency and Relative Importance Values (RIV) of the plant species enumerated in the soil seed bank of the 0 to 5 cm soil depth in the Dry season in the Teak plantation in Gambari Forest Reserve, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
1	*Chromolaena odorata*	4.97	16.54	85.56	17.58	17.06
2	*Sida acuta*	3.53	11.76	56.67	11.64	11.70
3	*Cynodon dactylon*	3.12	10.40	32.22	6.62	8.51
4	*Oplismenus burmannii*	2.97	9.88	31.11	6.39	8.14
5	*Mimosa pudica*	2.01	6.70	15.56	3.20	4.95
6	*Alternanthera sessilis*	1.00	3.33	20.00	4.11	3.72
7	*Boerhavia diffusa*	0.91	3.03	21.11	4.34	3.69
8	*Digitaria longiflora*	1.14	3.81	11.11	2.28	3.05
9	*Cyathula prostrata*	0.69	2.29	17.78	3.65	2.97
10	*Celosia leptostachya*	0.66	2.18	14.44	2.97	2.58
11	*Trianthema portulacrastrum*	0.76	2.52	11.11	2.28	2.40
12	*Mariscus alternifolius*	0.60	2.00	13.33	2.74	2.37
13	*Dactylotenium aegyptium*	0.89	2.96	7.78	1.60	2.28
14	*Triumfetta rhomboidea*	0.57	1.89	10.00	2.05	1.97
15	*Cymbopogon citratus*	0.56	1.85	10.00	2.05	1.95
16	*Phaseolus lunatus*	0.41	1.37	11.11	2.28	1.83
17	*Waltheria indica*	0.41	1.37	11.11	2.28	1.83
18	*Commelina benghalensis*	0.34	1.15	10.00	2.05	1.60
19	*Commelina erecta*	0.30	1.00	10.00	2.05	1.53
20	*Spigelia anthelmia*	0.34	1.15	8.89	1.83	1.49
21	*Oldenlandia corymboza*	0.31	1.04	8.89	1.83	1.43
22	*Axonopus compresus*	0.51	1.70	5.56	1.14	1.42
23	*Sida garckeana*	0.28	0.92	8.89	1.83	1.38
24	*Calopogonium mucunoides*	0.38	1.26	6.67	1.37	1.31
25	*Corchorus olitorius*	0.37	1.22	6.67	1.37	1.30
26	*Croton lobatus*	0.24	0.81	4.44	0.91	0.86
27	*Tithonia diversifolia*	0.24	0.81	4.44	0.91	0.86
28	*Gomphrena celosiodes*	0.19	0.63	4.44	0.91	0.77
29	*Amaranthus spinosus*	0.26	0.85	3.33	0.68	0.77
30	*Boerhavia erecta*	0.18	0.59	4.44	0.91	0.75
31	*Pouzolzia guineensis*	0.11	0.37	3.33	0.68	0.53
32	*Euphorbia hirta*	0.18	0.59	2.22	0.46	0.52
33	*Laportea aestuans*	0.09	0.30	3.33	0.68	0.49
34	*Acalypha ciliata*	0.13	0.44	2.22	0.46	0.45
35	*Melanthera scadens*	0.12	0.41	2.22	0.46	0.43

Table 4.18. Cont'd. Density, Relative Density, Frequency, Relative Frequency and Relative Importance Values (RIV) of the plant species enumerated in the soil seed bank of the 0 to 5 cm soil depth in the Dry season in the Teak plantation in Gambari Forest Reserve, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
36	*Phylathus amrus*	0.11	0.37	2.22	0.46	0.41
37	*Celosia trigyna*	0.08	0.26	2.22	0.46	0.36
38	*Phaulopsis ciliata*	0.08	0.26	2.22	0.46	0.36
Total		30.04	100.01	486.64	99.97	100.02

Key: D = Density; RD = Relative Density; F= Frequency; RF = Relative Frequency; RIV = Relative Importance Value.

Table 4.19. Density, Relative Density, Frequency, Relative Frequency and Relative Importance Values (RIV) of the plant species enumerated in the soil seed bank of the 5 to 10 cm soil depth in the Wet season in the Teak plantation at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
1	*Chromolaena odorata*	0.69	28.44	32.22	32.95	30.70
2	*Sida acuta*	0.52	21.56	26.67	27.27	24.42
3	*Cynodon dactylon*	0.42	17.43	8.89	9.09	13.26
4	*Alternanthera sessilis*	0.12	5.05	5.56	5.68	5.36
5	*Axonopus compresus*	0.12	5.05	3.33	3.41	4.23
6	*Commelina benghalensis*	0.12	5.05	3.33	3.41	4.23
7	*Mariscus alternifolius*	0.11	4.59	3.33	3.41	4.00
8	*Mimosa pudica*	0.07	2.75	4.44	4.55	3.65
9	*Oplismenus burmannii*	0.10	4.13	2.22	2.27	3.20
10	*Tithonia diversifolia*	0.06	2.29	2.22	2.27	2.28
11	*Cymbopogon citratus*	0.03	1.38	2.22	2.27	1.82
12	*Boerhavia diffusa*	0.03	1.38	1.11	1.14	1.26
13	*Cyathula prostrata*	0.01	0.46	1.11	1.14	0.80
14	*Waltheria indica*	0.01	0.46	1.11	1.14	0.80
Total		2.41	100.02	97.76	100.00	100.01

Key: D = Density; RD = Relative Density; F= Frequency; RF = Relative Frequency; RIV = Relative Importance Value.

Table 4.20. Density, Relative Density, Frequency, Relative Frequency and Relative Importance Values (RIV) of the plant species enumerated in the soil seed bank of the 5 to 10 cm soil depth in the Dry season in the Teak plantation in Gambari Forest Reserve, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
1	*Chromolaena odorata*	0.72	20.12	35.56	25.40	22.76
2	*Sida acuta*	0.56	15.48	20.00	14.29	14.88
3	*Mariscus alternifolius*	0.18	4.95	7.78	5.56	5.25
4	*Cynodon dactylon*	0.20	5.57	4.44	3.17	4.37
5	*Cymbopogon citratus*	0.17	4.64	5.56	3.97	4.31
6	*Mimosa pudica*	0.12	3.41	6.67	4.76	4.08
7	*Oplismenus burmannii*	0.18	4.95	4.44	3.17	4.06
8	*Celosia leptostachya*	0.17	4.64	4.44	3.17	3.91
9	*Axonopus compresus*	0.13	3.72	4.44	3.17	3.44
10	*Alternanthera sessilis*	0.12	3.41	4.44	3.17	3.29
11	*Dactylotenium aegyptium*	0.12	3.41	4.44	3.17	3.29
12	*Waltheria indica*	0.09	2.48	5.56	3.97	3.22
13	*Commelina erecta*	0.09	2.48	4.44	3.17	2.83
14	*Corchorus olitorius*	0.09	2.48	3.33	2.38	2.43
15	*Trianthema portulacrastrum*	0.08	2.17	3.33	2.38	2.27
16	*Sida garckeana*	0.07	1.86	2.22	1.59	1.72
17	*Croton lobatus*	0.06	1.55	2.22	1.59	1.57
18	*Triumfetta rhomboidea*	0.06	1.55	2.22	1.59	1.57
19	*Commelina benghalensis*	0.04	1.24	2.22	1.59	1.41
20	*Digitaria longiflora*	0.07	1.86	1.11	0.79	1.33
21	*Amaranthus spinosus*	0.02	0.62	2.22	1.59	1.10
22	*Acalypha ciliata*	0.04	1.24	1.11	0.79	1.02
23	*Melanthera scadens*	0.04	1.24	1.11	0.79	1.02
24	*Calopogonium mucunoides*	0.03	0.93	1.11	0.79	0.86
25	*Cyathula prostrata*	0.03	0.93	1.11	0.79	0.86
26	*Euphorbia hirta*	0.03	0.93	1.11	0.79	0.86
27	*Phylathus amrus*	0.03	0.93	1.11	0.79	0.86
28	*Oldenlandia corymboza*	0.02	0.62	1.11	0.79	0.71

Table 4.20. Cont'd. Density, Relative Density, Frequency, Relative Frequency and Relative Importance Values (RIV) of the plant species enumerated in the soil seed bank of the 5 to 10 cm soil depth in the Dry season in the Teak plantation in Gambari Forest Reserve, Ibadan, Nigeria (from the highest to the lowest RIV values).

No	Species	D	RD	F	RF	RIV
29	*Phaulopsis ciliata*	0.02	0.62	1.11	0.79	0.71
Total		3.58	100.03	139.96	99.96	99.99

Key: D = Density; RD = Relative Density; F= Frequency; RF = Relative Frequency; RIV = Relative Importance Value.

4.6 Similarity between the standing vegetation and the soil seed bank

Tables 4.21 and 4.22 show detailed information on the species and families recorded in both the above ground vegetation and soil seed bank. Among the different plant forms of the vegetation, no difference was found between the tree species of both seasons. The similarity was higher between the shrubs (85.71%) followed by the climbers (55.56%) and the herbaceous species (46.67%). There was no similarity between the different life forms of the above ground vegetation. Although all the species found in the 5 to 10 cm soil depth layer of each season were also present in the 0 to 5 cm soil depth layer of the corresponding season, there was dissimilarities between the soil seed banks of the wet and dry seasons. The highest similarity between the different soil depth and seasons was found between the 0 to 5 cm dry season soil depth and the 5 to 10 cm dry season soil depth (76.32%) followed by the similarity between the 0 to 5 cm wet season soil depth and the 5 to cm wet season soil depth (70%). The similarities between the 0 to 5 cm wet season soil depth and both dry season soil depth layers were 41.46 % for the 0 to 5 cm and 40% for the 5 to 10 cm soil depths respectively. The Jaccard similarity between the soil seed bank layers was lower than that of aboveground vegetation. The similarity between the seed bank and the main trees was very low. The extent of similarity in the species composition of above ground and seed bank flora is shown in Table 4.23.

4.7 Teak carbon stock in the coppiced teak plantation in the Gambari Forest Reserve, Busogboro, Ibadan, Nigeria

The average teak diameter at breast height (DBH) was 24.17 cm (± 0.15 standard error). However, it is important to note that only the individuals that had girth equal to or greater than 30 cm so the inferred DBH range 9 cm and onward were measured. The mean individual height was 13.46 ± 0.08 m. Figure 4.4 and Figure 4.5 show the distribution of the teak individuals sampled per height classes and DBH classes respectively. The mean teak biomass inferred using the allometric equation was 1503.22 Kg (± 22.38 SE) and 252.33 Kg (± 3.33 SE) for the aboveground biomass and the belowground biomass per hectare respectively. The total biomass per hectare was estimated as 1755.55 Kg (± 25.71 SE). The total carbon stock was estimated as half of the total biomass and was 877.78 Kg (± 12.85 SE) per hectare. Details of the total biomass and total carbon storage capacity per teak according to the diameter at breast height is provided in Table 4.24.

Table 4.21. List of species enumerated in both the vegetation and soil seed bank

No	Family	Species	Habit
1	Acanthaceae	*Phaulopsis ciliata*	Herb
2	Amaranthaceae	*Alternanthera sessilis*	Herb
3		*Celosia leptostachya*	Herb
4		*Cyathula prostrata*	Herb
5	Asteraceae	*Chromolaena odorata*	Shrub
6		*Tithonia diversifolia*	Shrub
7	Commelinaceae	*Commelina benghalensis*	Herb
8		*Commelina erecta*	Herb
9	Cyperaceae	*Mariscus alternifolius*	Sedge
10	Fabaceae	*Mimosa pudica*	Herb
11		*Phaseolus lunatus*	Vine
12	Malvaceae	*Sida acuta*	Shrub
13		*Waltheria indica*	Herb
14	Nyctaginaceae	*Boerhavia diffusa*	Herb
15	Poaceae	*Axonopus compresus*	Grass
16		*Cymbopogon citratus*	Herb
17		*Cynodon dactylon*	Grass
18		*Eleusine indica*	Grass
19		*Oplismenus burmannii*	Grass
20	Solanaceae	*Solanum americanum*	Herb
21	Verbenaceae	*Gmelina arborea*	Tree

Table 4.22. Number of species enumerated per family both in the vegetation and soil seed bank

No	Family	Count of Species
1	Acanthaceae	1
2	Amaranthaceae	3
3	Asteraceae	2
4	Commelinaceae	2
5	Cyperaceae	1
6	Fabaceae	2
7	Malvaceae	2
8	Nyctaginaceae	1
9	Poaceae	5
10	Solanaceae	1
11	Verbenaceae	1

Table 4.23 Jaccard similarity index (%) between the different layers based on their species composition

	SB 0-5 Wet	SB 0-5 Dry	SB 5-10 Wet	SB 5-10 Dry	Trees Wet	Trees Dry	Shrubs Wet	Shrubs Dry	Herbaceous Wet	Herbaceous Dry	Climbers Wet	Climbers Dry
SB 0-5 Wet	_											
SB 0-5 Dry	41.46	_										
SB 5-10 Wet	70.00	36.84	_									
SB 5-10 Dry	40.00	76.32	38.71	_								
Trees Wet	1.79	0.00	0.00	0.00	_							
Trees Dry	1.79	0.00	0.00	0.00	100.00	_						
Shrubs Wet	7.89	5.36	9.38	4.17	0.00	0.00	_					
Shrubs Dry	8.57	5.66	10.34	4.44	0.00	0.00	85.71	_				
Herbaceous Wet	42.86	25.93	33.33	28.26	0.00	0.00	0.00	0.00	_			
Herbaceous Dry	61.90	30.00	64.71	34.38	0.00	0.00	0.00	0.00	46.67	_		
Climbers Wet	2.70	1.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	_	
Climbers Dry	3.45	2.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	55.56	_

Keys: HD = Herbs Dry season, HW = Herbs Wet season, SBW = Seed bank Wet season, SBD = Seed bank Dry season, SD= Shrubs Dry season, SW = Shrubs Wet season, TD = Trees Dry, TW = Trees Wet season

Table 4.24 Total biomass and total carbon per tree based on the DBH class in Teak plantation stand at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

DBH ranges (cm)	0-10	10-20	20-30	30-40	40-50	50-60
Total Biomass (Kg)						
Mean	40.61	124.92	391.05	771.19	1437.87	2107.76
SE	0.28	1.50	3.07	5.03	14.39	16.93
Min	37.57	47.26	229.79	600.84	1164.61	1980.33
Max	43.89	221.34	586.13	1143.05	1951.04	2223.73
Total Carbon (Kg)						
Mean	20.3	62.45	195.52	385.59	718.93	1053.87
SE	0.14	0.75	1.53	2.51	7.20	8.46
Min	8.78	23.61	114.88	300.42	582.3	990.16
Max	21.94	110.67	293.06	571.52	975.52	1111.86

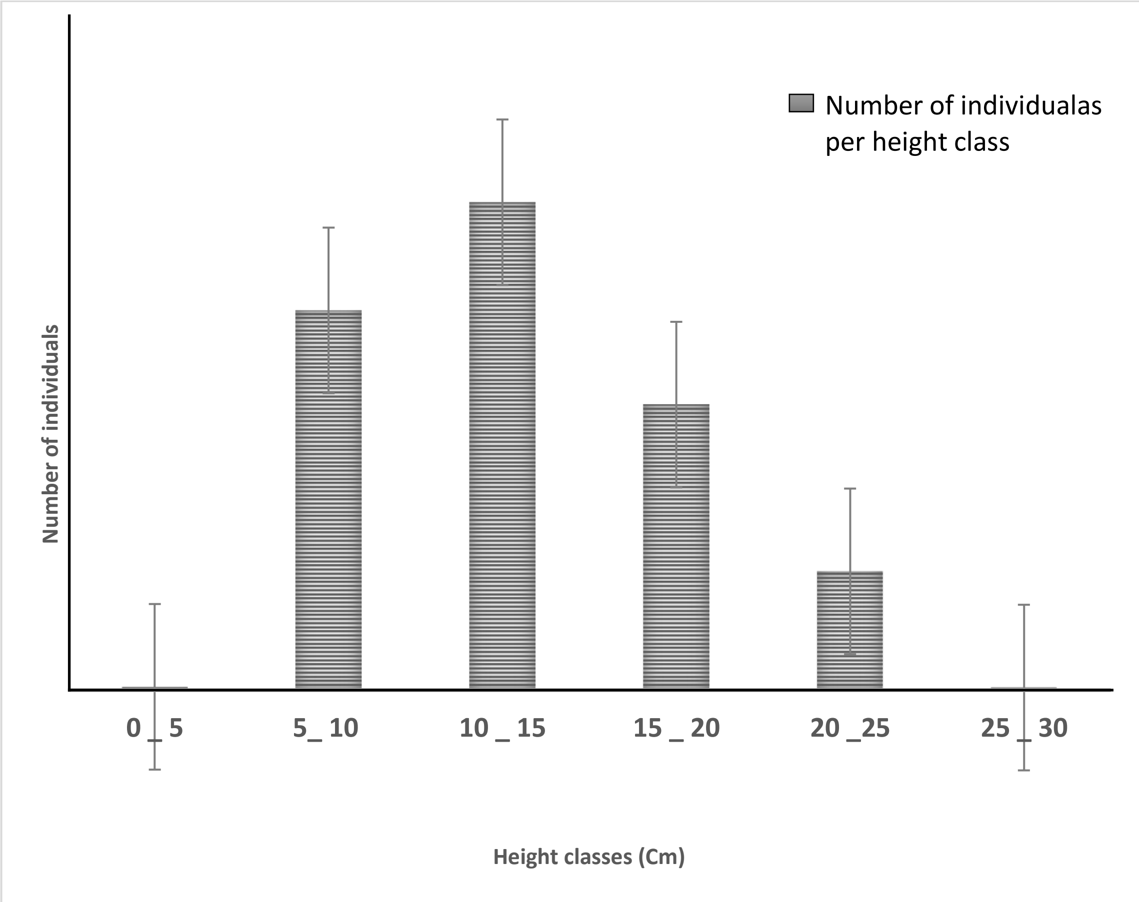

Figure 4.4 Height distribution of Teak individuals in the coppiced Teak plantation at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

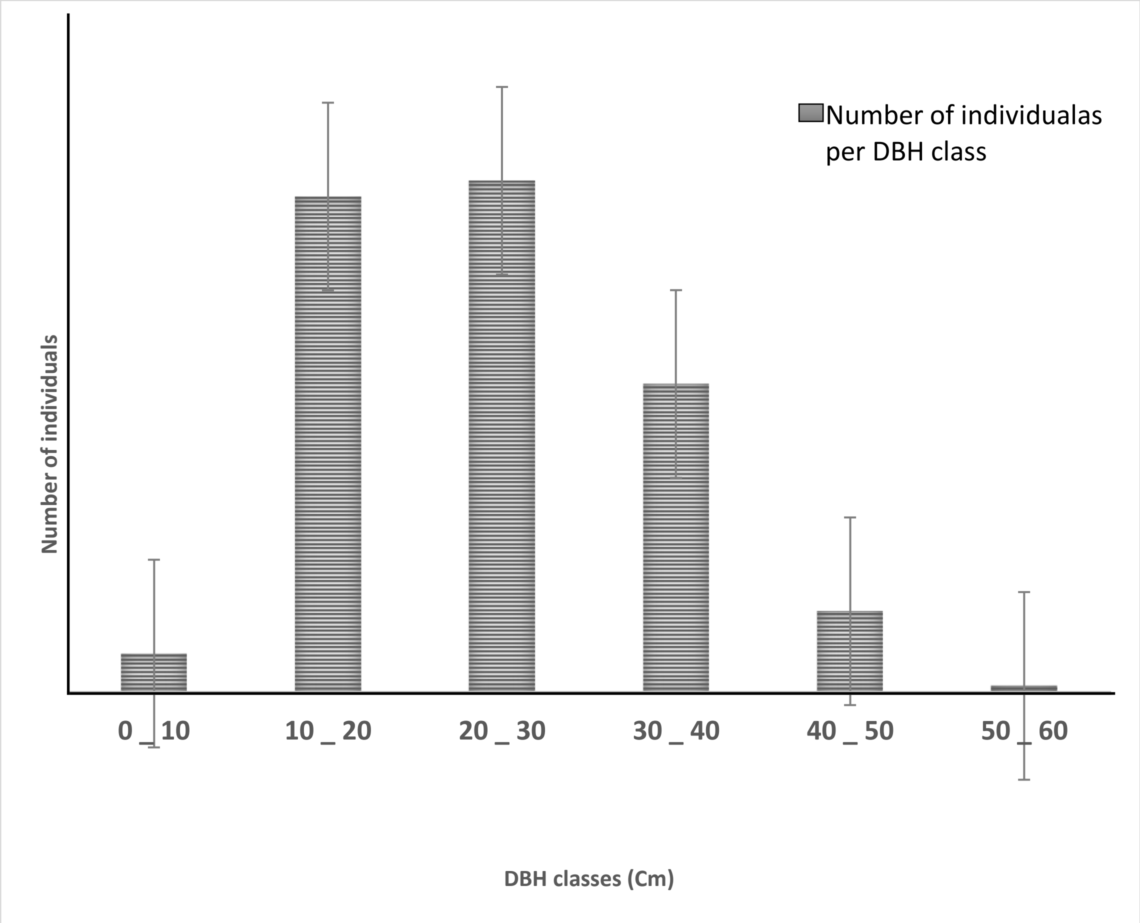

Figure 4.5 DBH distribution of Teak individuals in the coppiced Teak plantation at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

CHAPTER FIVE

5.0 DISCUSSION

Land use and land cover changes are critical issues that treat biodiversity and the natural environment. Great environmental consequences could result in great vulnerability to natural hazards. The increasing demand for wood and timber products as well as agricultural pressures are among the major causes of land conversion in the study area (Adedeji *et al.*, 2015).

In this study we found increasing transformation of the site into forest plantation and agricultural farms over the time. This highlights the increasing recognition of the socioeconomical and environmental importance of forest plantation by the local communities. However, the plantation witnesses various pressures such as illegal tree falling and bush fires which have considerable impacts on the productivity of the plantation. Ohers researchers also found similar pressures on secondary forest and forest plantations in southern Nigeria (Chima *et al.*, 2013; Adedeji *et al.*, 2015).

The species composition of the flora is an excellent tool to understanding the strengths and weaknesses of an ecosystem. In this study, we recorded an important number of species in aboveground flora and soil seed bank. The aboveground flora was dominated by tree species although the low growing plants were also well distributed in the forest monoculture showing the good resilience potential of the zone. The herbaceous layer was poorly represented in the aboveground flora and was dominated by exotic and human-introduced species while the soil seed bank was mainly made of herbaceous species. This corroborates many other reports on soil seed bank structure in forests and forest plantations (Senbeta and Teketay, 2001; Tesfaye *et al.*, 2004; Oke *et al.*, 2007; Jędrzejczak, 2013; Olatunji *et al.*, 2015; Chima and Alex, 2017).

The forest monocropping system was affected by the local biodiversity, as shown by the richness of indigenous plant species in the plantation and its soil seed bank. The studies in the forest reserve have also reported that indigenous species are important in the plantation areas (Adedeji *et al.*, 2015; Ige and Akinyemi, 2015). Although Teak conveniently tolerates cohabitation with other species, their incursion, even though many of these species were poorly distributed across the plantation, may drastically reduce or modify the proper development of its coppice shoots because they are light-demanding. Chima and Alex (2017) also reported for monocultural cropping system where they found out greater species richness and diversity in the forest plantations as compared to the natural forest. Awodoyin *et al*. (2013) found closer species richness in the low growing plants of cocoa stands in Ekiti, Oyo and Cross River States, but there are some dissimilarities between our species compositions. These differences may be due to the variations between the microclimate under the canopies of the two forms of plantations.

The aboveground species richness and abundance were greater in the wet season corroborating the findings of other researchers in tropical zones (Chen *et al.,* 2013). This variation may be related to various aspects such as the competition for water resources and the continuous human activities within the forest plantation which undergoes frequent bush fires and other kinds of deforestation. The shrub and climbing species were the most concerned.

The families with the highest number of species were Leguminosae followed by Poaceae, the Malvaceae and Apocynaceae. These results are similar to other reports of the vegetation in southwest Nigeria. For instance, in the report of Sanyaolu *et al.* (2018) the families Leguminosae and Apocynaceae were among the dominant families in most of their study sites. However, the Araceae and Moraceae families, dominant in their report were not well represented in the field. Also, Leguminosae had been important in various other reports on primary and secondary natural forest and forest plantation areas in the tropical zone (Ihenyen *et al.*, 2009; Awodoyin *et al.*, 2013; Adedeji *et al.*, 2015; Ige and Akinyemi, 2015).

The dominance of the Poaceae family may be attributed to frequent occurrence of bush fires in the forest plantation which might be favourable to the establishment of helophytes species. Since most of the grass species could behave as pioneer colonizers, any opening in the canopy would stimulate their establishment in the site.

Together with Leguminosae, the Poaceae family is one of the most important plant families in the savanna zone (Idrissa *et al.*, 2017; Souley *et al.*, 2018). Although it is less represented in the lowland rain forest and dry forest areas. This shift would, therefore, suggest a possible transition of the plantation stand to savanna (Adedeji *et al.*, 2015; Oke *et al.*, 2006).

The Shannon-Wiener diversity index and the Simpson index are good estimates of both the species richness and evenness. The values of these indices were low in the vegetation due to the monocultural nature of the ecosystem. However, the low growing plants were more diverse. This was in contrast to the findings of Tondoh *et al.* (2015) who found greater diversities in trees. Higher values of diversity indices were found in the soil seed bank suggesting that the soil seed bank could play an important role in establishing future communities across the study environment. The soil seed bank thus constitute a potential threat to the resilience of the teak plantation. Although the diversity of the seed bank followed the same trend with the results of Chima and Alex (2017), we found greater diversity compared to their results of the various monoculture site but closer diversity with their strictly protected forest. This could be attributed to a lesser impact of the stand management strategies to handle the establishment of other plants within the monocultures. However, the species of the seed bank were mostly non forest species and may not have serious damage on the ability of coppices to grow. Other researchers also found that the soil seed bank would not be a serious source of recruitment within teak plantation (Chima and Alex, 2017).

The species evenness and equitability were high in the herbaceous standing vegetation and seed bank layers regardless of the sampling period. The species dominance was generally low except for the trees layer due to the monocultural practice. The species distribution of the trees layer revealed the incursion of the other tree species in the teak plantation, although some of these species such as *Gmelina arborea* are also human-introduced species in the stands. Some indigenous plants of zones such as *Albizia zygia, Funtumia africana* and *Triplochiton scleroxylon* are invading in the study site. This results corroborates the results of Salami *et al.* (2016) who reported that the indigenous plants are still important in Gambari forest reserve. However, we noticed a shift in the density of individuals, between the two surveys irrespective of the species. The shift of density of individuals across all the species highlights the consistent anthropogenic pressure on the forest resources. Around 41% of the species were poorly represented with their RIV less than 1%. *Bombax buonopozense, Morinda lucida, Zanthoxylum zanthoxyloides,* although important in the study' zone, were the least represented species in the main trees layer in the survey.

The species distribution in the understory layer revealed an important presence of other trees saplings even though many of these species were absent in the big tree category. Saplings of *Tectona grandis* still dominated the understory but may be subjected to a serious competition which at the long term will result in lesser productivity of the plantation. It has been highlighted that even though teak combines different propagation strategies, which are the production of a large amount of seeds and the production of important coppice shoots after harvesting, competition from other species is very critic for its development (Ounban *et al.*, 2016). Species such as *Albizia zygia, Elaeis guineensis, Icacina trichantha, Alchornea laxiflora, Lecaniodiscus cupanioides, Markhamia tomentosa,* reported in various investigation in the lowland rainforest zone (Ogunleye *et al.*, 2004; Lemenih and Teketay, 2006; Larinde and Olasupo, 2011; Ige and Akinyemi, 2015; Olatunji *et al.*, 2015) were important in the understory showing that the plantation stands still had the capacity to regenerate to replace itself. However, *Gmelina arborea,* another exotic and planted as a monocultural species in other parts of the forest reserve (Adedeji *et al.*, 2015) is becoming important in the Teak stands as revealed by this study. The least abundant shrub species were *Afraegle paniculate, Ancylobotrys amoena, Celtis adolfi-friderici, Zanthoxylum zanthoxyloides, Rhigiocarya racemifera, Lawsonia inermis* and *Irvingia gabonensis*.

The low growing flora was dominated by *Sida acuta* and *Chromolaena odorata* both in the wet and dry seasons. *Chromolaena odorata* has been reported as a species with high invasive capacity in plantation stands (Awodoyin *et al.*, 2013) and secondary forest stands (Adedeji *et al.*, 2015) in Southwest Nigeria. Some grass and herb species such as *Cynodon dactylon*, *Oplismenus burmannii*, *Digitaria horizontalis* and *Alternanthera sessilis* were also abundant in the plantation corroborating other previous researches in forest monocropping (Oke *et al.*, 2007; Yang and Li, 2013; Chima and Alex, 2017).

The species richness of the soil seed bank has consistently increased from 20 species during the wet season survey to 38 species during the dry season. This may be due to the absence of the transient seeds in the soil samples of the wet season survey. It has been highlighted in some previous works that the seedling emergence method is powerful in examining the persistent seed bank but would highly underestimate the transient seed depending on the sampling time (Ghermandi *et al.*, 2012).

Among the woody plants recorded in the aboveground flora, only *Gmelina arborea* emerged from the seed bank. The dissimilarity found between the seed bank and the above ground plant species composition agrees with the results of Oke *et al.*

(2007) who found that the herbaceous species represented 98% of the seed bank of plantation stands in Ile Ife and also followed the same trend of the findings of Chima and Alex (2017) in Omo biosphere reserve. According to the latter authors, the paucity of the woody flora in the seed bank would be explained by the recalcitrant nature of their seeds. Their absence may also be related to some physiological characteristics of their seeds or the non-satisfaction of some of their germination requirements. According to Gaertner *et al.* (2009), although the seedling emergence method is efficient and more applicable especially, for large scale seed bank studies, but would drastically underestimate both the species composition and abundance.

The abundance of exotic species was also high in all the different plant layers regardless of the sampling season. Farinloye *et al.* (2018) also recorded a similar level of exotic species in their assessment in Ibadan. The ability of alien species to colonize an area through the establishment of persistent seed bank has been pointed out in different ecosystems across the globe (Gaertner *et al.*, 2009; Margherita and Osborne, 2009; Oke *et al.*, 2009; Butchart *et al.*, 2010; Chen *et al.*, 2013). In this study, we recorded high RIV for *Chromolenea odorata* and *Sida acuta* both exotic weed species, in the deeper topsoil layer suggesting their invasion in the plantation stands. *Chromolaena odorata*, *Sida acuta*, *Cynodon dactylon*, *Oplismenus burmannii* and *Alternanthera sessilis* were both in the surface (0 to 5 cm) top soil and the deeper (5 to 10 cm) top soil layers. However, *Cyathula prostrata* and *Oplismenus burmannii* were also important in the 0 to 5 cm soil deep while *Axonopus compresus*, *Cymbopogon citratus* and *Mariscus alternifolius* showed greater contribution to the species diversity of the deeper top soil layer. Most of the species recorded in our seed bank have lees then 1% contribution to the seedling's diversity.

The soil seed bank has been reported to be richer and more diverse compared to the low-growing plant layer in plantation areas (Oke *et al.*, 2007; Oladipo and Oke, 2007; Chima and Alex, 2017). Our results also showed greater diversity and species richness in the seed bank compared to the herbaceous layer. This could be attributed to the absence of woody plants in our soil seed bank. Out of the 41 species identified in the soil seed bank in this study, *Gmelina arborea* was the only woody species recorded. Other researchers have also reported poor representation of woody flora in the soil seed bank of various tree monocultural systems (Akinyemi and Oke, 2013). The same trend of dissimilarity between the seed bank and the woody vegetation have been observed in different types of forest under different forms of disturbances (Oke *et al.*, 2006; Yu *et al.*, 2007; Chima *et al.*, 2013; Olatunji *et al.*, 2015). For instance, Oke *et al.* (2007) identified only three woody species in their study while the herbaceous species accounted for (98%) of their record. Some authors suggested that the paucity of woody species in the seed bank may be linked to the short life duration of the forest species seeds being recalcitrant in nature (Lemenih and Teketay, 2006). The Jaccard similarity index between the seed bank and the different aboveground plant layers ranged from 0 to 81% with larger values recorded between the seed bank and herbaceous standing flora.

Forests sequester carbon dioxide from the atmosphere through photosynthesis and stored it into the soil. The capacity to sequester carbon varies with several biotic and abiotic factors and is also species specific (Houghton *et al.*, 2012; Alemu, 2016). Teak is known as one of the most important plant in term of carbon storage capacity. Although we only took in account of the Teak individuals with a circumference at 1.30 m equal to or greater than 30 cm were so the inferred DBH range 9 cm and onward, the biomass per hectare and the total carbon stock per hectare were relatively low in the forest plantation.

The results did not follow the same trend with the findings of Chukwu and Olajuyigbe (2017) in other part of the Gambari forest reserve and N'Gbala *et al.* (2017) in Teak plantation stands in Cote d'Ivoire. This may be explained by the fact that teak planted in agroforestry and mixed timber systems shows better growth performance compared to teak planted in monoculture system (James *et al.*, 2016). On another hand the plantation witnesses various exploitations of wood and timber resulting in a low number of adult steams thus implying the low carbon stock. Also the biomass of the young coppices and seedling with DBH lesser then 9 cm would be considerable as reported by N'Gbala *et al.* (2017) in Cote d'Ivoire.

The teak carbon stock was low in the plantation area. In their study conducted over various land use types in Malaysia James *et al.* (2016) reported that teak sequesters more carbon dioxide in mixed plantation than in a monocropping system. Furthermore, the joint effects of the coppicing status of plantation and the intensive anthropologic pressures may have resulted in the low carbon stock within the area. For instance Chukwu and Olajuyigbe (2017) found greater teak carbon sequestration in other part of Gambari Forest Reserve.

CHAPTER SIX

6.0 SUMMARY AND CONCLUSIONS

The investigation carried out to understand the trend of the vegetation over the last three decades revealed the effect of anthropogenic pressures on the plantation area which result in a gradual establishment of other flora both in the vegetation and soil seed bank of the coppiced teak plantation. The plantation was rich of 106 plant species among which 37 Trees, 19 Shrubs, 17 Climbers and 33 Herbaceous plants. The soil seed bank was rich of 41 plant species which include 1 Tree, 4 Shrubs, 2 Climbers and 34 Herbaceous plants. The soil seed bank flora species richness was greater during the dry season on one hand while it was greater in the 0 to 5 cm top soil layer on the other hand. *Chromolenea odorata* and *Sida actua* tended to dominate the soil seed bank in both seasons and soil depth layers. The similarity between the species composition of the vegetation and soil seed bank was low, especially for trees, shrubs and climbers. The teak carbon stock was low in the coppice plantation.

The low species diversity among trees is peculiar to monoculture plantation forest, and the relatively high species diversity among shrubs, climbers, herbaceous plants and soil seed bank are peculiar to coppiced plantation because of increased light penetration resulting from opened canopy. The low species dominance except of *Tectona grandis* in the trees revealed the capacity of the coppiced plantation to sustain itself if proper silvicultural practices were adopted. The frequency of *Gmelina arborea* in the vegetation as well as its establishment in the soil seed bank revealed that it may become a threat to the teak productivity in the plantation. Therefore, the plantation management in conservation with the other stakeholders should pay proper attention to its propagation within the plantation.

The results revealed that the plant species other than teak that had established in the vegetation and present in the soil seed bank are becoming a threat to the sustainable productivity and integrity of the teak plantation. The consistent soil seed bank of pioneer plant species, mostly agricultural weeds, indicates the commencement of natural succession that may threaten the reestablishment of the teak stands. Therefore, proper attention must be given to the ecological implications of those species specifically to the species known for their invasive abilities. The findings of this study also call for the development of strategies aimed at controlling the effect of the surrounding vegetation on the maintenance and productivity of the teak monoculture. The findings of this research also highlight the long-term implications of the establishment of wilding plants on the resilience and the self-maintenance capacities of the plantation.

This study has highlighted the alarming constitution of the persistent soil seed bank by some species such as *Chromolenea odorata*, *Sida acuta* and *Oplesimonous boorneii,* all of these are invasive species, within the plantation. The coppicing stage of the plantation and the incursion of other plant species have resulted in the low teak carbon stock in the plantation. Therefore, proper attention should be given to their impacts on the plantation and potentially the surrounding environment.

REFERENCES

Adedeji, O.H., Tope-ajayi, O.O. and Abegunde, O.L. 2015. Assessing and Predicting Changes in the Status of Gambari Forest Reserve , Nigeria Using Remote Sensing and GIS Techniques. *Journal of Geographic Information System* 7: 301–318.

Akinsoji, A. 2013. Quantitative Analysis of a Forest Fragment in Olokemeji Forest Reserve, Nigeria. *Journal of Natural Sciences Research* 3.13: 111–115.

Akinyemi, D.S. and Oke, S.O. 2013. Soil seedbank dynamics and regeneration in the three different pysiognomies in Shasha Forest in Southwestern Nigeria. *Ife journal of science* 15.2: 367–383.

Akpan-ebe, I.N. 2017. Reforestation in Nigeria : History , current practice and future perspectives. *REFORESTA* 3: 105–115.

Alemu, M.M. 2016. Soil Seed Bank and Natural Regeneration of Trees. *Journal of Sustainable Development* 9.2: 73–77.

Arruda, A.J., Buisson, E., Poschlod, P. and Silveira, F.A.O. 2018. How have we studied seed rain in grasslands and what do we need to improve for better restoration ? *Restoration Ecology* 26.S2: S84–S91.

Awodoyin, R.O., Akinyemi, C.Y., Bolanle, O.. and Antiabong, I.C. 2013. Spatial Distribution And Abundance Of Solanecio Biafrae (Olive & Heirne) C. Jeffrey And Structure Of Weed Communities In Some Cocoa Plots In Ekiti, Oyo And Cross River States, Nigeria. *Ife Journal of Science* 15.3: 661–676.

Barbour, M.G., Burk, J.H., Pitts, W.D., Gilliam, F.S. and Schwartz, M.W. 1999. Methods of sampling the plant community. *Terrestrial plant ecology*. Third edit edition. Addison Wesley Longman, Inc. 210–239

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.

Batista, A.P.B., De Mello, J.M., Raimundo, M.R., Scolforo, H.F., Dos Reis, A.A. and

Scolforo, J.R.S. 2016. Species richness and diversity in shrub savanna using ordinary kriging. *Pesquisa Agropecuaria Brasileira* 51.8: 958–966.

Bossuyt, B. and Honnay, O. 2008. Can the seed bank be used for ecological restoration? An overview of seed bank characteristics in European communities. *Journal of Vegetation Science* 19.6: 875–884.

Bouyoucos, G.J. 1951. A Recalibration of the Hydrometer Method for Making Mechanical Analysis of Soils. *Agronomy Journal* 43.9: 434–438.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total, organic, and available forms of phosphorus in soils. *Soil Science* 59: 39–45.

Bremner, J.M. and Mulvaney, C.S. 1982. Nitrogen-Total. *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties*. American Society of Agronomy, Soil Science Society of America, Madison. 595–624

Buisson, E., Jaunatre, R., Römermann, C., Bulot, A. and Dutoit, T. 2018. Species transfer via topsoil translocation : lessons from two large Mediterranean restoration projects. *Restoration Ecology* 26.S2: S179–S188.

Butchart, S.H.M., Walpole, M., Collen, B., Van Strien, A., Scharlemann, J.P.W., Almond, R.E.A., Baillie, J.E.M., Bomhard, B., Brown, C., Bruno, J., Carpenter, K.E., Carr, G.M., Chanson, J., Chenery, A.M., Csirke, J., Davidson, N.C., Dentener, F., Foster, M., Galli, A., Galloway, J.N., Genovesi, P., Gregory, R.D., Hockings, M., Kapos, V., Lamarque, J.F., Leverington, F., Loh, J., McGeoch, M.A., McRae, L., Minasyan, A., Morcillo, M.H., Oldfield, T.E.E., Pauly, D., Quader, S., Revenga, C., Sauer, J.R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S.N., Symes, A., Tierney, M., Tyrrell, T.D., Vié, J.C. and Watson, R. 2010. Global biodiversity: Indicators of recent declines. *Science* 328.5982: 1164–1168.

Chen, H., Cao, M. and Tang, Y. 2013. Soil seed banks in plantations and tropical seasonal rainforests of Xishuangbanna, Southwest China. *Journal of Tropical Forest Science* 25.3: 375–386.

Chesson, P., Gebauer, R.L.E., Schwinning, S., Huntly, N., Wiegand, K., Ernest, M.S.K., Sher, A., Novoplansky, A. and Weltzin, J.F. 2004. Resource pulses, species interactions, and diversity maintenance in arid and semi-arid environments. *Oecologia* 141.2: 236–253.

Chima, U.. and Alex, A. 2017. Below- And Above-Ground Tree Species Diversity In Natural Forest And Monoculture Tree Plantations At Omo Biosphere Reserve, Nigeria. *Journal of Research in Forestry, Wildlife & Environment* 9.1: 1–8.

Chima, U.D., Adedire, M.O., Aduradola, A.M. and Agboola, D.A. 2013. Evaluation of Seed Bank in Three Age-Sequences of Arable Land within a Biosphere Reserve in Southwestern Nigeria. *Journal of Environment and Ecology* 4.2: 46–58.

Chukwu, V.E. and Olajuyigbe, S.O. 2017. Estimation of Tree Biomass in Three Age-Series of Tectona Estimation of Tree Biomass in Three Age-Series of Tectona Grandis Linn . F in Gambari Forest Reserve , Nigeria. *Journal of Forest Science and Environment* 2.December: 9–15.

Djomo, A.N., Ibrahima, A., Saborowski, J. and Gravenhorst, G. 2010. Allometric equations for biomass estimations in Cameroon and pan moist tropical equations including biomass data from Africa. *Forest Ecology and Management* 260.10: 1873–1885.

Douh, C., Daïnou, K., Loumeto, J.J., Fayolle, A. and Doucet, J.L. 2014. Explorer la banque de graines du sol pour mieux comprendre la dynamique de régénération des forêts tropicales africaines (synthèse bibliographique). *Biotechnology, Agronomy and Society and Environment* 18.4: 558–565.

Egberongbe, K.R., Awodoyin, R.O. and Olubode, O.S. 2017. Fallow management potentials of Sesbania pachycarpa DC .: The green manure effects on Amaranthus cruentus L . in Ibadan , South Western Nigeria. *Agricultural Science Research Journal* 7(4).April: 171–176.

Evans, L.J. 1982. Cation exchange capacities and surface areas of Humic Gleysolic Ap horizons from southwestern Ontario. *Canadian Journal of Soil Science* 62.2: 291–296.

Faleyimu, O.I. and Agbeja, B.O. 2004. Socio-economic assessment of wood artifact products in Oyo state , Nigeria. *Food, Agriculture & Environment* 2.1: 347–354.

FAO. 2010. Global Forest Resource Assessment. 367 pp.

FAO. 2015. *Global Forest Resources Assessment 2015 Desk reference*. 253 pp.

Farinloye, K.F., Ojo, S.O. and Ayodele, I.A. 2018. Assessment of Flora Diversity in Areas of Different Land Uses Awba Dam Tourism Centre, Ibadan, Nigeria. *Proceedings of 6th NSCB Biodiversity Conference*. pp. 416–421. Paper presented at, 2018.

Fasola, T.R. 2007. Controlling the advancement of Savanna into southwestern Nigeria. *Zonas Aridas* 11.1: 251–259.

Fenner, M. and Thompson, K. 2005. *The ecology of seeds*. Cambridge, Cambridge university press. 1–260 pp.

Fourie, S. 2008. Composition of the soil seed bank in alien-invaded grassy fynbos: Potential for recovery after clearing. *South African Journal of Botany* 74.3: 445–453.

Gaertner, M., Breeyen, A. Den, Hui, C. and Richardson, D.M. 2009. Impacts of alien plant invasions on species richness in mediterranean-type ecosystems: A meta-analysis. *Progress in Physical Geography* 33.3: 319–338.

Gee, G.W. and Bauder, J.W. 1986. Particle Size Analysis. *Methods of Soil Analysis. Part A*. 2nd vol 9 edition. Klute, Ed. American Society of Agronomy, Soil Science Society of America, Madison. 383–411

Ghermandi, S.L.G.L. and L., Gonzalez, S. and Ghermandi, L. 2012. Comparison of methods to estimate soil seed banks: the role of seed size and mass. *Community Ecology* 13.2: 238–242.

Gioria, M., Jarošík, V. and Pyšek, P. 2014. Impact of invasions by alien plants on soil seed bank communities: Emerging patterns. *Perspectives in Plant Ecology, Evolution and Systematics* 16: 132–142.

Gioria, M., K, P.P. and Á, L.M. 2012. Soil seed banks in plant invasions : promoting species invasiveness and long-term impact on plant community dynamics. *Preslia*

84: 327–350.

Gomaa, N.H. 2012. Soil seed bank in different habitats of the Eastern Desert of Egypt. *Saudi Journal of Biological Sciences* 19.2: 211–220.

Henry, M., Besnard, A., Asante, W.A., Eshun, J., Adu-Bredu, S., Valentini, R., Bernoux, M. and Saint-André, L. 2010. Wood density, phytomass variations within and among trees, and allometric equations in a tropical rainforest of Africa. *Forest Ecology and Management* 260.8: 1375–1388.

Hopfensperger, K.N. 2007. A Review of Similarity between Seed Bank and Standing Vegetation across Ecosystems. *Oikos* 116.9: 1438–1448.

Houghton, R.A., House, J.I., Pongratz, J., Van Der Werf, G.R., Defries, R.S., Hansen, M.C., Le Quéré, C. and Ramankutty, N. 2012. Carbon emissions from land use and land-cover change. *Biogeosciences* 9.12: 5125–5142.

Idrissa, S., Habou, R., Machi, I.I., Mahamane, A. and Mahamane, S. 2017. Biodiversity and Structure of Woody Plants of Sahelian Rangelands of Baban Rafi, Niger. *International Journal of Biology* 9.4: 1–9.

Ige, P.O. and Akinyemi, G.O. 2015. Site Quality Assessment for Tectona grandis Linn.f Plantations in Gambari Forest Reserve, Nigeria. *Journal of Forestry Research and Management* 12: 58–67.

Ihenyen, J., Okoegwale, E.E. and Mensah, J.K. 2009. Composition Of Tree Species In Ehor Forest Reserve, Edo State, Nigeria. *Nature and Science* 7.8: 8–18.

IPCC. 2003. *Good Practice Guidance for Land Use , Land-Use Change and Forestry*. K.T. and F.W. Jim Penman, Michael Gytarsky, Taka Hiraishi, Thelma Krug, Dina Kruger, Riitta Pipatti, Leandro Buendia, Kyoko Miwa, Todd Ngara, Ed. IPCC National Greenhouse Gas Inventories Programme. 590 pp.

James, D., Phua, M.-H., Besar, N.A. and Mokhtar, M. 2016. Aboveground Carbon Stock Potential of Teak (Tectona grandis) under Different Land Use System in Balung Plantation, Tawau Sabah. *Transactions on Science and Technology* 3.1–2: 168–175.

Jędrzejczak, E. 2013. Soil seed bank in selected patches of vegetation in the beech forest of Beskid Śląski (Southern Poland). *Casopis slezskeho zemskeho muzea (A)* 62: 137–150.

Jiang, D.M., Wang, Y.C., Oshida, T., Luo, Y.M., Wang, H.M. and Zhou, Q.L. 2013. Review of research on soil seed banks in desert regions. *Disaster Advances* 6.S1: 315–322.

Kollert, W. and Cherubini, L. 2012. Teak resources and market assessment 2010. Rome, Italy16–17 pp.

Kollert, W. and Kleine, M. 2017. *IUFRO World Series Volume 36 The Global Teak Study*. 108 pp.

Larinde, S.L. and Olasupo, O.O. 2011. Socio-Economic Importance Of Fuelwood Production In Gambari Forest Reserve Area, Oyo State, Nigeria. *Journal of Agriculture and Social Research (JASR)* 11.1: 201–210.

Lawal, A.A. and Salami, K.D. 2018. Plant Species Diversity and Composition in Orchard of Federal University Dutse , Jigawa. *Proceedings of 6th NSCB Biodiversity Conference*. pp. 30–34. Paper presented at, 2018, Uniuyo.

Lemenih, M. and Teketay, D. 2006. Changes in soil seed bank composition and density following deforestation and subsequent cultivation of a tropical dry Afromontane forest in Ethiopia. *Tropical Ecology* 47.1: 1–12.

Li, Q., Fang, H. and Cai, Q. 2011. Persistent soil seed banks along altitudinal gradients in the Qilian Mountains in China and their significance for conservation management. *Journal of Agricultural Research* 6.10: 2329–2340.

Magurran, A.E. 2004. *Measuring Biological Diversity*. Blackwell Publishing. 264 pp.

Mahamane, A. 2005. *Etudes floristique, phytosociologique et phytogéographique de la végétation du Parc Régional du W du Niger. Volume 1 : Les groupements végétaux*. Université Libre de Bruxelles

Margherita, G. and Osborne, B. 2009. Assessing the impact of plant invasions on soil seed bank communities : use of univariate and multivariate statistical approaches. *Journal of Vegetation Science* 20.3: 547–556.

Mclean, E.O. 1982. Soil pH and Lime Requirement. *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties*. American Society of Agronomy, Soil Science Society of America, Madison. 199–224

Mengistu, D.A. and Salami, A.T. 2007. Application of remote sensing and GIS inland use / land cover mapping and change detection in a part of south western Nigeria. *African Journal of Environmental Science and Technology Vol.* 1.5: 99–109.

N'Gbala, F.N., Guéi, A.M. and Tondoh, J.E. 2017. Carbon stocks in selected tree plantations, as compared with semi-deciduous forests in centre-west Côte d'Ivoire. *Agriculture, Ecosystems & Environment* 239: 30–37.

Nelson, D.W. and Sommers, L.E. 1982. Total carbon, organic carbon, and organic matter. *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties*. American Society of Agronomy, Soil Science Society of America, Madison. 539–580

Ogunleye, A.J., Adeola, A.O., Ojo, L.O. and Aduradola, A.M. 2004. Impact Of Farming Activities On Vegetation In Olokemeji Forest Reserve, Nigeria. *Global Nest: the Int. J* 6.2: 131–140.

Oke, S., Oladipo, O., Ndiribe, C., Akinyemi, D. and Ojo, O. 2009. Soil seed bank dynamics in Tithonia diversifolia dominated fallowland at Ile- Ife, South-western Nigeria. *International Journal of Biological and Chemical Sciences* 3.5: 29–36.

Oke, S.O., Ayanwale, T.O. and Isola, O.A. 2007. Soil Seedbank in Four Contrasting Plantations in Ile-Ife Area of Southwestern Nigeria. *Research Journal of Botany* 2.1: 13–22.

Oke, S.O., Oladipo, O.T. and Isichei, A.O. 2006. Seed Bank Dynamics and Regeneration in a Secondary Lowland Rainforest in Nigeria. *International Journal of Botany* 2.4: 363–371.

Oladipo, O.T. and Oke, O.S. 2007. Seedbank Dynamics, Seedling Emergence and

Survival of Herbaceous Species in Succeccional Plots in Ile=Ife, Southwestern Nigeria. *Research Journal of Botany* 2.2: 76–85.

Olatunji, O.A., Oke, S.O., Isola, E.F., Akinyemi, D.S. and Omodara, A.A. 2015. Relationship between the standing vegetation, soil properties and soil seed bank of an industrially degraded vegetation of Iron Smelting Factory. *International Journal of Biological and Chemical Sciences* 9.2: 614–632.

Olsen, S.R. and Sommers, L.E. 1982. Phosphorus. *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties*. American Society of Agronomy, Soil Science Society of America, Madison. 403–430

Olubode, O.S., Awodoyin, R.O. and Ogunyemi, S. 2011. Floral diversity in the wetlands of apete river, eleyele lake and oba dam in Ibadan, Nigeria: Its implication for biodiversity erosion. *West African Journal of Applied Ecology* 18: 109–119.

Onyekwelu, J.C., Mosandl, R. and Stimm, B. 2008. Tree Species Diversity And Soil Status Of Primary And Degraded Tropical Rainforest Ecosystems In South-Western Nigeria. *Journal of Tropical Forest Science* 20.3: 193–204.

Ounban, W., Puangchit, L. and Diloksumpun, S. 2016. Development of general biomass allometric equations for Tectona grandis Linn.f. and Eucalyptus camaldulensis Dehnh. plantations in Thailand. *Agriculture and Natural Resources* 50.1: 48–53.

Oyebade, B.A. and Anaba, J.C. 2018. Individual tree basal area equation for a young Tectona Grandis (Teak) plantation in Choba , Port Harcourt , Rivers State , Nigeria. 16.January: 144–154.

Pachas, A.N.A., Sakanphet, S., Midgley, S. and Dieters, M. 2019. Teak (Tectona grandis) silviculture and research: applications for smallholders in Lao PDR. *Australian Forestry* 82.1: 94–105.

Perera, G.A.D. 2005. Diversity and dynamics of the soil seed bank in tropical semi-deciduous forests of Sri Lanka. *Tropical Ecology* 46.1: 65–78.

Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology* 13: 131–144.

Price, J.N., Wright, B.R., Gross, C.L. and Whalley, W.R.D.B. 2010. Comparison of seedling emergence and seed extraction techniques for estimating the composition of soil seed banks. *Methods in Ecology and Evolution* 1: 151–157.

Rhoades, J.D. 1982a. Cation Exchange Capacity. *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties*. American Society of Agronomy, Soil Science Society of America, Madison. 149–158

Rhoades, J.D. 1982b. Soluble Salts. *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties*. American Society of Agronomy, Soil Science Society of America, Madison. 167–180

Rutishauser, E., Noor'an, F., Laumonier, Y., Halperin, J., Rufi'ie, Hergoualc'h, K. and Verchot, L. 2013. Generic allometric models including height best estimate forest biomass and carbon stocks in Indonesia. *Forest Ecology and Management* 307: 219–225.

Saatkamp, A., Poschlod, P. and Venable, D.L. 2014. The Functional Role of Soil Seed Banks in Natural Communities. *Seeds: The Ecology of Regeneration in Plant Communities*. 263–295

Salami, K.D., Akinyele, A.O., Adekola, P.J. and Odewale, M.A. 2016. Tree species composition and regeneration potential of Onigambari Forest Reserve , Oyo State. *Direct Research Journal of Agriculture and Food Science* 4.3: 39–47.

Sanyaolu, V., Awodoyin, R.O. and Ogunyemi, S. 2018. Effect of Ornamental Plants on Adjoining Ecosystem of The Parks and Gardens , Obafemi. *Proceedings of 6th NSCB Biodiversity Conference*. pp. 90–103. Paper presented at, 2018, Uniuyo.

Senbeta, F. and Teketay, D. 2001. Regeneration of indigenous woody species under the canopies of tree plantations in Central Ethiopia. *Tropical Ecology* 42.2: 175–185.

Smith, H.F., Ling, S. and Boer, K. 2017. Teak plantation smallholders in Lao PDR: what influences compliance with plantation regulations? *Australian Forestry* 80.3: 178–187.

Smith, K.A. and Li, S. 1993. Estimation of potentially mineralisable nitrogen in soil by

KCl extraction. *Plant and Soil* 157.2: 167–174.

Souley, M.H.I., Saley, K., Chaibou, I., Moussa, B.M., Mahamane, A. and Saadou, M. 2018. Diversité Inter Décennale De La Végétation De La Vallée De Goulbi N ' Kaba Mahaman Hamissou Illo Souley Issa Chaibou. *European Scientific Journal* 14.9: 161–183.

Stradic, S. Le, Fernandes, G.W. and Buisson, E. 2018. No recovery of campo rupestre grasslands after gravel extraction : implications for conservation and restoration. *Restoration Ecology* 26.S2: S151–S159.

Takim, F.O., Fadayomi, O., Ekeleme, F. and Amosun, J.O. 2013. Relationship Between the Soil Seedbank and Weed Population As Influenced By Land Use Intensity in Southern Guinea Savanna of Nigeria. *Nigerian Journal of Agriculture, Food and Environment* 9.3: 36–41.

Tesfaye, G., Teketay, D., Assefa, Y. and Fetene, M. 2004. The Impact of Fire on the Soil Seed Bank and Regeneration of Harenna Forest , Southeastern Ethiopia. *Mountain Research and Development* 24.4: 354–361.

Thompson, K. and Grime, J.P. 1979. Seasonal Variation in the Seed Banks of Herbaceous Species in Ten Contrasting Habitats. *Journal of Ecology* 67.3: 893–921.

Tiebel, K., Huth, F. and Wagner, S. 2018. Soil seed banks of pioneer tree species in European temperate forests: a review. *iForest - Biogeosciences and Forestry* 11.1: 48–57.

Tondoh, J.E., Kouamé, F.N., Martinez Guéi, A., Sey, B., Wowo Koné, A. and Gnessougou, N. 2015. Ecological changes induced by full-sun cocoa farming in Côte d'Ivoire. *Global Ecology and Conservation* 3: 575–595.

Török, P., Kelemen, A., Valkó, O., Miglécz, T., Tóth, K. and Tóth, E. 2018. Succession in soil seed banks and its implications for restoration of calcareous sand grasslands. *Restoration Ecology* 26.S2: S134–S140.

Trabaud, L., Ferrandis, P., Gonzalez-ochoa, A.I. and Herranz, J.M. 1997. Vegetation épigée et banque de semences du sol : leur contribution à la stabilité cyclique des pinèdes mixtes de Pinus halepensis et P . pinaster. *Canadian Journal of Botany* 75: 1012–1021.

Wang, Y., Jiang, D., Toshio, O. and Zhou, Q. 2013. Recent advances in soil seed bank research. *Contemporary Problems of Ecology* 6.5: 520–524.

Yan, Q., Zhu, J., Zhang, J., Yu, L. and Hu, Z. 2010. Spatial distribution pattern of soil seed bank in canopy gaps of various sizes in temperate secondary forests, Northeast China. *Plant and Soil* 329.1–2: 469–480.

Yang, D. and Li, W. 2013. Soil seed bank and aboveground vegetation along a successional gradient on the shores of an oxbow. *Aquatic Botany* 110: 67–77.

Yevide, A.S.I., Ganglo, J.C., Lucas, R.G.K. and CARNNIÈRE, C. DE. 2014. Which Abiotic Factors Have the Most Influence on the Growth of Trees in Beninese Coppice Teak Stands ? *Suranaree Journal of Science and Technology* 22.1: 51–59.

Yu, S., Sternberg, M., Kutiel, P. and Chen, H. 2007. Seed mass, shape, and persistence in the soil seed bank of Israeli coastal sand dune flora. *Evolutionary Ecology Research* 9.2: 325–340.

Zaghloul, M.S. 2008. Diversity in soil seed bank of Sinai and implications for conservation and restoration. *African Journal of Environmental Science and Technology* 2.7: 172–184.

APPENDICES

Appendix 1: SPECIES DATA MATRIX

Date ……………… Locality ……….................. N° transect …..… N° quadrat………

GPS coordinates: N…………………… E…………………… Elevation ……………….

Observer's Name ……………………………………………………………………..

Species	Common/Local name	Density	Observations

Appendix 2: DENDROMETRY SURVEY CARD

Date ……………… Locality ……….................. N° transect …..… N° quadrat………

GPS coordinates: N…………………… E……………….… Elevation ……………….

Observer's Name ………………………………………………………………..

Species	Common/Local name	Stem circumference (cm)	High (m)		Observations
			Base	Top	

Appendix 3: SEEDLINGS RECORD CARD

Date ……………… Locality ……….................. N° transect …..… N° quadrat………

GPS coordinates: N…………………… E………………… Elevation ………………

Observer's Name ……………………………………………………………..……...

Species	Common/ Local names	Density		Observations
		00-05 cm	05-10 cm	

Appendix 4. Species enumerated in the vegetation and soil seed bank per season and soil depth in the coppiced teak plantation in Gambari Forest Reserve, Ibadan.

No	Families	Species	Habit	Vegetation		SSB 0-5		SSB 5-10	
				Wet	Dry	Wet	Dry	Wet	Dry
1	Acanthaceae	*Phaulopsis ciliata*	herb	+			+		+
2	Alzoaceae	*Trianthema portulacrastrum*	herb				+		+
3	Amaranthaceae	*Alternanthera sessilis*	herb	+	+	+	+	+	+
4	Amaranthaceae	*Amaranthus spinosus*	herb				+		+
5	Amaranthaceae	*Celosia leptostachya*	herb	+		+	+		+
6	Amaranthaceae	*Celosia trigyna*	herb				+		
7	Amaranthaceae	*Cyathula prostrata*	herb	+	+	+	+	+	+
8	Amaranthaceae	*Gomphrena celosiodes*	herb				+		
9	Annonaceae	*Annona senegalensis*	tree	+	+				
10	Annonaceae	*Cleistopholis patens*	tree	+	+				
11	Apocynaceae	*Alstonia boonei*	tree	+	+				
12	Apocynaceae	*Alstonia congensis*	tree	+	+				
13	Apocynaceae	*Ancylobotrys amoena*	Liane	+	+				
14	Apocynaceae	*Funtumia africana*	tree	+	+				
15	Apocynaceae	*Funtumia elastica*	tree	+	+				
16	Apocynaceae	*Parquetina nigrescens*	vine	+	+				
17	Apocynaceae	*Rauvolfia vomitora*	Shrub	+					
18	Apocynaceae	*Secamone afzelli*	vine	+					
19	Arecaceae	*Elaeis guineensis*	tree	+	+				
20	Arecaceae	*Laccosperma secundiflora*	Rattan	+					
21	Asteraceae	*Ageratum conyzoides*	herb	+					
22	Asteraceae	*Chromolaena odorata*	Shrub	+	+	+	+	+	+
23	Asteraceae	*Crassocephalum crepidoides*	herb	+					
24	Asteraceae	*Melanthera scadens*	herb				+		+
25	Asteraceae	*Synedrella nodiflora*	herb	+					
26	Asteraceae	*Tithonia diversifolia*	Shrub	+	+	+	+	+	
27	Bignoniaceae	*Kigelia africana*	tree	+	+				
28	Bignoniaceae	*Markhamia tomentosa*	tree	+	+				

29	Bignoniaceae	*Newbouldia laevis*	tree	+	+				
30	Boraginaceae	*Cordia auriantiaca*	tree	+	+				
31	Boraginaceae	*Cordia millenii*	tree	+	+				
32	Boraginaceae	*Heliotropium indicum*	herb	+					
33	Cannabaceae	*Celtis adolfi-friderici*	tree	+	+				
34	Cannabaceae	*Celtis integrifolia*	tree	+	+				
35	Clusiaceae	*Harungana madagascariensis*	Shrub	+	+				
36	Commelinaceae	*Commelina benghalensis*	herb	+	+	+	+	+	+
37	Commelinaceae	*Commelina erecta*	herb	+	+	+	+		+
38	Commelinaceae	*Palisota hirsuta*	herb	+					
39	Cyperaceae	*Cyperus esculentus*	Sedge	+					
40	Cyperaceae	*Mariscus alternifolius*	Sedge	+	+	+	+	+	+
41	Dioscoreaceae	*Dioscorea dumetorum*	vine	+					
42	Dioscoreaceae	*Dioscorea Praehensilis*	vine	+					
43	Euphorbiaceae	*Acalypha ciliata*	herb				+		+
44	Euphorbiaceae	*Alchorneae laxiflora*	Shrub	+	+				
45	Euphorbiaceae	*Croton lobatus*	Shrub				+		+
46	Euphorbiaceae	*Croton zambesicus*	tree	+	+				
47	Euphorbiaceae	*Euphorbia hirta*	herb				+		+
48	Euphorbiaceae	*Macaranga barteri*	Shrub	+	+				
49	Euphorbiaceae	*Phylathus amrus*	herb				+		+
50	Fabaceae	*Abrus precatorius*	vine	+					
51	Fabaceae	*Acacia ataxacantha*	shrub	+	+				
52	Fabaceae	*Albizia zygia*	tree	+	+				
53	Fabaceae	*Amphimas pterocarpoides*	tree	+	+				
54	Fabaceae	*Calopogonium mucunoides*	vine				+		+
55	Fabaceae	*Desmodium velutinum*	herb	+					
56	Fabaceae	*Dialium guineense*	tree	+	+				
57	Fabaceae	*Eurythrophleum guineensis*	tree	+	+				
58	Fabaceae	*Gliricidia sepium*	Shrub	+	+				
59	Fabaceae	*Leptoderris micrantha*	vine	+					
60	Fabaceae	*Milletia thonningii*	Shrub	+	+				
61	Fabaceae	*Mimosa pudica*	herb	+	+	+	+	+	+

62	Fabaceae	*Mucuna flagellipes*	vine	+	+				
63	Fabaceae	*Mucuna sloanei*	vine	+					
64	Fabaceae	*Phaseolus lunatus*	vine	+	+	+	+		
65	Fabaceae	*Piptadeniastrum africanum*	tree	+	+				
66	Icacinaceae	*Icacina trichantha*	Liane	+	+				
67	Irvingiaceae	*Irvingia gabonensis*	tree	+	+				
68	Lecythidaceae	*Napoleonaea vogelii*	Shrub	+					
69	Loganiaceae	*Spigelia anthelmia*	herb				+		
70	Loranthaceae	*Phragmanthera capitata*	Shrub	+	+				
71	Lythraceae	*Lawsonia inermis*	Shrub	+	+				
72	Malvaceae	*Bombax buonopozense*	tree	+	+				
73	Malvaceae	*Ceiba pentandra*	tree	+	+				
74	Malvaceae	*Cola gigantea*	tree	+	+				
75	Malvaceae	*Dombeya buettneri*	Shrub	+	+				
76	Malvaceae	*Grewia carpinifolia*	Shrub	+	+				
77	Malvaceae	*Sida acuta*	Shrub	+	+	+	+	+	+
78	Malvaceae	*Sida garckeana*	herb				+		+
79	Malvaceae	*Triplochiton scleroxylon*	tree	+	+				
80	Malvaceae	*Waltheria indica*	herb	+	+	+	+	+	+
81	Meliaceae	*Cedrela odorata*	tree	+	+				
82	Menispermaceae	*Chasmanthera dependens*	vine	+	+				
83	Menispermaceae	*Rhigiocarya racemifera*	Liane	+					
84	Moraceae	*Ficus exasperata*	tree	+	+				
85	Moraceae	*Ficus tonningii*	tree	+	+				
86	Moraceae	*Milicia excelsa*	tree	+	+				
87	Myristicaceae	*Pycanthus angolensis*	tree	+	+				
88	Nyctaginaceae	*Boerhavia diffusa*	herb	+	+	+	+	+	
89	Nyctaginaceae	*Boerhavia erecta*	herb				+		
90	Pandaceae	*Microdesmis puberula*	Shrub	+	+				
91	Phyllanthaceae	*Bridelia micrantha*	Shrub	+	+				
92	Phyllanthaceae	*Phyllanthus muellerianus*	Shrub	+	+				
93	Poaceae	*Andropogon tectorum*	Grass	+					
94	Poaceae	*Axonopus compresus*	Grass	+	+	+	+	+	+

95	Poaceae	*Bambusa vulgaris*	Grass	+	+				
96	Poaceae	*Cymbopogon citratus*	herb	+	+	+	+	+	+
97	Poaceae	*Cynodon dactylon*	Grass	+	+	+	+	+	+
98	Poaceae	*Dactylotenium aegyptium*	Grass				+		+
99	Poaceae	*Digitaria horizontalis*	Grass	+					
100	Poaceae	*Digitaria longiflora*	Grass				+		+
101	Poaceae	*Eleusine indica*	Grass	+		+			
102	Poaceae	*Oplismenus burmannii*	Grass	+	+	+	+	+	+
103	Poaceae	*Panicum brevifolium*	Grass	+					
104	Poaceae	*Panicum laxum*	Grass	+					
105	Poaceae	*Sporobolus pyramidalis*	Grass	+	+				
106	Polygalaceae	*Carpolobia alba*	Shrub	+	+				
107	Rubiaceae	*Mitragyna stipulosa*	tree	+	+				
108	Rubiaceae	*Morinda lucida*	tree	+	+				
109	Rubiaceae	*Oldenlandia corymboza*	herb				+		+
110	Rubiaceae	*Rytigyna nigerica*	Shrub	+	+				
111	Rutaceae	*Afraegle paniculata*	tree	+	+				
112	Rutaceae	*Zanthoxylum zanthoxyloides*	tree	+	+				
113	Sapindaceae	*Lecaniodiscus cupanioides*	tree	+	+				
114	Sapindaceae	*Paullinia pinnata*	vine	+	+				
115	Sapotaceae	*Synsepalum dulcificum*	vine	+	+				
116	Solanaceae	*Nicotiana rustica*	herb	+					
117	Solanaceae	*Schwenckia americana*	herb	+					
118	Solanaceae	*Solanum americanum*	herb	+	+	+			
119	Tiliaceae	*Corchorus olitorius*	herb				+		+
120	Tiliaceae	*Triumfetta rhomboidea*	Shrub				+		+
121	Urticaceae	*Laportea aestuans*	herb				+		
122	Urticaceae	*Pouzolzia guineensis*	Shrub				+		
123	Verbenaceae	*Gmelina arborea*	tree	+	+	+			
124	Verbenaceae	*Stachytarpheta jamaicensis*	Shrub	+					
125	Verbenaceae	*Tectona grandis*	tree	+	+				
126	Vitaceae	*Cissus populnea*	vine	+	+				
Total	_	_	_	106	79	20	38	14	29

Appendix 5: Soil physicochemical properties per sampling unit in Teak plantation stand at Gambari Forest Reserve, Busogboro, Ibadan, Nigeria.

Sample Label	pH (H2O)	O.C	O. M	TN %	Na Cmol/kg	Ca Cmol/kg	Mg Cmol/kg	K Cmol/kg	Fe mg/kg	cu mg/kg	Mn mg/kg	Zn mg/kg	p mg/kg	% Sand	% Clay	% Silt	T C
T1P1	6.23	0.98	1.69	0.08	1.045	11.517	1.267	0.326	1480	2	120	76	134.19	80.6	11	8.4	SL
T1P2	6.19	1.4	2.41	0.12	1.075	10.898	0.921	0.297	560	3	224	126	66.79	74.6	9	16.4	SL
T1P3	6.57	2.29	3.95	0.2	1.115	21,657	2.176	0.653	1580	4.5	702	182	95.23	74.6	15	10.4	SL
T1P4	6.2	2.15	3.71	0.91	1.365	20.449	2.367	0.534	1410	4.3	801	90	283.62	70.6	21	8.4	SCL
T1P5	6.22	1.3	2.24	0.11	1.296	9.142	0.216	0.475	960	5.5	460	162	85.79	74.6	15	10.4	SL
T1P6	6.16	2	3.45	0.17	1.303	5.689	1.301	0.326	1320	2.3	452	82	95.23	72.6	13	14.4	SL
T2P1	6.14	1.74	2.99	0.15	1.212	7.187	1.645	0.742	1580	5.4	420	222	106.24	74.6	11	14.4	SL
T2P2	6.18	1.02	1.75	0.09	1.284	19.361	1,972	0.623	1920	3.3	570	106	113,14	88.3	10	1.7	LS
T2P3	6.05	2	3.45	0.17	0.958	17.874	2.656	0.356	2130	6.1	645	92	81.43	78.6	9	12.4	LS
T2P4	6.43	1.94	3.34	0.17	1.177	7.156	1.989	0.237	2240	3.7	748	78	296.33	70.6	17	12.4	SL
T2P5	6.25	2.7	4.68	0.2	1.122	17.565	3.972	0.365	880	3.4	500	86	293.18	82.6	11	6.4	LS
T2P6	6.03	2	3.45	0.17	1.263	16.347	4.112	0.386	1470	4.1	723	114	164.44	84.6	9	6.4	LS
T3P1	6.08	2.79	4.81	0.24	1.084	19.162	2.737	0.386	2020	7.2	832	296	50.09	80.6	17	2.4	SL
T3P2	6.05	1.46	2.52	0.13	0.969	16.627	2,183	0.415	3570	3.6	144	72	108.54	86.1	11	2.9	LS
T3P3	6.07	2	3.45	0.17	1.322	19.082	1.341	0.297	2220	2	276	64	73.08	74.6	10.	14.9	SL

T3P4	6.38	1.46	2.52	0.13	1.08	8.842	1.517	0.386	2300	3	298	122	48.52	82.6	11	6.4	LS
T3P5	6.12	2.15	3.71	0.19	1.038	15.549	1.155	0.445	1410	4.2	483	56	279.39	79.6	11	9.4	SL
T3P6	6.09	1.3	2.24	0.11	1.191	20.998	1.957	0.742	2200	2.8	612	82	279.27	84.6	11	4.4	LS
T4P1	6.2	1.5	2.59	0.13	0.918	14.092	1.515	0.326	440	1.8	268	58	85.06	80.6	12	7.4	SL
T4P2	6.44	1.28	2.21	0.11	0.884	9.701	1.747	0.534	2440	3	400	124	64.25	80.6	7	12.4	LS
T4P3	6.4	2.03	3.51	0.18	1.078	17.146	1.762	0.445	940	2	284	64	156.7	78.6	9	12.4	SL
T4P4	6.27	1.2	2.07	0.1	1.089	15.23	1.029	0.386	860	2.7	534	72	288.95	74.6	11	14.4	LS
T4P5	6.08	3	5.33	0.27	1.311	6.527	2.056	0.297	2200	4.9	1100	150	294.76	68.6	13	18.4	SL
T4P6	6.21	1.3	2.24	0.11	1.169	22.196	1.979	0.326	1440	3.3	438	86	150.52	82.6	11	6.4	LS
T5P1	6.39	2.3	3.94	0.2	1.285	24,192	2.706	0.445	2140	9.3	1018	246	55.9	70.6	13	16.4	SL
T5P2	6.51	2.75	4.74	0.24	1.137	20.599	2.278	0.504	1760	3	714	116	299.72	74.6	13	12.4	SL
T5P3	6.58	2.31	3.99	0.2	1.136	17.395	1.498	0.623	1960	4.9	804	180	144.96	80.6	13	6.4	SL
T5P4	6.29	2.03	3.5	0.18	1.019	20.2	2.079	0.653	1000	2.9	1142	42	285.92	84.6	9	6.4	LS
T5P5	6.14	3.83	6.6	0.33	1.324	14.461	2.401	0.682	2310	4.1	753	130	274.67	69.6	10.	19.9	SL
T5P6	6.12	2.31	3.98	0.2	1.329	13.593	2.24	0.712	1440	3.8	666	168	62.44	82.6	11	6.4	LS

Key: for textural class (TC); LS = Loamy sand SL = Sandy Loam SCL = Sandy Clay Loam S = Sand