THE DIVERSITY AND SPATIAL VARIABILITY OF WOODY SPECIES IN YABO AREA, SOKOTO STATE

BY

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A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL MANAGEMENT

DEPARTMENT OF GEOGRAPHY,
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DECLARATION

I hereby declare that this thesis titled **'THE DIVERSITY AND SPATIAL VARIABILITY OF WOODY SPECIES IN YABO AREA, SOKOTO STATE'** has been carried out by me in the Department of Geography under the supervision of Prof. I.A. Jaiyeoba and Dr. B.A. Sawa and is thus, the product of my research. The information derived from relevant literature has been duly acknowledged in the text and the list of references provided. No part of this thesis was previously presented for another degree or diploma at any university.

…… …….

Murtala DANGULLA Date

CERTIFICATION

This thesis titled '**THE DIVERSITY AND SPATIAL VARIABILITY OF WOODY SPECIES IN YABO AREA, SOKOTO STATE'** by Murtala DANGULLA, meets the regulations governing the award of the degree of Master of Science in Environmental Management of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to the memory of my late father; Alhaji Muhammadu Bande Dangulla (May his soul rest in perfect peace, Ameen) and my loving mother, Hajiya Hauwa'u Umar.

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ABSTRACT

In Sokoto State as in most parts of Nigeria, people depend on woody species in the wild for energy sources, construction poles and other uses. Unfortunately however, the stock and diversity of such vital resources has continued to dwindle. This study assesses the diversity and spatial variability of woody species in Yabo area, Sokoto State. A total of 32Km^2 around Yabo town was earmarked for the study within which, a total of 50 sample points were randomly generated using IDRISI ANDES software. On each of the sample points, a quadrat of 50m x 50m dimension was laid and all woody species thereon were identified and enumerated. The study examined the prevailing land use/land cover of the study area and also measured woody diversity parameters which include height, diameter at breast height, basal area, density, diversity and biomass. In addition, dominance at both species and family levels were determined by the Importance Value Index (IVI). Seven major land use types were identified and a total of 671 woody stems which belonged to 40 species, 35 genera and 12 families were identified and enumerated. The highest number of stems (271) was recorded in the savannah woodland and the farmland (137) whilst the lowest was recorded over the built-up area (15) and bare ground (24). Analysis of the importance value index revealed that the dominant species in the area are *Azadirachta indica, Balanites aegyptiaca, Senna Sieberiana, Combretum micranthum, Guiera senegalensis, Mimosa pigra, Parkia biglobosa,* and *Piliostigma reticulatum* which together account for about 67.2% of the species. The extrapolation of the results obtained to the entire study area revealed that overall, 171,600 (54 stands per hectare) woody stands abound in the study area. Result of ANOVA and DMR tests shows that the biomass is the most variable parameter amongst the land uses while species density is the least. The observed species and actual number of tree stands in the area are generally low and are a reflection of severe land degradation going on in the area. Drivers of woody biodiversity loss in the area are poor physical conditions in terms of soils, vegetation and inherent extreme variability of climate. These are compounded by unsustainable use of natural resources as manifested in agricultural and grazing activities, and wood extraction. The urgent need to halt the degradation trend and improve upon the state of woody species in the area was stressed.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

The importance of woody species to man cannot be overemphasized. Beyond their economic value, shrubs and trees act as biological filters by helping to cleanse the environment of pollutants such as oxides of carbon, toxic gases and heavy metals (Chakraverty and Jain, 1984). Woody species also play a stabilizing role to landform and soils and maintaining cycling of oxygen and other elements essential for life. Much erosion has been caused by clearing woody plants from steep slopes or from the banks of creeks and rivers. Many wildlife species depend upon woody plants to provide essential components of their habitats. Despite the important role played by woody species in the environment, recent assessment shows a continued and steady overall decline in wild species' population and diversity.

Although species extinctions are the most conspicuous result of biodiversity loss, it was estimated that distinct subpopulations are becoming extinct some three orders of magnitude faster than species (Rands, *et al,* 2010). In most developing countries, the rate of forest clearing and tree felling is so rapid that it is feared more species may be lost eventually. It is estimated that by the year 2025, the world population will be about 8.5 billion. The increase in population will demand higher exploitation of the natural resources for the production of food, fibre and forests. On the other hand, the state of the world's natural resources, especially those associated with agricultural production, appears to be declining in many areas at far higher rates. Moreover, there is concern that the capacity of the natural resources to play their broader environmental role might be

threatened. These situations imply the need for more attention for the management of natural resources and for the development of sustainable production options (ISC, 1995). The key pressures driving biodiversity loss are overexploitation of species, invasive alien species, pollution, climate change, and especially the degradation, fragmentation, and destruction of habitats (Rands, *et al,* 2010).

Increase in human population is almost always accompanied by habitat destruction, introduction of alien species and increased pressure on the available environmental resources. Approximately 40% of the land that can support tropical closed forest for example now lacks it, primarily because of human actions. According to the estimate by the Food and Agricultural Organization and United Nations Environmental Programme, 7.6 million hectares or nearly 1% of the world forest cover is being permanently cleared or converted into the shifting-cultivation cycle by the late 1970s. The absolute amount is 76,000 square kilometers a year, which is greater than the entire country of Costa Rica. According to this analysis, the remaining global forest cover would either be completely removed or seriously disturbed by the year 2135 A.D. This is close to the year by which the World Bank estimates that the human population will reach 11 billion (The World Bank, 1984).

The continued growth of human populations and of per capita consumption in the arid and semi arid region of Nigeria have resulted in unsustainable exploitation of Earth's biological diversity, exacerbated by poor land use practices and climate (Rands, *et al.,* 2010). Increased human population in the region necessitates increased need for food, fuel and fibre, which invariably leads

to increased pressure on biodiversity (Leveque and Mounolou, 2003). Thus in this region, as in many areas, woody species component of biodiversity are under tremendous pressure. This may not be unconnected with the diversity of their use in the building, transportation medicinal supplies, energy supply, etc. Understanding the diversity and distributions of woody species in the region therefore will lead to better understanding of plant communities as a whole, and their conservation and utilization.

1.2 STATEMENT OF THE RESEARCH PROBLEM

The diversity of species provides ecosystem services that sustain the biospheric activities. It also helps to protect the natural systems and enhance their productivity. Environmental conservation and protection is therefore of paramount importance in order to ensure the sustainability of the environment and its resources.

Extinction of species is a natural phenomenon. It has been estimated that surviving species constitute about 1% of the species that have ever lived (Corker, 2003). Nevertheless, the rate at which species are now becoming extinct as a result of human action is worrisome and unprecedented in geological times. Leveque and Mounolou (2003) identify significant population growth, utilization of previously untouched territories and increasing efficiency of technological means of exploitation to be the major causes.

The loss of species in tropical ecosystems, such as the rainforest, is well publicized and there are today predictions and estimates of future species losses in the ecosystem (Corker, 2003). It is estimated that, 3.4% of plants, 11.7% of mammals, 1.3% of birds, 2.2% of reptiles, 12% of amphibians, 8.5% of fresh water fish and 0.005% of invertebrates are threatened in Nigeria

(USAID, 2008). In Nigeria, there is extreme pressure on biodiversity and tropical forests that is continuously mounting. Wildlife, trees, and many other plants are overharvested and poached, and the natural environment faces increased degradation from expanding unsustainable agriculture, water pollution, air pollution, and a variety of other anthropogenic factors (USAID, 2008). It has also been asserted that as at the year 2005, Nigeria had the highest rate of deforestation rate in the world and this resulted to the loss of 55.7 percent of its primary forests between 2000 and 2005, principally due to logging, agricultural expansion, and fuel wood collection (FAO 2005).

Over much of Northern Nigeria, people depend on woody species for food, energy and fiber. Herbs, barks and roots of trees also provide the much needed means for the prevention and treatment of diseases and psychological disorders. In Sokoto state, as in most parts of Nigeria, woody species remained the most prominent source of domestic energy supply as alternatives such as coal, kerosene, cooking gas and/or electricity are either grossly inadequate and unaffordable, or non-existent. The increasing human population in the region has also necessitated an increased demand for food and shelter and therefore, expansion of settlements and farms. This invariably leads to the clearance of large areas of land for farming and residential purposes. Similarly, the system of open, intensive animal rearing in the area has exposed woody species in the region to continuous browsing and as such, degradation.

Unfortunately, very few investigations on the composition, structure, diversity and spatial variability of woody species have been carried out. There is therefore paucity of information on woody species in particular and biodiversity in general for the region. According to a report by the Panel on Biodiversity Research Priorities in 1992, pertinent information on biological diversity in most developing countries is too sparse or scattered to be of practical use or even unavailable in

most cases. There only exists a good deal of "gray" literature consisting of unpublished reports, files in government archives and studies of limited distribution (P.B.R.P, 1992). In Nigeria, despite concerns about the status of the many species of plants, animals, and lower organisms in the country, information on the status of biodiversity is meager (USAID, 2008). For many areas in the country, there is simply lack of reliable data on the status of the biodiversity. This study aims at providing some information on the status of woody biodiversity for the Yabo area of Sokoto State.

The pertinent questions that the research project seeks to find answer to are:

i. What is the status of the woody species in the area?
ii. What are the dominant woody species in the area?
iii. What is the spatial distribution of the woody species in the area?
iv. What are the physical characteristics of the woody species in the area?
v. What are the drivers of woody species loss in the area?

1.3 AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to assess the diversity and spatial variation of woody species in Yabo area of Sokoto State. This aim will be accomplished through the following specific objectives:

i. identify the dominant land use/land cover of the study area using Remote Sensing (RS) and Geographic Information Systems (GIS);
ii. undertake an inventory of woody species over different land uses in the study area;
iii. determine the composition and structure of the woody species over the identified land uses; and
iv. examine the major drivers of biodiversity loss in the study area.

1.4 HYPOTHESIS

The research hypothesis emerging from the aim and objectives of the study is:

There are no significant differences in the characteristics of woody biodiversity amongst the different land use types in the Yabo area.

1.5 SCOPE OF THE STUDY

The study area is Yabo area of Sokoto State. The focus of the study is on the assessment of diversity of woody species and the spatial variability across the landscape. This includes identification and characterization of major land use/land cover in the area and the assessment of the status, characteristics and spatial variability of associated woody species. The spatial extent of the study area is some 6km to 7km radius around Yabo town. The total area to be covered for the study is about 32km^2. For the purpose of this study, woody species is defined as trees and shrubs that are at least 2.5cm in diameter and 2m tall (Mueller-Dombois and Ellenberg, 1974)

1.6 JUSTIFICATION OF THE STUDY

Conservation and sustainable utilization of biological resources is perhaps the most pressing challenge of scientists and policy makers in the current millennium. This is because, while concerted efforts have been made to identify and describe species over space and time, there are still a large number of species that exist outside the borders of human knowledge especially in the developing countries. This may be partly due to lack of adequate moral and financial commitment by these countries to sufficiently explore and update information on the number and spatial distribution of species in their territories. As such therefore, the impacts of human activity and that of climate change on the species cannot be adequately assessed; the free ecosystem and protective services provided by the species cannot be clearly understood while the overall goal of biodiversity

protection and conservation cannot be achieved. Knowledge of species diversity and of the nature, extent, composition and structure of biological species is one of the most important steps to biodiversity conservation over space and time.

Woody plant species are an important source of domestic fuel, building materials and edible fruits not only in Yabo area but also in Nigeria as a whole as well as in many parts of the developing world. However, their over-exploitation leads to the depletion of biodiversity and the deterioration of environmental quality. It is a known fact that valuable biodiversity resources are being lost as a result of both natural and anthropogenic disturbances and mismanagement.

This study will not only provide information on the composition and structure of woody species in the study area, it will also serve as a basis for the preservation, management and propagation of woody species biodiversity in the area as well as an incentive for environmental protection through campaign and societal education on the relevance and importance of woody species to the ecological environment and humanity at large. It will also provide a basis for further research both for academic and policy purposes in the study area in particular and the state or country in general.

CHAPTER TWO

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 THEORETICAL FRAMEWORK

This study of the spatial variation of woody species biodiversity hinges on two ecological theories of competition and disturbance. These theories to a greater extent explain local scale species diversity, especially among sessile or stationary organisms, that spend most of their life time in one place; probably because they are fixed to the spot. These include plants that are rooted to the soil and sea weeds that are glued to rocks and other aquatic animals.

The theory of competition (also known as the Gause's law of competitive exclusion) presupposes that it is difficult for species to coexist when the type and intensity of their physical and nutrient requirements are the same. According to the theory of competition, when two species are competing for the same resources – water, sunlight or soil nutrients, one of them may eventually outweigh the other. This was found out by a Russian Biologist, G.F. Gause in observing how microbes behave in culture in the lab. In this observation, Gauss found out that he could not get two similar species that keep going in the same culture medium. Adams (2009) explains that the only way two species can coexist is if each one of them is better at taking only a certain part of some important resources for itself, or if one plant specializes at growing in patches of waterlogged soil and the other growing nearby prefers drier patches. The important thing here is that each species has its forte- a particular strength that no other species can push it out from.

The theory of disturbance on the other hand emphasizes that no single species can do best in an environment that gets disturbed every once in a while. Disturbance may be in form of fire, flooding, landslide, severe drought or from a human source and when it happens, favors one species that do well in quickly colonizing the open ground and multiplying up. The population of these fast colonizing species grows fast because from early on in their lives, they put to producing offspring taking a relatively short time to reach maturity. The slower growing and more demanding species take a long time to overtop and shade out these fast colonizers.

This study draws on these two theories to attempt to explain the spatial variation of woody species in the study area which may be brought about by either the spatial difference in the intensity of human disturbance or the spatial variability of soil nutrients.

2.2 LITERATURE REVIEW

2.2.1 The Concept of Biodiversity

The term biodiversity is used to cover all the variety of life that can be found on the surface of the Earth which includes plants, animals, fungi and microorganisms and also to cover the diversity of communities that they form and the habitats in which they live. The term has been variously defined by scholars in their individual and collective efforts of explaining the variation and variability of life forms that exist on the surface of the earth. Taxonomists, economists, agronomists and sociologists each have their own partial view of the concept.

Biologists tend to define biodiversity as the diversity of all living beings. Farmers are interested in exploiting the manifold potential deriving from variations over soils, territories and regions. Industry sees a reservoir of genes useful in biotechnology or a set of exploitable biological resources such as timber and fish. As for the general public its main concern is with landscapes and charismatic species threatened by extinction (Leveque and Mounolou, 2003). In this instance also, those engaged in the study of natural history see biodiversity as the biotic elements of nature that can be described and classified. To environmental activists, biodiversity is an intrinsic value-laden quality of natural systems that should be preserved for its own sake. To conservation biologists, biodiversity is a measurable parameter relevant to an understanding of community structure, environmental processes and ecosystem functions (Van Dyke, 2008).

The Convention on Biological Diversity (CBD, 1992) defines biodiversity as the variability among living organisms from all sources including, *inter alia,* terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. Biological diversity is the resource upon which families, communities, nations and future generations depend. It is the link between organisms, binding each into an interdependent community or ecosystem in which all living creatures have their place and role (CBD, 1992). Biodiversity therefore encompasses three levels – ecosystem diversity (i.e. variety of ecosystems); species diversity (i.e. variety of different species); and genetic diversity (i.e. variety of genes within species). It also includes the bacteria and microbes that transform waste into usable products, insects that pollinate crops and flowers, coral reefs and mangroves that protect coastlines, and the biologically-rich landscapes and seascapes that provide enjoyment are only a few (TEEB, 2009).

2.2.2 Types and Levels of Biodiversity

Discussions on biodiversity mostly focus on the degree of nature's variety, including both the number and frequency of ecosystems, species or genes in a given assemblage (Mc Neely *et.al,* 1990). Ecosystem diversity is the diversity among systems in a given area. It refers to diversity at community level and covers the variety of communities of organisms within particular habitats as well as the physical conditions under which they live. Ecosystem diversity relates to broad differences between ecosystem types and the diversity of habitats and ecological processes within ecosystems. Human beings and other living creatures exist in form of communities and interact with one another as well as the air, water, rocks, soils and other abiotic organisms around them (NRC, 1992).

Species diversity can be explained in terms of the differences between species, ranging from common annual herbs to bacteria of deep ocean trenches, their arrangement into classifications reflecting their phyletic relationships, and the complex patterns of variation and distribution that they show (GBA, 1995). Species diversity is an important parameter of a plant community which is connected to ecosystem dynamics and environmental quality. Within a species, all normal individuals are capable of breeding with the other individuals of the opposite sex belonging to the same species, or at least they are capable of being genetically linked with them through chains of other breeding individuals (Pearce and Moran, 1994).

Genetic diversity on the other hand is the sum of genetic information contained in the genes of individuals of plants, animals and micro-organisms. Each species is made up of many organisms, and virtually no two members of the same species are genetically identical. Genetic differentiation

within species occurs as a result of either sexual reproduction, in which genetic differences from individuals may be combined in their offspring to produce new combinations of genes, or from mutations which cause changes in the DNA. The significance of genetic diversity is often highlighted with reference to global agriculture and food security (Cooper *et al*, 1992).

2.2.3 The Amount and Distribution of Global Biodiversity

Biological diversity is not evenly distributed over the surface of the planet. It is generally believed that biodiversity is more abundant and diverse in the tropical areas of the world. The rate at which new types of organisms form increases as one moves closer to the equator (Leveque and Mounolou, 2003). However, many estimates put the number of described global species to about 1.4 million. From this estimate, approximately 750,000 are insects, 41,000 are vertebrates, and 250,000 are plants (that is, vascular plants and bryophytes). The remainder consists of a complex array of invertebrates, fungi, algae, and microorganisms (Wilson, 1988).

The distributional pattern of global biodiversity is influenced by many factors among which are altitudinal and latitudinal locations, climate and disturbance. Altitude affects the distribution of biodiversity inversely, that is the higher the altitude, the lower the distribution of species because increases in altitude produce environmental and climatic effects which might not be favorable for the existence of many species (Van Dyke, 2008).

Similarly, the distribution of life forms is shown to increase from high to low latitudes. For instance, Williams *et al*, (1997) carried out an exercise combining available data about the

distribution of families for plants, amphibians, reptiles, and mammals which was mapped onto a cylindrical equal-area projection of the world, using equal-area grid cells of 10^0. The results revealed a consistent gradient of richness from high to low latitudes with northern South America as the area of maximum family diversity (Dirzo and Raven, 2003).

In marine environments, diversity is highest in coral reef habitats, in coastal zones and estuaries, and is higher in tropical marine ecosystems than in temperate ones. In terrestrial habitats, the diversity of tropical rainforests is higher than all other habitats; it is, in fact, legendary. Investigators have found up to 300 different tree species per hectare in study plots in Peru (Wilson, 1988). As many ant species (43) and genera (26) were collected from an individual tropical rainforest tree in Peru as are present in all of the British Isles (Wilson 1988).

However despite the proportionately greater size of the ocean surface, just fewer than 15 per cent of known species are marine. This can be explained by the fact that marine environments are not only more homogeneous and provide less opportunity for speciation, but they have been less extensively explored than terrestrial environments. Phyla that have colonized the terrestrial world diversified more; the most obvious example being insects, which are phylogenetically 'derived' from crustaceans (Leveque and Mounolou, 2003).

In temperate areas, freshwater wetlands contain disproportionately high levels of species diversity at the landscape level. Wetlands may be particularly important in systems of low diversity. Island floras and faunas tend to have high rates of endemism, and make disproportionately high contributions to world biodiversity. (Van Dyke, 2008).

2.2.4 Significance of Biodiversity

Biodiversity provides the society with a wide array of goods and services that may be of direct, indirect, or potential use to humanity; these according to McNeely *et al* (1990), are often referred to as "biological resources". To most people the existence of many species is important because many species furnish various sources of food, clothing, shelter, and medicine for people. The presence of a great number of species forms one of the most important bases of life for humans throughout our planet (Sophat, 2004). Biodiversity has biological, economic, ecological, socio-cultural and aesthetic values.

Biodiversity has biological values in that they are the source of all the food and many of the medicines, fibers, fuels, and industrial products used by man. Although relatively few species are consumed as food, their productivity in both traditional and modern agricultural systems depends on genetic diversity within the species and interactions with other species found in the agro-ecosystem. Some genes have the ability to confer resistance to specific diseases or pests, make crops more responsive to inputs such as water or fertilizers, or confer hardiness enabling the crop to be grown in more extreme weather or soil conditions (NRC, 1999).

Biodiversity contributes positively to agriculture which is the mainstay of the global economy and also provides raw materials on which many industries depend. This therefore implies that biodiversity directly or indirectly affects the source of human livelihood. Insect pollination, natural parasitism and predation are some ecosystem services provided by biodiversity (CBC, 1997). According to Farnsworth (1988), wild species of plants and animals have been the source of important pharmaceutical products since time immemorial. According to the World Health

Organization estimates, some 80% of people in developing countries obtain their primary health care in the form of traditional medicines (NRC, 1999). Apart from fishing, hunting and tourism which are a good source of revenue, humans also use a relatively small number of livestock species for food and transportation.

Besides serving economic values, biodiversity also performs ecological function since all species depend on others in intricate ways for survival. By implication, destroying one species can affect one or several other species (Smith, 2001). Ecological values include aesthetic and cultural benefits. Each species and ecosystem adds to the richness and beauty of life on Earth (Smith, 2001). Millions of people enjoy hunting, fishing, camping, hiking, wildlife watching, and other outdoor activities based on nature. Once a species becomes extinct it is gone forever. When an ecosystem is destroyed it is impossible to replicate it (Sophat, 2004).

The provision of free ecosystem services is another ecological function of biodiversity. Ecosystem services include such invaluable functions of watershed regulation, nutrient cycling and microclimate mediation, the provision of global services such as climate regulation and carbon sequestration, and evolutionary processes. These functions are mediated through the component organisms of an ecosystem – its biodiversity of plants, animals and microbes, all of which are interlinked in complex ways (Pearce *et al*, 2007). Biodiversity maintains and restores the environmental quality and productivity, prevents pollution, regulates water flows, maintain soil fertility, control flood and pests and protects coastal zones from storm damage. All these and many more are ecosystem services provided free of charge by the earth's biological diversity.

2. 2.5 Global Loss of Biodiversity

Despite its various uses, biodiversity is increasingly being lost throughout the world. Myers (1979) posited that the world was losing one species per day in the 1970s, and by the mid-1980s, the loss will increase to about one species per hour. By the end of this century, the planet earth could lose anywhere from 20 to 50% of its species.

It has been estimated that in the last century, about 35% of mangroves, 40% of forests and 50% of wetlands were lost. It was asserted that in just fifty years, sixty percent of ecosystem services could not be provided more while species loss is 100 to 1,000 times than in geological times and will get worse with climate change while 80% of the world's fisheries are fully or over-exploited (TEEB, 2009).

Several factors have contributed to the loss of global biodiversity loss. These factors range from the natural, geological or climatic processes, human activities to the effects of invasive alien species in the environment.

Natural, geological and climatic processes have, from time immemorial, been significant causes of biodiversity loss and species extinction. According to a report by the National Research Council (1992), the diversity of life on Earth has never been, and never will be, static. Global biodiversity has fluctuated through geologic time as evolution has added new species and extinction has taken them away. According to the report, responses of species to changes in their physical and biological environments have led to the fluctuations in diversity over relatively long periods of time.

Climate change affects natural as well as societal and economic systems, such as human health and agriculture. Increased temperatures and pressure on water resources, a rise in the frequency of extreme weather events, flooding and bushfires, increased sea level rise and associated coastal erosion will all impact enormously on biodiversity. Species migrations, extinctions and changes in populations, range and seasonal and reproductive behaviour are among the responses that have been recorded, and these are likely to continue and even accelerate as climate continues to change in decades to come (ECNC, 2005).

Humans are the basic cause of these losses, because in the process of securing a living from the land, people modify it. The human population is growing at a faster rate in tropical latitudes than anywhere else and these results in more habitat destruction in the tropics. In fact, the greatest losses of species are reported to occur in the tropics, which contain half of the world's remaining forests. It was advocated that present tropical forests will be destroyed by the beginning of the next century and that because these forests are the world's richest in terms of species numbers, their destruction becomes the primary source of a global loss of species (Wilson, 1988).

Human activities that directly impinge on the amount and distribution of biodiversity include, though not limited to, the direct destruction, conversion, or degradation of ecosystems resulting to the loss of entire assemblages of species (Soulé, 1991). Others include overexploitation, habitat disturbance, pollution, and the introduction of exotic species which accelerate the loss of individual species within communities or ecosystems. As genetic variability is lost, however, the species as a whole becomes more vulnerable to other factors, more susceptible to problems of inbreeding, and less adaptable to environmental change (NRC, 1992).

Agricultural activities (including crop and livestock farming and plantations), extraction activities (mining, fishing, logging, and harvesting), and the development of infrastructure (such as human settlements, industry, roads, dams, and power lines) are seen as the primary causes of habitat loss. In Nigeria for instance, agricultural lands increased from 53.8% of the total land area in 1976 to 60.8% in 1995, with a concomitant loss of natural habitats like savannas and forests. Agricultural land conversion continued in the country to the detriment of the natural habitats and the species within them that still remain (USAID, 2008). Extraction activities affect 34% of plants species and 53% of bird species while developmental activities affect 769 threatened plant species and 373 bird species and about 59 of the threatened mammals (Dirzo and Raven, 2003).

Population pressures, poverty, and inequitable land tenure systems leave people with little choice but to adopt overly intensive resource use practices as a result of which habitat loss becomes very severe. The use of traditional fuels such as firewood, charcoal, crop residues, manures for cooking and other energy needs is known to deplete soil, water, and biological resources and further destroying biological resources (CBC, 1997).

Direct exploitation is the second most important driver of global biodiversity loss in the World. It was estimated that direct exploitation of natural resources such as mining, hunting, fishing, trading, exploitation of leaves, herbs, roots, barks and in some cases, stems of plants species for medicinal purposes account for a considerable threats to communities of birds, mammals, and plants species. IUCN reports that more than 20,000 species of plants are used for medicinal purposes and nearly half of that number is potentially threatened by over-harvesting or by the loss of their habitat (Martinez *et al*, 2006).

Introduction of alien invasive plants and animal species also contributes significantly to global loss of biodiversity. This has been estimated by the IUCN to affect 30% of all threatened birds, 15% of the plants and about 10% of the mammals. Invasive alien species have been shown to threaten between 25% and 40% of native plants stem in the United States and to also affect virtually all threatened species in Hawaii. This is because they alter ecosystem, decrease native species abundance and richness via competition, predation, hybridization and indirect effects. They also change community structure and alter genetic diversity (McGeoch *et.al* 2010).

Because losses of biodiversity are irreversible and have far reaching consequences, their impact on human biological, economic and social conditions cannot be overemphasized. Loss of a diversity of genes within species, species within ecosystems and ecosystems within a region affects the ability of ecological communities to resist or recover from disturbances and environmental change, including long-term climatic change and also widens the likelihood that further environmental disturbance will result in serious reductions in the goods and services that the Earth's ecosystems can provide (GBA, 1995).

Species extinction and population loss in different ecosystems has also reduced global genetic diversity. Such losses reduce the fitness and adaptive potential of both species and ecosystems, thus limiting the prospects for recovery after possible disturbance. For instance, a third of the 6,500 breeds of domesticated animals are estimated to be threatened or already extinct due to their very small population sizes (FAO, 2009).

Habitat losses in the tropics translate directly into biotic losses. Brook, Sodhi, and Ng (2003) reported massive biotic extinctions in Singapore due to loss of over 95% of the rainforest since 1819, with most known extinct taxa (34−87%) being species of butterflies, fish, birds, and mammals. Accordingly, anthropogenic activities such as logging are degrading and destroying tropical rainforests at a rate unprecedented in history. This may lead to the depression of human well-being and livelihood, flood protection, climate stability, crop pollination, and many other ecosystem services as cited by Balmford & Bond, (2005). Similarly, habitat loss can facilitate the spread of some zoonotic diseases as contemporary deforestation seems to lead to an increase in the distribution of mosquitoes with concomitant increases in malaria transmission (Sodhi, 2007).

Deforestation which is explained as clearing plants and especially the woody species has been closely related to environmental degradation and consequently, accelerating climate change. For instance, Omofonmwan and Osa-Edoh (2008), asserted that with deforestation, soils are exposed to erosion devastation, floods occur, and rivers and lakes, are filled up with silt. The water becomes dirty and impure for mankind. The removal of tree canopy (particularly the leaves) has effect on the rainfall of that area, as there is less leaf surface area for the transpiration of water, which in turn affects the relative humidity of the atmosphere (Omiegbe, 1999).

When humans alter ecosystems, large mammals are typically the first species to disappear. They are hunted for meat, hides, and horns; they are harassed and killed if they pose a threat; they require expansive habitat; and they are susceptible to diseases, such as anthrax, rinderpest, and distemper, that are spread by domestic animals. The ecological and economic consequences of

losing large mammal populations vary depending on the location and the ecological role of the species lost. The loss of carnivores has induced trophic cascades; in the absence of top predators, herbivores can multiply and deplete the plants which in turn drive down the density and the diversity of other species (Sodhi and Ehrlich, 2010).

2.2.6 Biodiversity Loss in Nigeria

Due to its tropical location, Nigeria is blessed with a great diversity of plants, insects and animal species. Although information about the exact number and status of these species in the country is minimal (USAID, 2008), some estimates put the figures of Nigerian biodiversity to be in the neighborhood of 20,000 species of insects, 1,000 species of birds, 247 species of mammals, 123 species of reptiles, 1,000 species of fish and about 7,895 species of plants (FGN, 2001).

Loss of biological diversity in Nigeria, however, like many other developing countries, is enormous. The International Union for the Conservation of Nature (IUCN) stated that the Red List of Globally Threatened species contains 148 animal and 146 plant species that are found in Nigeria. The list also included 3 animal species and 15 plant species classified to be critically endangered (USAID, 2008).

Deforestation is perhaps the most important cause of biodiversity loss in Nigeria. It has been reported that about four fifths of Nigeria was once savanna, but much of this land has been converted to agriculture or grazing lands. Is has also been reported that undisturbed forest including rainforests and savanna woodlands made up 2.9 percent of the total area of Nigeria in 1976-78 but only 1.3 percent in 1993-95 (USAID, 2008). This by implication means that many

species have been destroyed while many have also been endangered or threatened to extinction (Usman and Adefalu, 2010).

The continued growth of population in Nigeria which brought about an increased demand for shelter, food and fibre, coupled with high rise in the cost of domestic energy have caused recourse to firewood as an alternative source of energy for domestic uses (Ati *et al.,* 2010). This situation has led to exerting enormous pressure on biodiversity, especially the woody biodiversity. This is worsened by the poverty rate in the country which has necessitated over reliance on primary products and the use of forest resources as sources of food and livelihood (Usman and Adefalu, 2010). The rapid increase in human population has also resulted in rapid decline in environmental quality and human living conditions as people only cared about what to get out of the environment for their own immediate needs and uses, without caring very much for the consequence, especially for succeeding generations (Omofonmwan and Osa-Edoh, 2008).

Agriculture which accounts for about 60.8% of total land area in Nigeria accounts for a large percentage of biodiversity loss in the country. Shifting cultivations, plantations, and use of fire in agricultural practices result to the clearing and conversion of large hectares of land, the result of which leads to habitat degradation and consequently, biodiversity loss (USAID, 2008).

Socio-economic factors such as illiteracy, poverty and corruption greatly causes unwise use of the natural environment, lead to the degradation of the environment (Omofonmwan and Osa-Edoh, 2008) and generally affect the abundance and distribution of biological diversity in many tropical countries (Sodhi, 2008) which Nigeria is a part. Other factors responsible for biodiversity loss in Nigeria include uncoordinated land use policy, lack of well defined programmes and weak legal

machineries that adequately protect, conserve and promote biological diversity (Anadu, 1987; USAID, 2008).

CHAPTER THREE

ENVIRONMENT OF THE STUDY AREA

3.1 LOCATION OF THE STUDY AREA

The study area is some 6-7 km radius around Yabo town in Sokoto State and covers some 32 km^2 (Figure 3.1). Yabo town is the administrative headquarter of Yabo local government area. Yabo Local Government is located between latitudes 12°28′00″N and 13°00’00’’N and longitudes 4°44′58″E and 5°11’50’’E. It has a total land area of 789 km² and a population of 115,011 according to the 2006 census. It is bordered in the north by Bodinga and Silame Local Governments, in the south by Tambawal Local Government, in the east by Shagari and in the west by parts of Kebbi state (Figure 3.2).

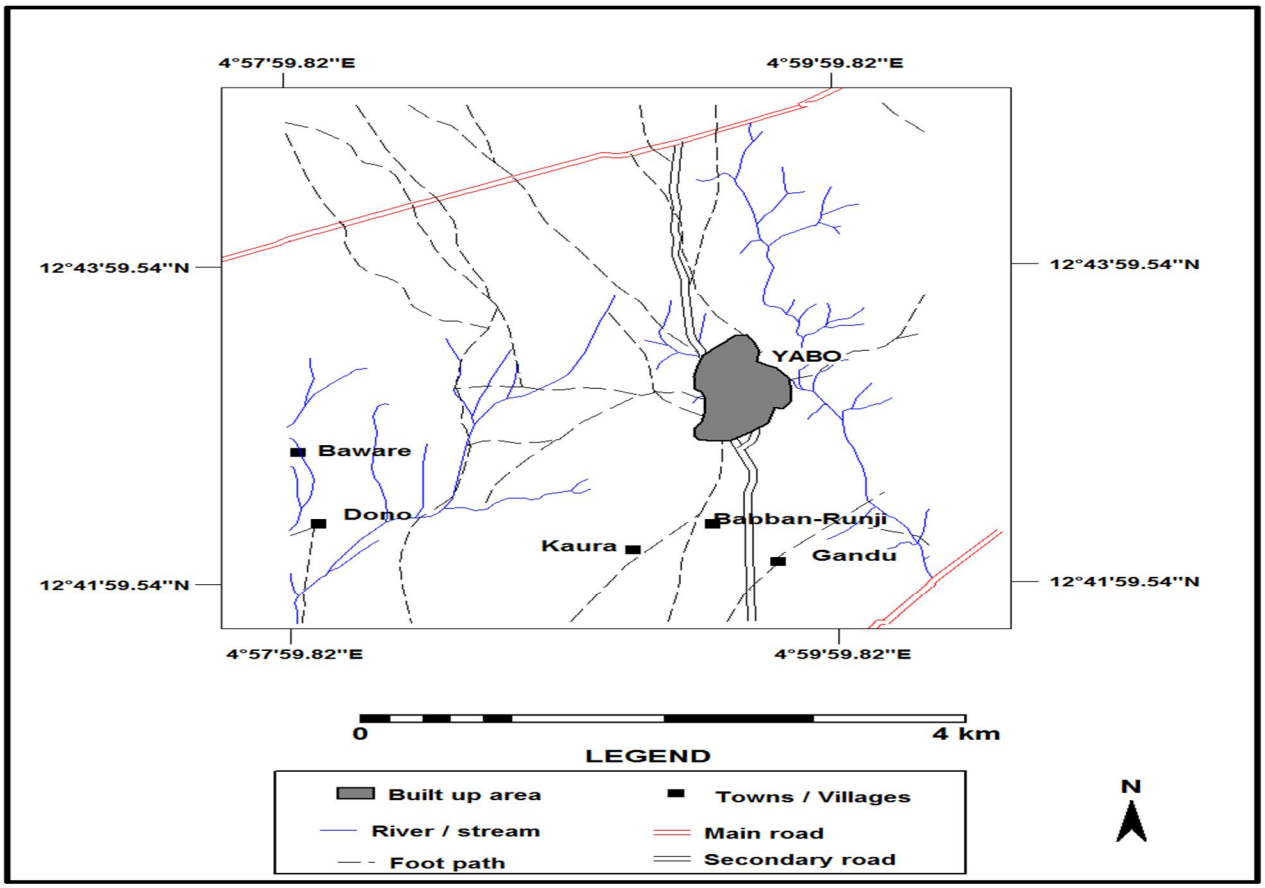


Figure 3.1: Location of the Study Area
(Source: Argungu Sheet 28S.E and Dange Sheet 29 S.W)

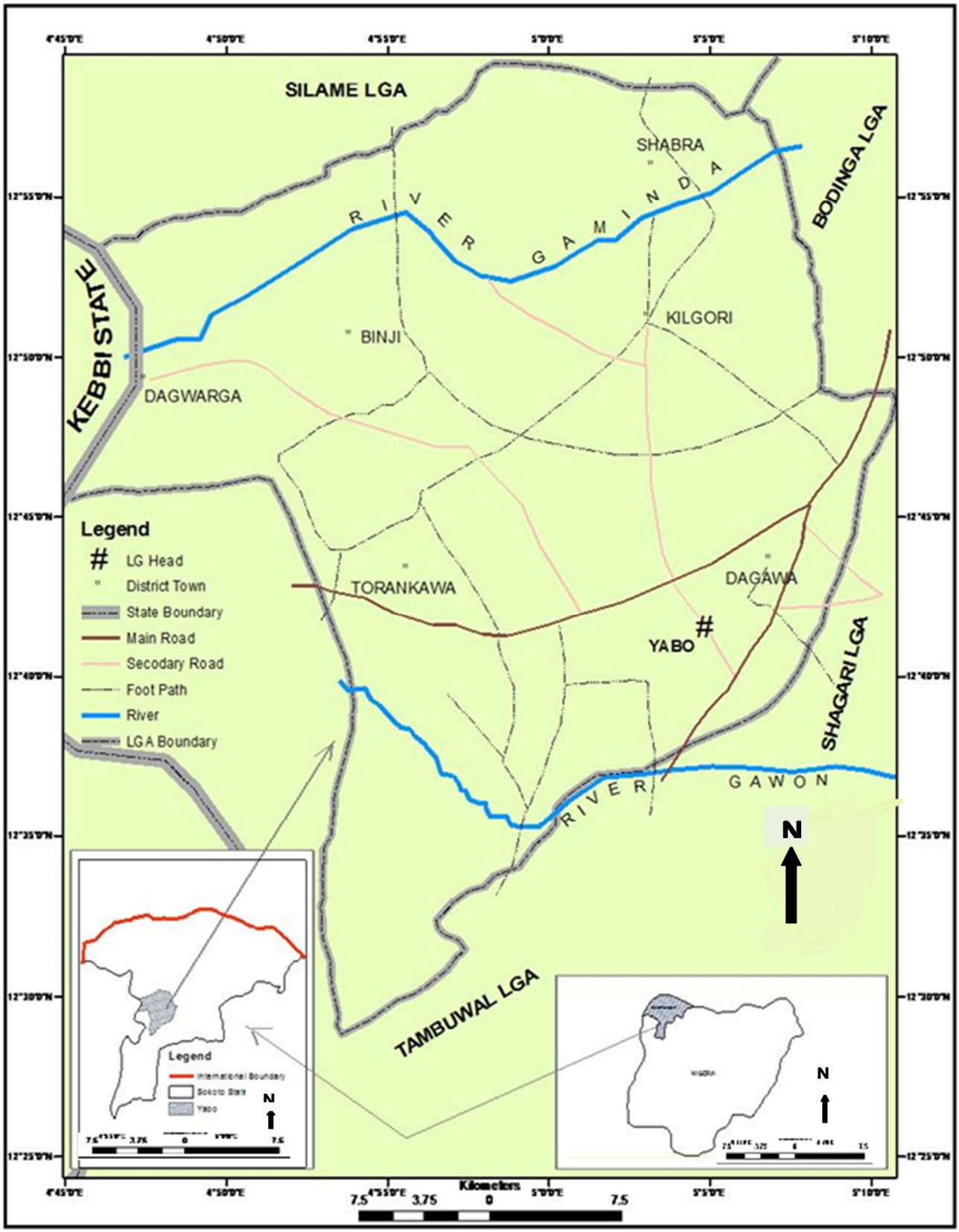


Figure 3.2: Yabo Local Government Area in Sokoto State.

3.2 PHYSICAL CONDITION

3.2.1 Climate

The area lies in the sudano-sahelian ecological zone which is semi arid. It is characterized by three seasons – the cool and dry, the hot and dry and the hot and wet (Alagbe, 2006).The area is influenced by the Tropical Continental air mass (cT) during the months of November to February. The cT is a south moving, cold air mass that is associated with cool and dry, dusty winds. This period is referred to as the harmattan season. Temperature during this period could be as low as 22^{o}Celcius. The hot season prevails in the area in the months of March to May and is associated with high temperature of up to 38^{o} to 40^{o}Celcius. The hot and wet season on the other hand usually starts from the month of May and lasts for about four months only. The Maritime Tropical air mass (mT) which is a moist, northward moving West African monsoon influences the area from May to October (SSG, 2004).

Rainfall in the area with emphasis on the annual totals, incidence and distribution is highly variable from year to year (Swindell, 1986; Adelana *et al*, 2006). While some years may be relatively dry, some are relatively wet (Figure 3.3a). Some months also experience more rainy days than others but most rains occur during the relatively short but intense thunderstorms usually at the beginning and end of the rainy season (Swindell, 1986). According to a Sokoto State Government publication (2004), the area has a mean rainfall of 814.33mm. Figure 3.3 (a and b) show long term rainfall and temperature trends for Sokoto which lies some 43km north east of Yabo town.

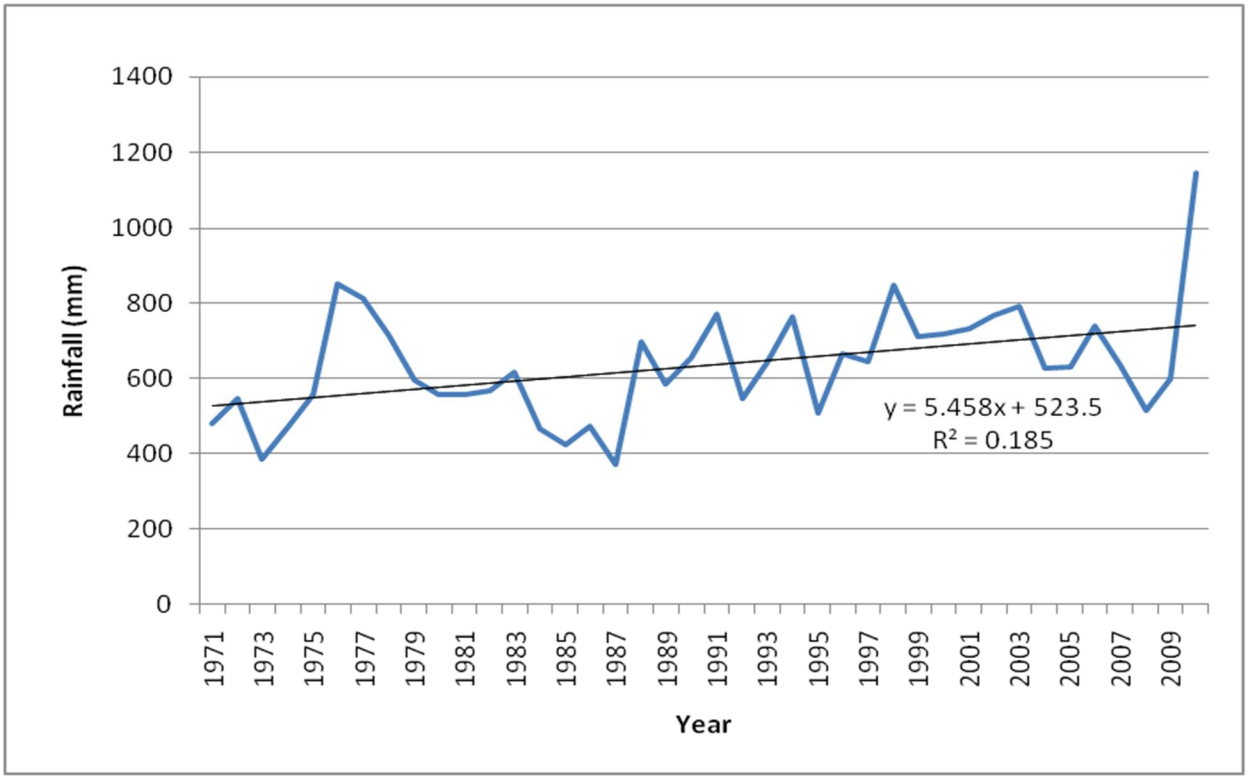


Figure 3.3a: Mean Annual rainfall for Sokoto from 1970 – 2010 (Data Source: NIMET)

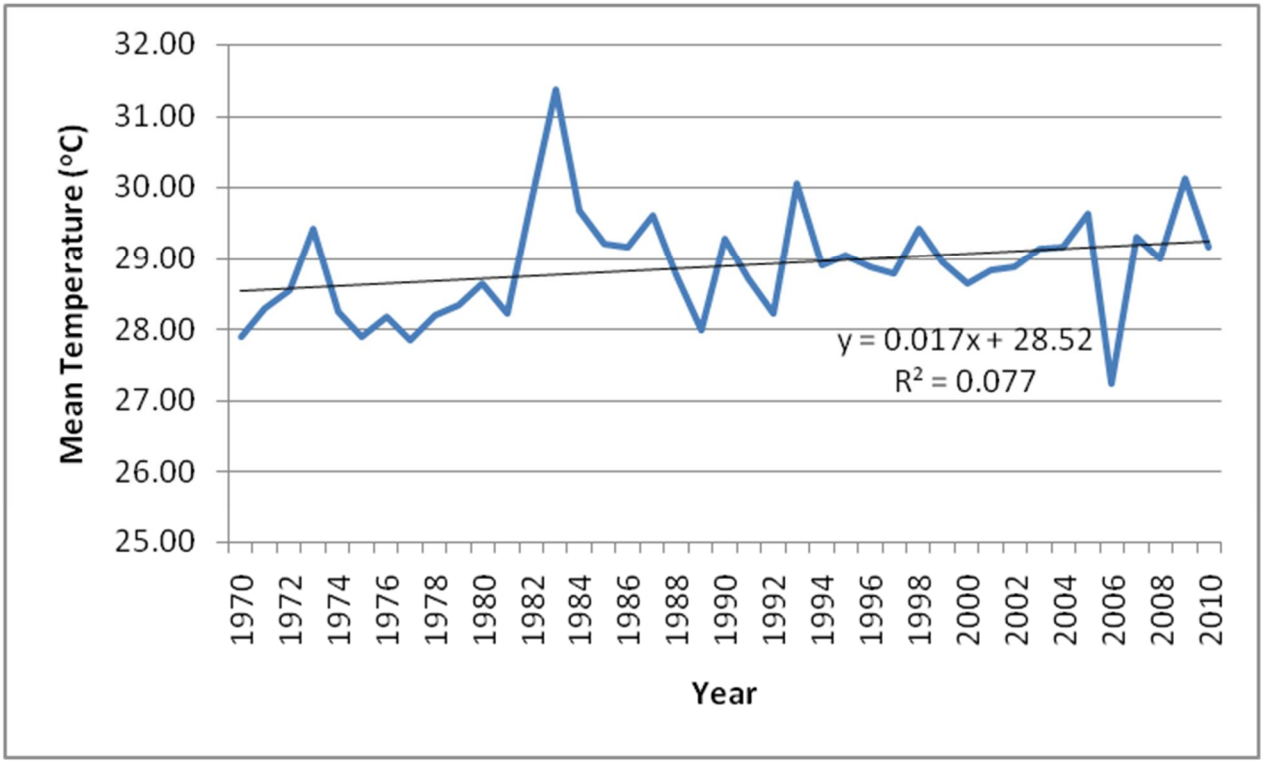


Figure 3.3b: Mean Annual Temperature for Sokoto from 1970 – 2010 (Data Source: NIMET)

3.2.2 Geology, Relief and Drainage

The study area is located in the Taloka formation, belonging to the cretaceous Rima group which is part of the extensive Sokoto basin (Maduabuchi, 2002). The Sokoto basin is generally underlain by a sequence of inter-bedded semi-consolidated gravels, sands, clays and some limestone and ironstone of cretaceous to quartenary age resting on pre- cambrain basement complex rocks which outcrop extensively to the East and South of Zamfara State as well as to the South of Kebbi State. This basin consists predominantly of a gently undulating plain with an average elevation varying from 250 to 400 meters above sea level. The plain is continuously interrupted by steep sided, flat topped hills with a lower escarpment popularly referred to as the "Dange Scarp" (Kogbe, 1979). The Taloka formation has a maximum thickness of 180m and consists of fine to coarse sand, silty sands, shales and sandstones with many layers of clay/shale within the latter (Maduabuchi, 2002).

The topography of the area consists of gently undulating plain dotted with residual hills that are of sedimentary nature with an average height of 285m (Abdu *et al*, 1982). The drainage pattern is predominantly radial and populated by ephemeral rivers that drain rain water into rivers *Gawon* and *Gamind.* These rivers are only active in the rainy season but their surrounding is moist enough to support small scale market gardening. They also provide clean sand that is used for concrete buildings mostly during the dry season.

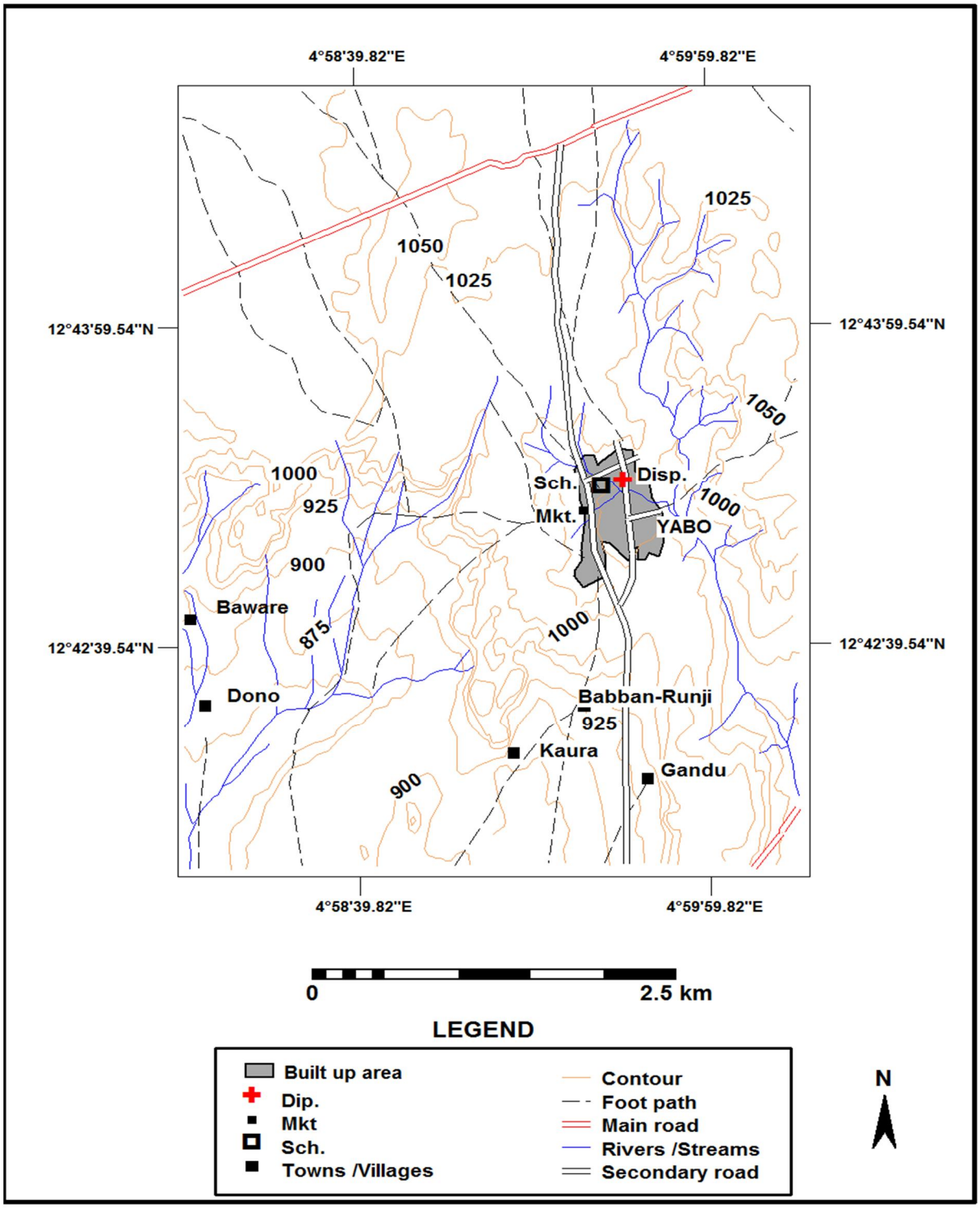


Figure 3.4: Relief and Drainage of the Study Area
(Source: Argungu Sheet 28S.E and Dange, Sheet 29 S.W)

3.2.3 Soil

The soils in the area are predominantly sandy, ferruginous and light (Swindell, 1986). They are characterized by low level of organic matter, total nitrogen and cation exchange capacity. They range from moderate to well drained with a low water retention capacity and a poor structural development (Ogunwale *et al,* 2002). However, there are isolated regions in the study area where the soil is either hydromorphic or lateritic. The hydromorphic soils are found in the low lying, *fadama* areas and are comparatively higher than the predominant sandy soils in organic matter content, water holding capacity, soil nutrients and bulk density (Swindell, 1986). The lateritic soils on the other hand are found in the rocky areas.

3.2.4 Vegetation

The vegetation consists of mostly short feathery grasses and some scattered trees most of which are deciduous in character. The tree species are mostly those that can adapt to dry conditions and are fire resistant (SARDA, 1992). The vegetation can be said to be a mosaic of different types but whose pattern of distribution is very largely influenced by human activity though physical factors may assume local importance (Abdu *et al*, 1982). Tree species in the area include though not restricted to *Acacia albida*, *Acacia senegalensis, Khaya senegalensis, Guiera senegalensis, Combretum micranthum, Combretum nigricans, Senna arereh, Mimosa pigra, Butyrospermum parkii*, *Parkia biglobosa*, *Azadirachta indica*, *Adansonia digitata* and *Mangifera indica.* The herbaceous species include *Senna tora, Borreria radiate, Eragrotis tremula, Commelina africana, Digitaria debilis, Cenchrus bifloris, Pennisetum hordeides, Mitracarpus scaber, Ipomea muricata and Ipomea asarifolia* to mention but a few. It can generally be said that, natural vegetation of sparse shrubs of less than 6m high dominate the area (Alagbe, 2006).

3.3 POPULATION, SETTLEMENT AND LAND USE

3.3.1 Population and Settlement

The area can be said to be moderately populated. According to the 2006 census, Yabo Local Government area has a total population of 115,011. The breakdown reveals that 51.53% (59,265) of the total population are males while 48.47% (55,746) are females. At a growth rate of 3.01%, the area is projected to have a population of 137,409 by the year 2012 (NPC, 2006). Settlement in the area is dispersed. Most settlements are found at the foot of the numerous residual hills, along water bodies or close to wetlands, where water for animals and irrigation activities is not far from ground surface.

3.3.2 Land use

Land use in the area can be broadly categorized into agricultural, residential and institutional with little commercial use. Agriculture is the predominant human activity in the area and as such, agricultural land use is the major land use. As the area is moderately populated, residential land use also accounts for a considerable proportion of the area. The area has been a center of learning since the jihad period and a predominantly Muslim community; it has a considerable number of mosques, islamiyya schools, cemeteries and opened grounds. Similarly, Yabo town serves as an administrative headquarter both at the district and local government levels. It therefore houses the local government secretariat and the local government education authority.

The area lacks any form of modern industry. Commercial activities are cottage or domestic industries that are usually associated with particular families. These include blacksmithing, dyeing, wood curving, mat making, pottery, leather works and weaving. The Yabo central market is

perhaps the most outstanding commercial area which is observed on weekly basis. There are also retail and service shops littering the area in a rather disorderly manner.

3.4 SOCIO-ECONOMIC ACTIVITIES

The indigenous population consists of Hausas and the Fulanis. While the Hausas are predominantly farmers, the Fulanis are predominantly animal rearers. The Hausas complement the cultivation of crops with animal rearing both as a source of farm manure and income. The Fulanis on the other hand compliment animal rearing with farming.

Farming in the area is mainly subsistent. Crops cultivated on this basis include cereals such as millet, guinea corn, sorghum and rice. They also include beans, groundnut and tuber crops especially cassava and sweet potatoes as well as tree crops such as mango, guava, cashew and locust beans among others. However few crops are cultivated for commercial purpose, some of which are sugarcane, onions, tomatoes, pepper and a variety of vegetables (SARDA, 1992). Dominant animals reared in the area include cattle, sheep, goats and camels.

3.5 LAND DEGRADATION AND DESERTIFICATION

Land degradation is explained as the decline and subsequent deterioration in the quality or production capacity of land usually caused by anthropogenic and/or natural factors. Desertification on the other hand is the “diminution or destruction of the biological potential of land, and can lead ultimately to desert-like conditions. The causes of desertification can be summarized into over cultivation, over grazing, deforestation and mismanagement of irrigated cropland while its manifestations are soil and vegetation degradation (Grainger, 1990).

As human population increases, more land is converted for residential and agricultural purposes and more domestic energy needed. This coupled with an increase in the number of livestock, poses profound threat to vegetation and animals in the study area. As a result of this, some tree species as well as animals are no longer available in the area. Land degradation is a problem that affects many parts of Africa especially in the sub-Sahara region. The productivity of some lands in Africa has declined by 50% as a result of soil erosion and desertification. (Eswaran *et al*, 2001).

In the study area, there are evidences of land degradation as caused by over cultivation, over grazing and deforestation. The wetlands at the eastern and southern parts of the study area where sugar cane used to be produced in commercial quantity have now shrunk in size and depreciated in productive capacity due to increasing dryness. There is noticeable decline in the amount of vegetation cover and in the number of wild animals in the area which could be explained by increasing fragmentation and habitat destruction as a result of excessive exploitation of forest resources. Similarly, gullies are increasing in number, width and depth; hence eating into the available arable land. Other features of land degradation can be seen in form of soil compaction, reduction in cultivable lands and general reduction in the volume of farm produce in the area.

CHAPTER FOUR

MATERIALS AND METHODS

4.1 TYPES AND SOURCES OF DATA

This study used both the primary and secondary data to achieve the outlined objectives. Table 4.1 summarizes the data required and their respective sources. For the identification of dominant land use over the study area, satellite imagery of the study area is required and this was obtained from the Global Land Cover Facility (GLCF) downloaded from the University of Maryland's website. Data on composition and structure of woody plants species in the study area was obtained from detail field survey that was carried out. Species were identified and described on the field with the help of a field herbarian. However, specimens of unidentified species were also taken to the laboratory of the Department of Forestry and Fisheries, Usmanu Danfodiyo University, Sokoto where they were identified and described. Information on the general environment of the study area was obtained essentially from literature and corroborated during the detail field survey.

Table 4.1: Types and Sources of Data

S/N	Type of Data	Source
i.	Data on Land use/Land cover	Landsat ETM^{+} Satellite Imagery, obtained from the GLCF 2005 and downloaded from the University of Maryland (USA)'s website
ii.	Information on Environment of the study area	Literature review corroborated by field survey
iii.	Data on woody species and characteristics	Field and laboratory analysis

4.2 RESEARCH DESIGN AND METHODOLOGY

The approach methodology employed in this study is summarized in figure 4.1.

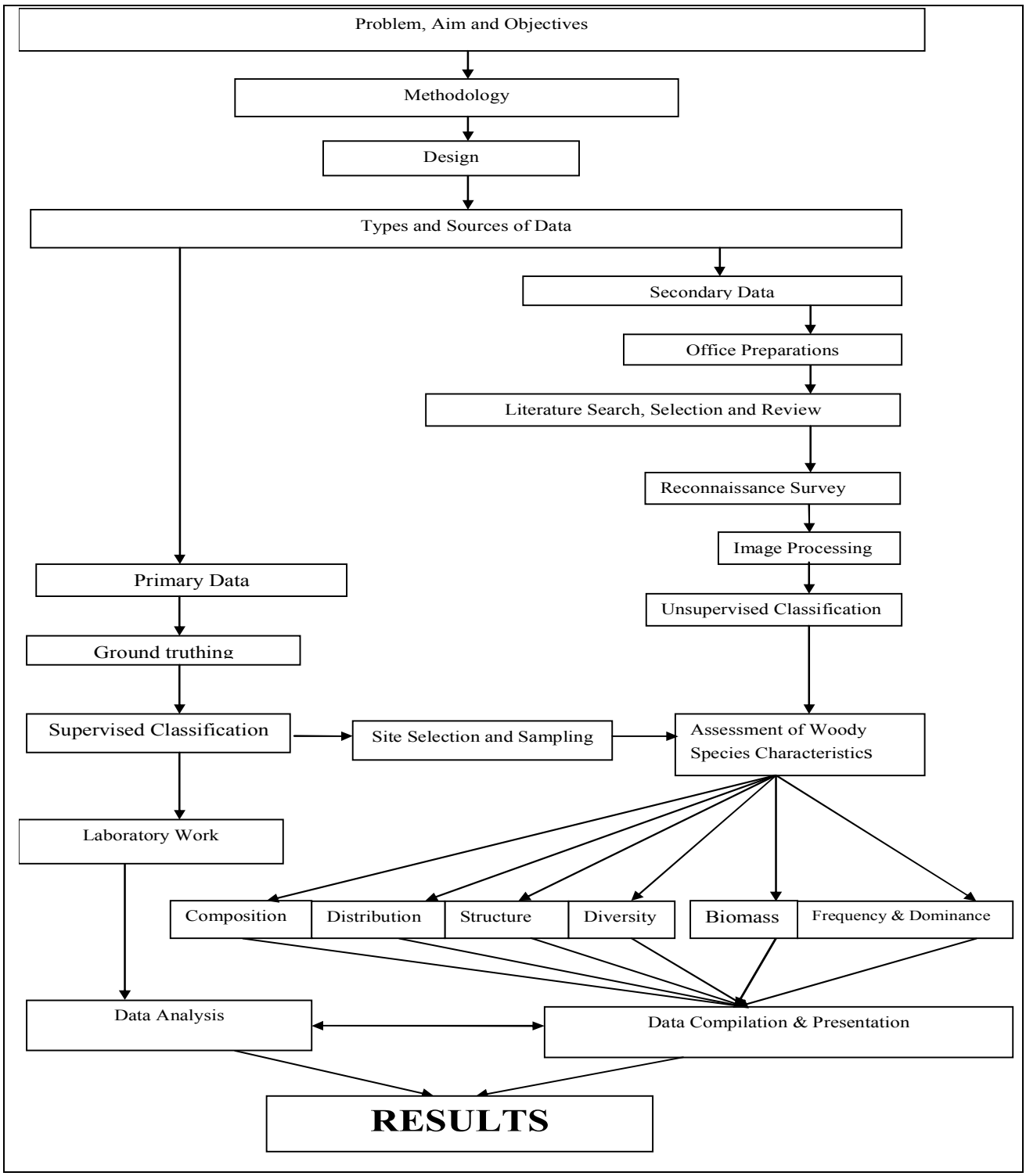


Figure 4.1: Flow chart of approach methodology adopted in the study

4.2.1 Reconnaissance Survey

Reconnaissance survey was the first major activity undertaken in the course of the study and was carried out from the 11th to the 14th of August, 2011. The objective of the survey was to familiarize with the study area and gain a general overview of the environment. Local communities in the study area and their surroundings were visited. The outcome of the survey include identification and sensitization of some key community leaders on the objective of the study, a general overview and acquisition of the very fragmenting information available on the environment of the study area.

4.2.2 Imagery Processing

The Landsat 5 Thematic Mapper (TM^{+}) imagery which was used was at a resolution of 30m x 30m and covers an area of about 32 km^2 (12^0 41'45''N - 12^0 45'00''N and 4^0 58'00''E - 5^0 00'20''E) around Yabo town. The IDRISI ANDES V.15.0 software was used in the imagery processing. The IDRISI ANDES is a raster based GIS and image processing software which uses the principle of algorithm in image analysis (Eastman, 1997). The software used a simple stratified random sampling method to generate clusters of land use/land cover types based on the intensity and digital number of the pixels; this process is described as the unsupervised classification. The software also has an in-built randomization facility which permitted the random selection of 50 pixels, proportionately across the recognizable land use clusters on the imagery. This approach allowed for maximum representativeness and also gave every pixel in the imagery an equal chance of being selected. These 50 pixels formed the basis for ground truthing and subsequent detail field survey.

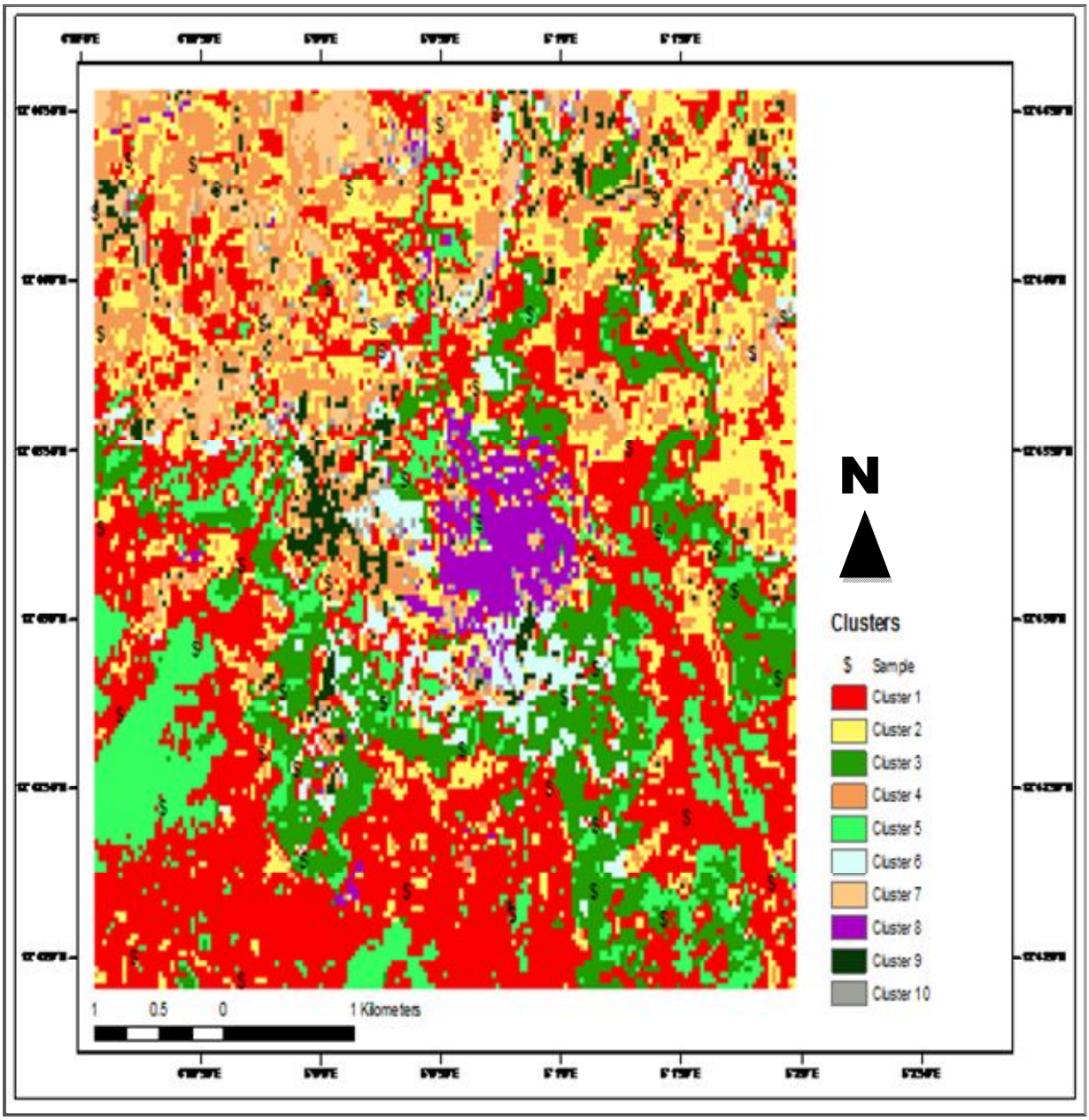


Figure 4.2: Unsupervised Classification of the LANDSAT Imagery of the Study Area

In all, ten dominant clusters representing different land use categories were recognized on the map. Figure 4.2 shows these clusters while table 4.2 gives the statistics.

Table 4.2: Area Coverage of Clusters

S/N	CLUSTER	AREA COVERAGE (M^2)	COLOUR	NO of SAMPLES
1.	Cluster 1	9780119.2	Red	15
2.	Cluster 2	4863765.8	Amber	8
3.	Cluster 3	3798653.6	Green	6
4.	Cluster 4	3637251.1	Orange	6
5.	Cluster 5	3154742.7	Violet	5
6.	Cluster 6	1771534.4	Light Green	3
7.	Cluster 7	1458231.5	Yellow	2
8.	Cluster 8	1406974.8	Blue	2
9.	Cluster 9	1231093.7	Purple	2
10.	Cluster 10	865626.7	Cyan	1
	Total Area Coverage	**31967993.5**		**50**

4.2.3 Ground Truthing

Ground truthing is an explorative tour of the study area with the aim of verifying the true nature and location of points, areas and objects as they appear on the downloaded imagery. For this study therefore, ground truthing was carried out from the 1st to the 15th of September, 2011. All of the 50 points that have been selected during the procession and classification process were visited. The only exception was a particular point that was not accessible at the time of ground truthing but which was however accessed during the detail field survey. Two steps were taken in the ground truthing exercise. First, the coordinates (lat/long) of the selected points were inputted into the way point list of an *etrex* GPS. Second, the points were traced and identified with the aid of the GPS and a topographic map of the study area (Dange, Sheet 29) serving as the base map.

All information related to the nature of the terrain, type and nature of the vegetation, as well as the type of human activity observed at the point was recorded. This information was used as the basis for defining the type of land use and also for classifying the land cover of the area.

4.2.4 Image Editing and Classification

Image editing refers to the conscious attempt at checking of irregularities or over laps, as well as over/under shootings of the imageries. The results of the ground truthing provided the basis for the correction of any possible error in the imagery used and also allowed for the development of a legend that explained the land use/land cover types or classes of the area.

For the purpose of categorizing and grouping all pixels in the image into related groups or classes, a supervised image classification was carried out. The imagery was classified using the information gathered during the ground truthing exercise. Although there are no sharp boundaries that would have been obtainable with the use of a more sophisticated image processing software such as the ERDAS IMAGINE, use of the IDRISI ANDES thus allows for adequate categorization of image pixels based on the similarity of information collected.

4.3 DETAIL FIELD SURVEY

4.3.1 Instruments

The following instruments were used in the detail field survey. They are:

(a) Topographic map of the study area (Argungu, Sheet 28 SE and Dange, Sheet 29 SW)
(b) Global Positioning System (GPS)
(c) Haga's Altimeter
(d) 100m Measuring Tape
(e) Digital Camera

4.3.2 Sampling

The quadrat vegetation sampling method was used in this study. In the quadrat method, the plots are laid around a predetermined central point using a measuring tape at a radius of the chosen size of the quadrat. Quadrats can be of any size, depending on the size and morphology of the plant species under study and also on the pattern of distribution (Gilbertson *et al*, 1985). For this study, 50 quadrats of 50m x 50m size were used. The choice of the size was to allow for optimum inclusion of species in the inventory due to the sparse nature of vegetation in the study area.

In establishing the quadrats, the coordinates of the selected points (Appendix II) which were entered into the way point list of the Global Positioning System (GPS) formed the center of the quadrat and from which, 25m was measured in the four cardinal directions to give a squared quadrat of 50m x 50m. All woody species in the quadrat were identified and enumerated; their scientific and vernacular names were recorded. However, specimens of those species that could not be identified on the field had to be taken to the laboratory (of the Department of Forestry and Fisheries, Usmanu Danfodiyo University, Sokoto) for proper identification and description.

Beside species identification and enumeration, information on the structural characteristics of species was also gathered and computed. These include species density, structure, biomass and diversity.

Species Density: Species density is the aggregate of woody species per a unit area. For convenience, this is expressed as per hectare. Species density was in this study determined by summing up the number of individuals of respective species in the study area and expressing it on per hectare basis (Hundera and Deboch, 2008).

Species and Family Frequencies: Species frequency is the rate of occurrence of individual species in all the sample plots. Species and family frequencies were determined as the proportion of the sample plots in which a particular species or family appeared. To determine the species or family frequency distribution, the frequencies were grouped into classes and expressed as A, B, C, D and E frequencies (Upadhaya *et al*, 2004; Demisse, 2006; Patrice *et al* 2007 and Asteggiano, 2008) where:

A = 1 – 20%,

B = 21 – 40%,

C = 41 – 60%,

D = 61 – 80%, and

E = 81 – 100

Species and Family Dominance: Dominance refers to higher occurrence of a species or group of species in a particular environment. Species and family dominance were determined by the Importance Value Index (IVI) which is given as the sum of Relative Frequency (RF) + Relative Dominance (RD) + Relative Basal area (RBa). IVI ranges from 0 – 300% (Savadogo *et al,* 2007).

The IVI is given as:

$$\text{RF}\left(\frac{\text{a}}{b}\text{x}100\right) + \text{RD}\left(\frac{\text{c}}{d}\text{x}100\right) + \text{RBa}\left(\frac{\text{e}}{f}\text{x}100\right)$$

Where:

a = species frequency

b = sum of all species frequencies

c = number of individuals of a species

d = total number of individual species

e = basal area of a species

f = total basal area of all species

While the dominant species was determined as the species with the highest IVI value, the dominant family was determined as the sum of IVI values of all the species belonging to a particular family (Mueller-Dombois and Ellenberg, 1974; Demisse, 2006; Asteggiano, 2008).

Woody Structure: Woody species structure in this study was determined by measuring 3 parameters; these are vertical, horizontal and quantitative structures (Kershaw, 1973). In this study, the vertical structure was obtained by measuring tree height using Haga's Altimeter; the horizontal structure was obtained by measuring the trees' diameter at breast height (1.3m above the ground) using a diameter tape, while the quantitative structure was obtained by computing the species density per hectare. Species basal area was on the other hand obtained as:

$BA = (^1/_2 d)^2 \times \Pi$

Where:

BA = Basal Area

D = Tree Diameter

$\Pi = 3.142$ (constant)

Woody Biomass: Woody biomass is explained as the amount of organic matter or plant tissue, found at a particular time and place. Species biomass was determined based on a regression equation developed by Brown *et al*, (1989) and modified by FAO (1997) for calculating tree biomass in dry climates. The equation is given as:

Y = exp {-1.996+2.32*ln(D)}

Where:

Y = Biomass per tree (kg),

exp = e – (the base of natural logarithms), raised to the power of (…)

ln (D) = Natural log of Diameter at breast height

Woody Species Diversity: Species diversity refers to the number of different species in a particular area (Redowan, 2010). In determining the species diversity across the study area, the Shannon Wiener's Index (H) was used. The Shannon-Wiener index combines both species abundance and richness and is usually found to fall between 1.5 and 3.5 and is rarely above 5.0 (Magurran, 2004 cited in Patrice *et al*, 2007). The Shannon Weiner's Index is given as:

$$H = -\sum_{i=1}^{k} pi \log pi$$

Where:

K = Number of species,

pi = number of individual species

4.4 STATISTICAL ANALYSIS OF DATA

Both descriptive and inferential statistics were employed in this study. The descriptive statistics was employed for summarization of collected data generally where the data was summarized in means and standard deviation. Inferential statistics on the other hand were employed to test the relationship among vegetation parameters and to also test the hypothesis that there are no

significant differences in the character of the woody biodiversity over the different land use types. In this regard, the F- ratio Analysis of Variance (ANOVA) and the Duncan Multiple Range Test (DMRT) were used to test for the spatial variability of woody species and their characteristics across the different land use types. All analyses were performed using the SPSS statistics (version 17.0). All statistical tests were tested at the 0.05 probability level.

CHAPTER FIVE

RESULTS AND DISCUSSION

5.1 LAND USE PATTERN

Table 5.1 summarizes the aggregate land use/land cover statistics while figure 5.1 shows the land use pattern in the study area. Information collected from ground truthing was used to analyze and summarize the land use pattern as well as the land cover of the area. The study area, covering some 32km^2, comprises of 7 major land use types. These are farmland, rocky area, scrubland, savannah woodland, bare ground, built-up area and wetland. Farmland or agricultural land use, which occupies 35% of the study area, is the dominant land use type. This is followed by rocky area and scrubland, which account for 15.3% and 12.8% of the area, respectively. Savannah woodland, bare ground and the built-up area account for 11.9%, 11.3% and 10% of the area, respectively. The least land use type in the study area is wetland, which accounts for only 3.8% of the area.

Table 5.1: Statistics of Land use Pattern of the study area

S/N	Land use/Land cover	COVERAGE (KM^2)	% COVERAGE
1.	Farmland	11.2	35.0
2.	Rocky Area	4.9	15.3
3.	Scrubland	4.1	12.8
4.	Savannah Woodland	3.8	11.9
5.	Bare Ground	3.6	11.3
6.	Built-up Area	3.2	10.0
7.	Wetlands/Water	1.2	3.8
		32.0	**100**

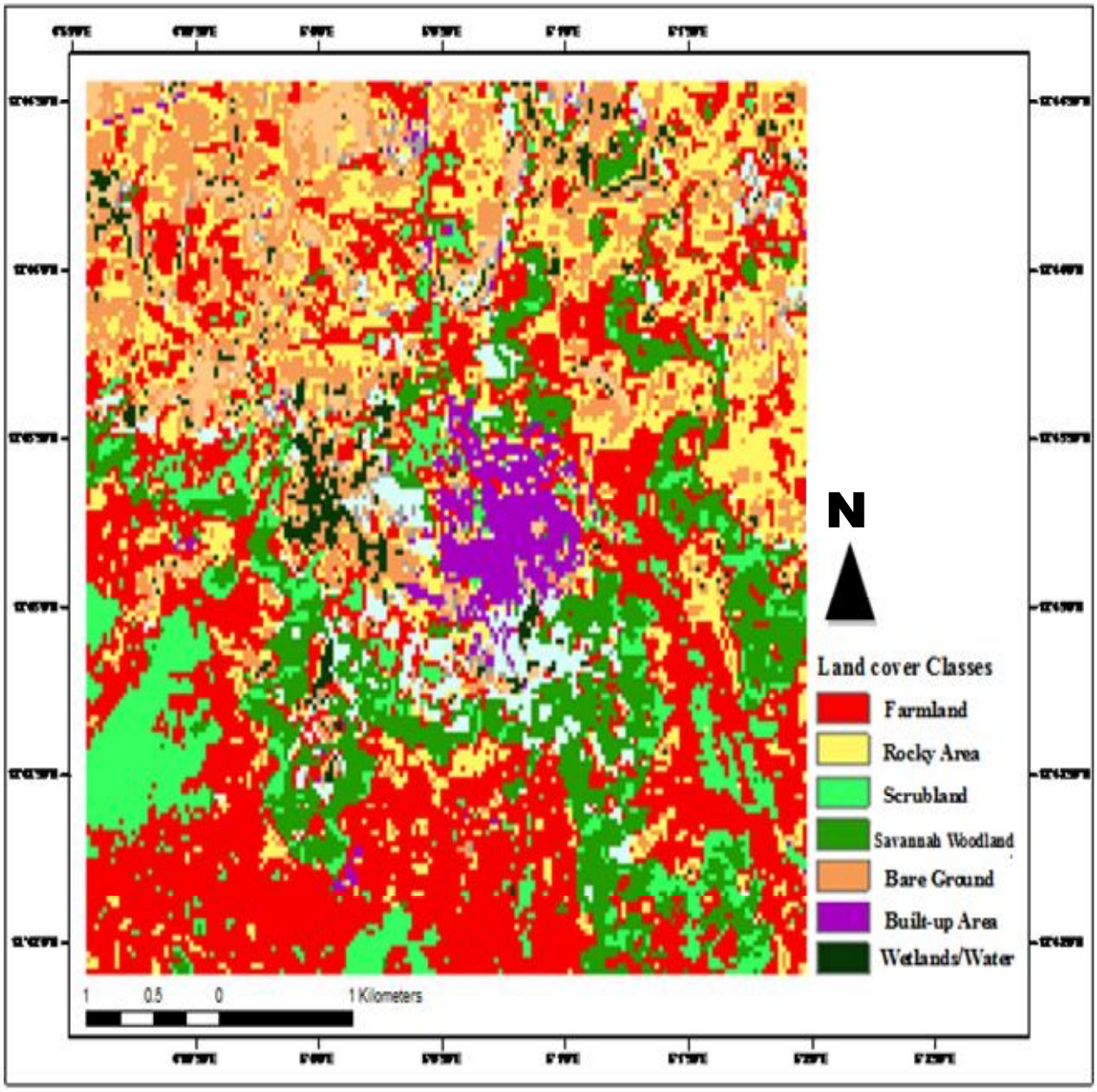


Figure 5.1: Land use Pattern of the Study Area

5.1.1 Farmland

Farmland is regarded for the purpose of this study as an area of land that is permanently dedicated to cultivation of rain fed crops. The distribution of the farmland, and intensity of use, is governed by two main factors; proximity to settlement and topography. The main farming areas are on the more undulating terrains located on the foot slope of the hill ranges and on floodplain around settlement and along major road attires. By contrast, there are little farming activities on the boulder stewed slopes and plateau of the hill ranges. The rain fed farming system in the area can be described as bush fallow. In earlier times, it may well have been a true system of shifting agriculture but as population densities increased and the need to be close to the main road, the population probably becomes increasingly reluctant to move their villages as shifting system would almost certainly require.

The vegetation community of the farmlands consists of a peculiar non-natural vegetation type. It consists of remarkably uniform immature trees of economic value that are scattered throughout a mosaic of cultivated fields and short-term fallows covered with mostly annual grasses, otherwise regarded as weeds (Plate 5.1). Such grasses may include *Rhynchelytrum repens, Panicum kerstingii, Setaria pallide-fusca, Aristida sp.* and *Hackelochloa granularia.* Although the community is a direct result of human activities, the trees are largely indigenous and represent either the few surviving species of once-dense tree savannah woodland, which formally covered the whole area, or trees deliberately planted by man. The community is a biotic climax (plagio-climax), stable whilst cultivation continues. Prominent among such trees are *Parkia biglobosa, Azadirachta indica, Piliostigma reticulatum, Senna Sieberiana, Vitex doniana, Lannea microcarpa and Rogeria adenophylla*.



Plate 5.1: Typical Farmland in the study area

Like in most developing countries and especially the savannah regions, agricultural land use predominate all other land use types. Similarly, the study area is devoid of industries, large water bodies, natural forests, plantations or recreational areas that may have reduced the size of the farmlands. The vast landscape therefore cannot be put to any better use but agriculture, hence the prominence of farmlands.

5.1.2 Rocky Area

Overlying much of the hill crests and plateaus is a layer of indurated lateritic materials or stones rubbles (Plate 5.2). Such layers appear at the surface as capping to small hills and as miniature escarpments.



Plate 5.2: Typical Rocky Area in the study area

Vegetation cover of rocky areas consists of few woody species most of which are short, thin and widely spaced. The dominant species in this land use type are *Guiera senegalensis, Azadirachta indica, Senna Sieberiana and Acacia Sieberiana.*

5.1.3 Scrubland

This community has evolved from the system of bush fallowing practiced in the area (Plate 5.3). Here, the interval between successive crops is long enough to allow shrubby coppice and sucker regeneration to take place from stumps and rootstocks that have not yet been eliminated by cultivation. It is in this zone that the farming system is in transition from haphazard bush fallowing to fixed cultivation. Fallow trees and shrubs of this zone include *Gueira senegalensis* and *Combretum micranthum.* The grasses and forbs include *Andropogon gayanus, Digitaria diagonalis, Eragrostis aspera, E. tremula, Hyperthelia dissolista, Hyperrhenia violascens, and Imperata cylindria.*

Green pastures and grasslands are important for livestock (animal) farming in the Savannah. Intensive fodders, feedlots and equipped grasslands are not available. Animals are moved from place to place in search of greener pastures virtually every day. Pure grassland represents a degraded land cover class. When shrubs and woodland lost their stability and resilience, they transform into pure grasslands. They have stunted grasses and they provide temporary grazing lands. Over the years, the scrubland in many areas have transformed into grassland. Literally, increase in the area of grassland translates into increased grazing lands for animals, but by implication, it implies increased desiccation of former wood and shrub lands of the Guinea and lower Sudan zone of the area.



Plate 5.3: Typical Scrubland Vegetation in the study area

5.1.4 Savannah Woodland

The vegetation here includes such remnants of the climax as have survived modifications imposed by recurrent annual fires and light to moderate bush fallowing, and animal grazing (Plate 5.4). The dominant woody species include *Combretum micranthum, Azadirachta indica, Mimosa pigra, Senna Sieberiana, Gueira senegalensis* and *Acacia macrostchya*

The savannah wood land is the only vegetation type that is close to natural vegetation as human activities have modified in one form or the other most available vegetation and landscape. In these

areas, there is relatively a high population of plants species and predominance of woody vegetation. These areas are neither farmland nor are they rocky in nature. They are found to account for 11.9% of the study area.

The savannah woodland together with the scrubland are to a large extent the repositories of natural resources. However, these are also the areas where much human exploitation of especially woody species takes place. These are areas from where much of the energy for cooking in the area comes from. Thus, the quality, stocking condition and productivity of the areas continue to deteriorate.



Plate 5.4: Typical Savannah Woodland in the study area

5.1.5 Bare Ground

Bare grounds are areas that have few or no vegetation, though they may be dotted by occasional trees or shrubs (Plate 5.5). Dominant woody species in these areas include *Acacia nilotica, Acacia Sieberiana,* and *Calotropis procera.*. The community represents an incontrovertible evidence of increased desiccation of land ecosystems in the study area. They comprise of open excavation and mine pits, and erosion surfaces.



Plate 5.5: Typical Bare Ground over the study area

5.1.6 Built-up Area

Built-up areas or urban lands indicate settlements, both in urban and rural areas, that are large enough to be mapped based on the minimum mapping scale adopted for the exercise. *Azadirachta indica* is the main woody species found in the built-up area (Plate 5.6). This land use type typically has the biggest woody species because of protection against exploitation.



Plate 5.6: *Azadirachta indica* in Built-up Area

5.1.7 Wetlands and Water Bodies

Wetlands are areas of marshes, fern, peatland or water, whether natural or artificial, permanent or temporary. Deeper, heavy flood plain soils which are subject to periodic moisture extremes for some three to four months support characteristic grassy vegetation. The morphology of the grasses varies with the water depth and soil condition, but composed of various combinations of species, including *Echinchloa spp, Andropogon gayanus* and *Mimosa asperata*. The grassland seldom supports woody vegetation. If they do, they tend to carry a scattered population of *Mangifera indica, Psidium guajava* and *Moringa oleifera* though *Azadirachta indica, Mitragyna inermis,* locally mingled with *Terminalia macroptera* (Plate 5.7). Similarly, over clayey soil, where drainage is severely impeded, the surface is frequently bare of herbaceous vegetation or may be occupied by widely scattered plants of *Cissus spp.,* or a low growth of annual grasses and herbs, or a mixture of both. If perennial bunch grasses are present, they are often found in very shallow, seasonally flooded basins and are perched on individual mounds or turrets of muddy soil up to about 15cm high.

The sustainable utilization of wetlands in the sub region is very much desirable. Over the years, wetlands in the study area have come under intense and often unsustainable human pressure and utilization for agriculture and grazing. Competition for available limited resources in the areas has often resulted in frequent conflicts among different users. Increase in irrigation and floodplain agriculture as well as water impoundments to compensate for loss of prime agricultural lands and water sources due to natural occurrences is leading to loss of natural wetlands.



Plate 5.7: *Mangifera indica* in Wetlands

5.2 VARIATION OF WOODY BIODIVERSITY

5.2.1 Composition and Distribution

A total of 671 individual stands of woody species were identified and enumerated in the area. These belong to 40 species, 35 genera and 21 families. The composition of the species revealed that *Azadirachta indica, Balanites Aegyptiaca, Senna Sieberiana, Combretum micranthum, Guiera senegalensis, Mimosa pigra, Parkia biglobosa and Piliostigma reticulatum* which together account for about 67.2% of the species are the most dominant (Table 5.2). The remaining 32 species account for 32.8%. The variability in the frequency and dominance of species in the study area may not be unconnected with the species level of adaptability to the environment, their relative tolerance to disturbance, as well as water, nutrient and/or other environmental requirements. The most dominant families on the other hand are *Anacardiaceae, Balanitiaceae, Caesalpiniaceae, Combretaceae, Fabaceae, Leguminosae* and *Melieceae*.

Table 5.2: Floristic Composition of Woody Species over the Study Area

S/N	Species	Genus	Family	Local Name		
					Total	%
1	*Acacia macrostachya*	*Acacia*	*Fabaceae*	Gardaye	24	3.6
2	*Acacia nilotica*	*Acacia*	*Fabaceae*	Bagaruwa	5	0.7
3	*Acacia Sieberiana*	*Acacia*	*Fabaceae*	Farar Kaya	8	1.2
4	*Anogeissus leiocarpus*	*Anogeissus*	*Combretaceae*	Marke	1	0.1
5	*Aristida mutabilis*	*Aristida*	*Poacaea*	Dashi	1	0.1
6	*Azadirachta indica*	*Azadirachta*	*Meliaceae*	Dogon Yaro	95	14.2
7	*Balanites Aegyptiaca*	*Balanites*	*Balanitiaceae*	Aduwa	21	3.1
8	*Boscia angustifolia*	*Boscia*	*Capparidiaceae*	Anza	12	1.8
9	*Cadaba farinosa*	*Cadaba*	*Capparaceae*	Bagaye	1	0.1
10	*Calotropis procera*	*Calotropis*	*Apocynaceae*	Tunfafiya	3	0.4
11	*Senna Sieberiana*	*Senna*	*Fabaceae*	Malga	82	12.2
12	*Ceiba pentandra*	*Ceiba*	*Malvaceae*	Rini	1	0.1
13	*Combretum ghasalense*	*Combretum*	*Combretaceae*	Taramniya	2	0.3
14	*Combretum micranthum*	*Combretum*	*Combretaceae*	Geza	71	10.6
15	*Combretum nigricans*	*Combretum*	*Combretaceae*	Tsiriri	1	0.1
16	*Cordia africana*	*Cordia*	*Fabaceae*	Alilliba	1	0.1
17	*Delonix regia*	*Delonix*	*Fabaceae*	Dorowar Turawa	9	1.3
18	*Detarium microcarpum*	*Detarium*	*Caesalpiniaceae*	Taura	6	0.9
19	*Diospyros mesipiliformis*	*Diospyros*	*Ebenacea*	Kaiwa	1	0.1
20	*Eucalyptus oblique*	*Eucalyptus*	*Myrtaceae*	Zaiti	2	0.3
21	*Faidherbia albida*	*Faidherbia*	*Fabaceae*	Gawo	2	0.3
22	*Ficus vallis-choudae*	*Ficus*	*Moraceae*	Balgomi	8	1.2
23	*Gardenia erubescens*	*Gardenia*	*Rubiaceae*	Gaude	3	0.4
24	*Guiera senegalensis*	*Guiera*	*Combretaceae*	Sabara	84	12.5
25	*Khaya senegalensis*	*Khaya*	*Meliaceae*	Madacci	2	0.3
26	*Lannea microcarpa*	*Lannea*	*Meliaceae*	Faru	20	3.0
27	*Lawsonia inermis*	*Lawsonia*	*Rubiaceae*	Lalle	17	2.5
28	*Maerua crassifolia*	*Maerua*	*Capparaceae*	Jirga	3	0.4
29	*Mangifera indica*	*Mangifera*	*Anacardiaceae*	Mangoro	17	2.5
30	*Mimosa pigra*	*Mimosa*	*Fabaceae*	Gumbi	51	7.6
31	*Moringa oleifera*	*Moringa*	*Moringaceae*	Zogale	6	0.9
32	*Parkia biglobosa*	*Parkia*	*Leguminosae*	Dorowa	17	2.5
33	*Piliostigma reticulatum*	*Piliostigma*	*Caesalpiniaceae*	Kalgo	30	4.5
34	*Prosopsis africana*	*Prosopsis*	*Fabaceae*	Kirya	2	0.3
35	*Psidium guajava*	*Psidium*	*Myrtaceae*	Gwaiba	11	1.6
36	*Rogeria adenophylla*	*Rogeria*	*Pedaliaceae*	Loda	11	1.6
37	*Tamarindus indica*	*Tamarindus*	*Fabaceae*	Tsamiya	1	0.1
38	*Vitex doniana*	*Vitex*	*Verbenaceae*	Dunya	11	1.6
39	*Ximenia americana*	*Ximenia*	*Olacaceae*	Tsada	9	1.3
40	*Ziziphus abyssinica*	*Ziziphus*	*Rhamnaceae*	Magarya	19	2.8
					671	100.0

The distribution of the species in relation to land use type is presented in figure 5.2 and appendix III. The species composition varies considerably over the different land use types. However, the highest number of individual stands was recorded in the savannah woodland (271). This was followed by farmland and scrubland, which have 137 and 113 woody stands respectively. The lowest number of individual stands was recorded over the built-up area and bare ground, which have15 and 24 stands respectively. The values for wetlands and Rocky area are intermediate, that is 57 and 54 stands respectively. While only *Azadirachta indica* was found in all the 7 land use types, 17 species, which include *Anogeissus leiocarpus, Aristida mutabilis, Cadaba farinosa, Calotropis procera, Ceiba pentandra, Combretum ghasalense, Combretum nigricans, Cordia africana, Delonix regia, Diospyros mesipiliformis, Eucalyptus oblique, Faidherbia albida, Gardenia erubescens, Khaya senegalensis, Moringa oleifera, Psidium guajava,* and *Tamarindus indica* were only found in one land use type each.

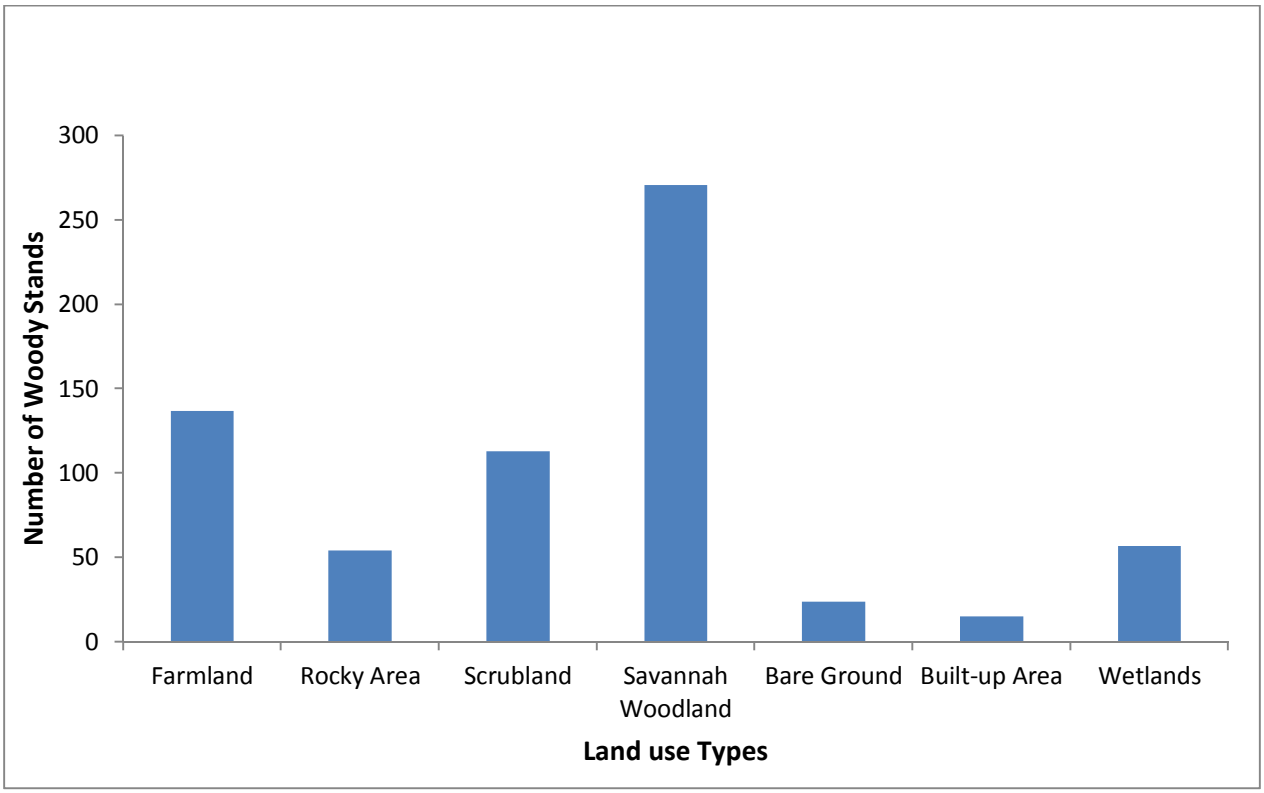


Figure 5.2: Distribution of Woody Stands

5.2.2 Species Frequency and Dominance

Analysis of species frequency (Figure 5.3 and Appendix IV) revealed some level of variability across the study area. Species with the highest frequency are *Azadirachta indica* (54%), *Senna Sieberiana* (44%) and *Guiera senegalensis* (32%). Those with the least frequency on the other hand are *Anogeissus leiocarpus, Aristida mutabilis, Cadaba farinosa, Ceiba pentandra, Combretum ghasalense, Combretum nigricans, Cordia africana, Eucalyptus oblique, Faidherbia albida, Khaya senegalensis, Tamarindus indica,* each of which has a frequency of 2%. *Acacia Sieberiana, Gardenia erubescens, Maerua crassifolia, Moringa oleifera, Prosopsis africana* and *Psidium guajava* each has a frequency of 4%. The variability in the composition, distribution and frequency of species recorded over the land use types may be explained in terms of species resilience, their usability, as well as variability in environmental factors. *Senna Sieberiana*, *Guiera senegalensis* and *Azadirachta indica,* for example, are known to have high tolerance to environmental stress and disturbance as well as high regenerative capacity (FACT net, 1997). These species appeared in more sample plots and are therefore more frequent than all others.

Species that have the lowest frequencies fall into two categories. The first category comprises of those species which have their distribution and frequency being to some extent determined by environmental conditions that are more favorable to them. In this wise, while *Moringa oleifera* and *Psidium guajava* that do better in moist environments were found in the wetlands only, *Acacia Sieberiana* that does better in dryer areas was mostly found in the bare ground. For this reason, the frequency of these species is low. The second category of low frequency species are those that are used for fuel wood, as animal feed or in the preparation of herbal medicines. Anthropogenic pressure on species such as *Anogeissus leiocarpus, Aristida mutabilis, Cadaba farinosa, Ceiba*

pentandra, Combretum ghasalense, Combretum nigricans, Delonix regia Faidherbia albida, Khaya senegalensis and *Tamarindus indica* is very high in the area which account for their low frequency. Similarly, sample plots that are close to human settlements are usually more prone to exploitation and as such, more disturbed than those relatively far away. On farmlands on the other hand, most trees found were those with economic values.

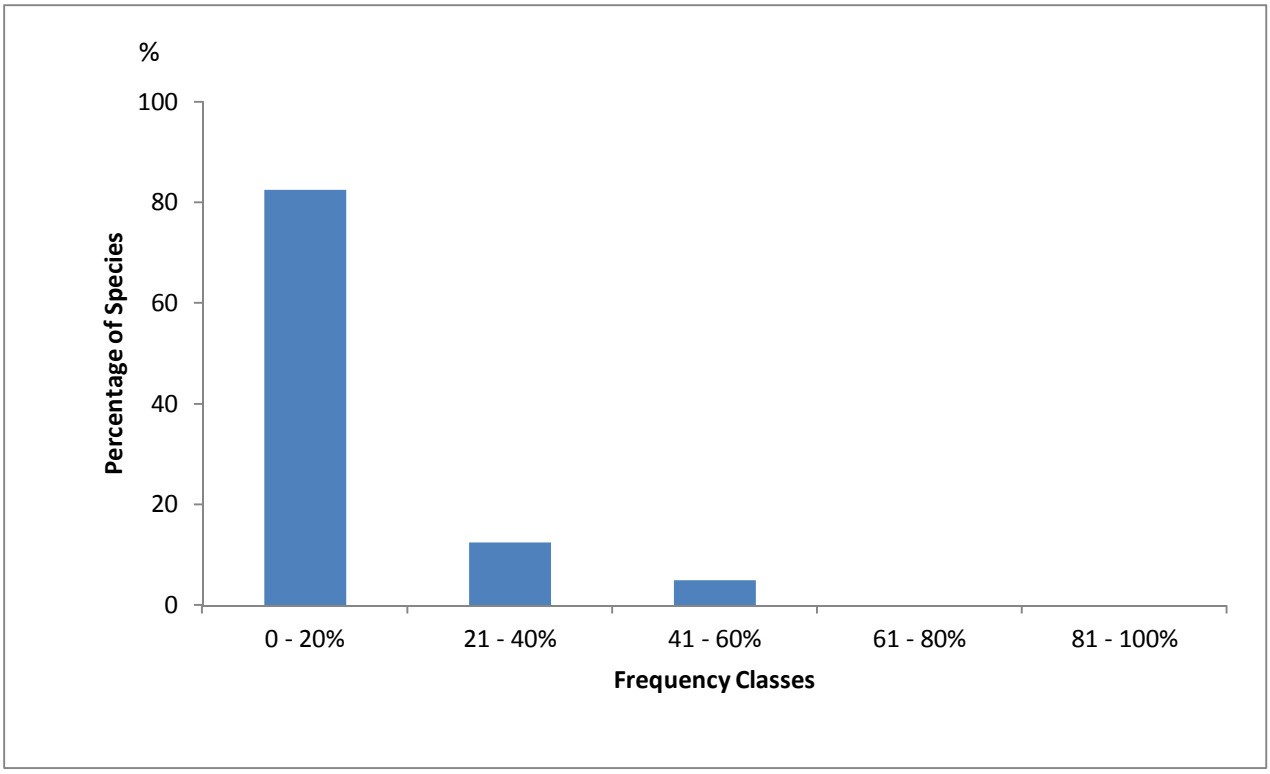


Figure 5.3: Species Frequency Distribution

The species frequency (Figure 5.3) distribution was obtained by grouping the species into 5 classes – A (1 – 20%), B (21 – 40%), C (41 – 60%), D (61 – 80%) and E (81 – 100%), based on their percentage occurrences (Demisse, 2006) and the result revealed a reversed J shape similar to the observation of Upadhaya *et al*, 2004; Patrice *et al* 2007 and Asteggiano, 2008). Class A has the highest number of individuals at 82.5%, and class B has 12.5% while class C accounts for only 5%. No species was recorded to have a frequency class of more than 60%.

Table 5.3: Species Importance Value Index

S/N	Species	Total	RF	RD	RBA	IVI (SD)
1	*Acacia macrostachya*	24	1.81	3.58	0.4	5.78
2	*Acacia nilotica*	5	1.36	0.75	0.21	2.31
3	*Acacia Sieberiana*	8	0.9	1.19	0.1	2.2
4	*Anogeissus leiocarpus*	1	0.45	0.15	0.33	0.94
5	*Aristida mutabilis*	1	0.45	0.15	0.01	0.61
6	*Azadirachta indica*	95	12.22	14.16	37.34	63.71
7	*Balanites Aegyptiaca*	21	5.88	3.13	3.82	12.83
8	*Boscia angustifolia*	12	4.52	1.79	0.47	6.78
9	*Cadaba farinosa*	1	0.45	0.15	0.12	0.72
10	*Calotropis procera*	3	1.36	0.45	0.52	2.32
11	*Senna Sieberiana*	82	9.95	12.22	14.47	36.64
12	*Ceiba pentandra*	1	0.45	0.15	1.24	1.84
13	*Combretum ghasalense*	2	0.45	0.3	1.5	2.25
14	*Combretum micranthum*	71	5.88	10.58	1.18	17.65
15	*Combretum nigricans*	1	0.45	0.15	0.31	0.91
16	*Cordia africana*	1	0.45	0.15	0.15	0.75
17	*Delonix regia*	9	0.45	1.34	1.91	3.7
18	*Detarium microcarpum*	6	1.81	0.89	1.15	3.85
19	*Diospyros mesipiliformis*	1	0.45	0.15	0.42	1.03
20	*Eucalyptus oblique*	2	0.45	0.3	0.39	1.14
21	*Faidherbia albida*	2	0.45	0.3	1.56	2.31
22	*Ficus vallis-choudae*	8	2.26	1.19	0.33	3.79
23	*Gardenia erubescens*	3	0.9	0.45	0.03	1.38
24	*Guiera senegalensis*	84	7.24	12.52	0.75	20.51
25	*Khaya senegalensis*	2	0.45	0.3	0.27	1.02
26	*Lannea microcarpa*	20	6.33	2.98	0.27	9.58
27	*Lawsonia inermis*	17	1.81	2.53	0.35	4.69
28	*Maerua crassifolia*	3	0.9	0.45	0.18	1.53
29	*Mangifera indica*	17	1.81	2.53	5.45	9.79
30	*Mimosa Pigra*	51	4.52	7.6	1.53	13.65
31	*Moringa oleifera*	6	0.9	0.89	0.08	1.88
32	*Parkia biglobosa*	17	4.52	2.53	8.86	15.92
33	*Piliostigma reticulatum*	30	6.79	4.47	4.85	16.11
34	*Prosopsis africana*	2	0.9	0.3	1.06	2.26
35	*Psidium guajava*	11	0.9	1.64	0.16	2.71
36	*Rogeria adenophylla*	11	2.26	1.64	1.22	5.12
37	*Tamarindus indica*	1	0.45	0.15	0.26	0.87
38	*Vitex doniana*	11	1.36	1.64	2.31	5.31
39	*Ximenia americana*	9	1.81	1.34	0.13	3.28
40	*Ziziphus abyssinica*	19	3.17	2.83	4.29	10.29
		671	100	100	100	300

RF = Relative Frequency: RD = Relative Density: RBA = Relative Basal Area:
IVI = Importance Value Index: SD = Species Dominance

Table 5.3 presents the analysis of species dominance which was determined by calculating the Importance Value Index. In using the importance value index, higher values indicate more dominance of a particular species at a particular site (Koonkhunthod *et al,* 2007).

Overall, 8 species were found to be the most dominant in the study area. Of these *Azadirachta indica* was the most dominant. It has the highest relative frequency, highest relative density and highest relative basal area and as such, highest importance value of 63.71. It was followed by *Senna Sieberiana*, which has a relative frequency value of 9.95, relative density of 12.22 and a relative basal area of 14.47; thus a total importance value of 36.64. *Guiera senegalensis* was the third most dominant species in the study area with an importance value of 20.51 followed by *Combretum micranthum* with an importance value of 17.65. Others are *Piliostigma reticulatum, Parkia biglobosa, Mimosa Pigra* and *Balanites Aegyptiaca* with importance values of 16.11, 15.92, 13.65 and 12.83 respectively.

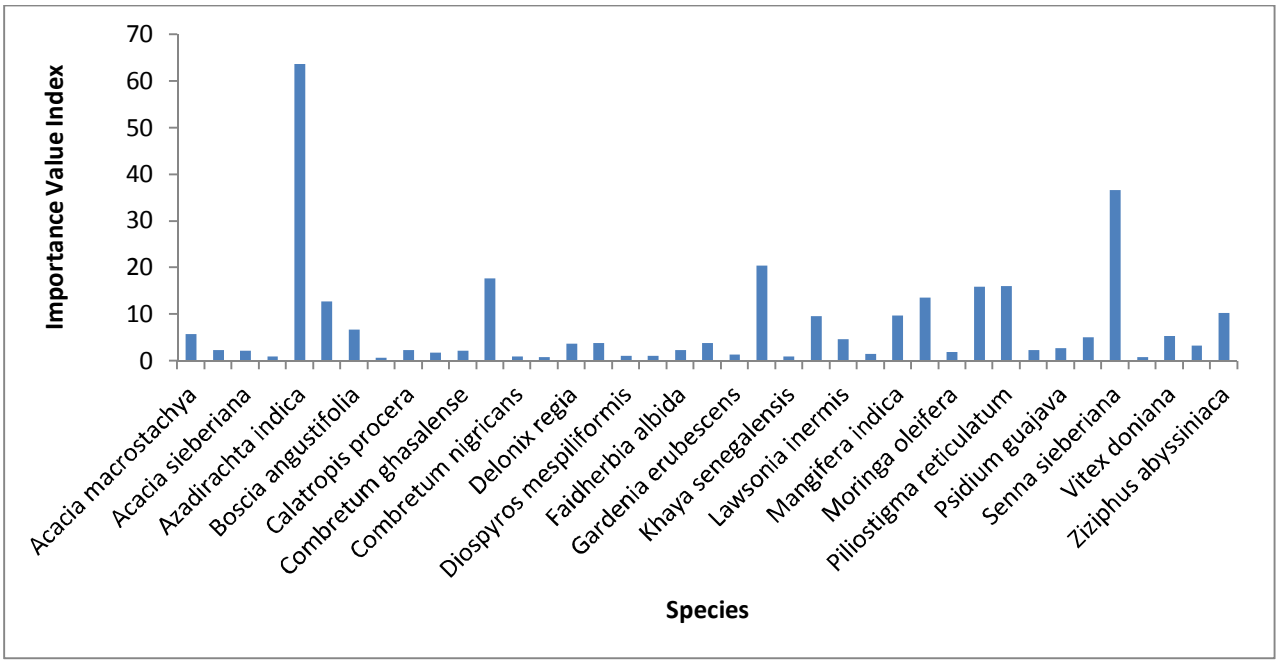


Figure 5.4: Species Dominance

The dominance of *Azadirachta indica* or neem tree as it is otherwise called may be partly explained by the fact that the species was widely propagated in the Northern region by the Government through the Northern Nigeria Forestry Department in the 1950's for wood supply and wind breaking purposes (Usman and Adefalu, 2010). The species adapts to a broad range of climate and soil conditions, it tolerates extremely high temperatures and it is highly drought tolerant (FACT net, 1997). *Senna Sieberiana* on the other hand has higher propagation capacity and tolerability; *Parkia biglobosa* enjoys some protection as an economic tree in the farms while *Mimosa pigra* and *Balanites aegyptiaca* are both thorny and hard. They are therefore neither good as sources of fuel wood nor are they good as animal fodder. Human and animal pressure on these species is relatively low and hence, their dominance in the study area.

Table 5.4: Family Frequency and Dominance of Woody Species over the Study Area

SN	Family	Family Frequency (%)	Family Dominance
1	*Anacardiaceae*	34	43.6
2	*Apocynaceae*	6	4.1
3	*Balanitiaceae*	24	30.5
4	*Caesalpiniaceae*	34	48.0
5	*Capparaceae*	6	2.4
6	*Capparidiaceae*	20	3.8
7	*Combretaceae*	30	26.6
8	*Ebenacea*	2	3.4
9	*Fabaceae*	58	297.6
10	*Leguminosae*	22	71.0
11	*Malvaceae*	2	9.9
12	*Meliaceae*	52	407.0
13	*Moraceae*	10	2.7
14	*Moringaceae*	4	0.7
15	*Myrtaceae*	6	4.4
16	*Olacaceae*	3	6.0
17	*Pedaliaceae*	10	9.8
18	*Poacaea*	2	0.1
19	*Rhamnaceae*	5	10.0
20	*Rubiaceae*	4	0.2
21	*Verbenaceae*	6	35.0

Table 5.4 shows the family frequency and dominance in the study area. The Family frequency was obtained by calculating the proportion of sample plots in which a particular family occurred, while the family dominance was obtained by summing up the dominance values of all species that belong to the same family. Although the family *Fabaceae* had a higher family frequency of 58%, *meliaceae* has the highest dominance value of 407.0 and is therefore the most dominant family. Other dominant families include *Leguminosae, Caesalpiniaceae* and *Anacardiaceae* with family dominance of 71.0, 48.0 and 43.6 respectively. The least families in order of dominance are *Poacaea, Rubiaceae* and *Moringaceae* which have dominance values of 0.1, 0.2 and 0.7 respectively.

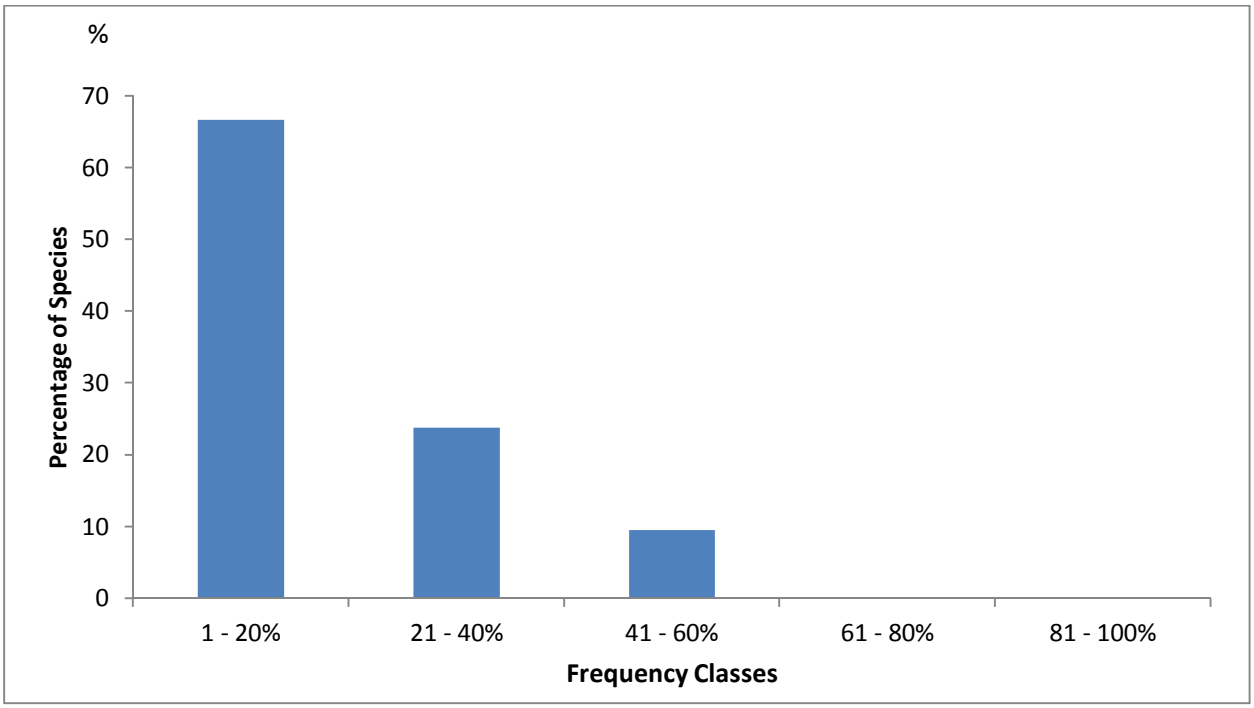


Figure 5.5: Family Frequency Distribution

Figure 5.5 shows the family frequency distribution. The frequencies were grouped A (1 – 20%), B (21 – 40%), C (41 – 60%), D (61 – 80%) and E (81 – 100%) according to their percentage occurrence to determine their distributions. Family frequency class A has the highest number of

individuals and accounts for 65% of the total species; family frequency B accounts for 20% while Family frequency class C accounts for only 10%.

5.2.3 Woody Species Structure

Vertical, horizontal and quantitative structures of woody species in this study were established based on the species height, diameter, basal area and density as obtained from the detail field survey (APPENDIX V). With respect to height, the tallest species is *Ceiba pentandra* which has a mean height of 24.9m. This is followed by *Eucalyptus oblique* (17.5m), *Faidherbia albida* (15.1m) and *Diospyros mesipiliformis* (14m). The shortest species on the other hand are *Aristida mutabilis* (6.0m), *Boscia angustifolia* and *Pteleopsis habeensis* (5.9m each), *Guiera senegalensis* (5.8m) and *Gardenia erubescens* (5.3m).

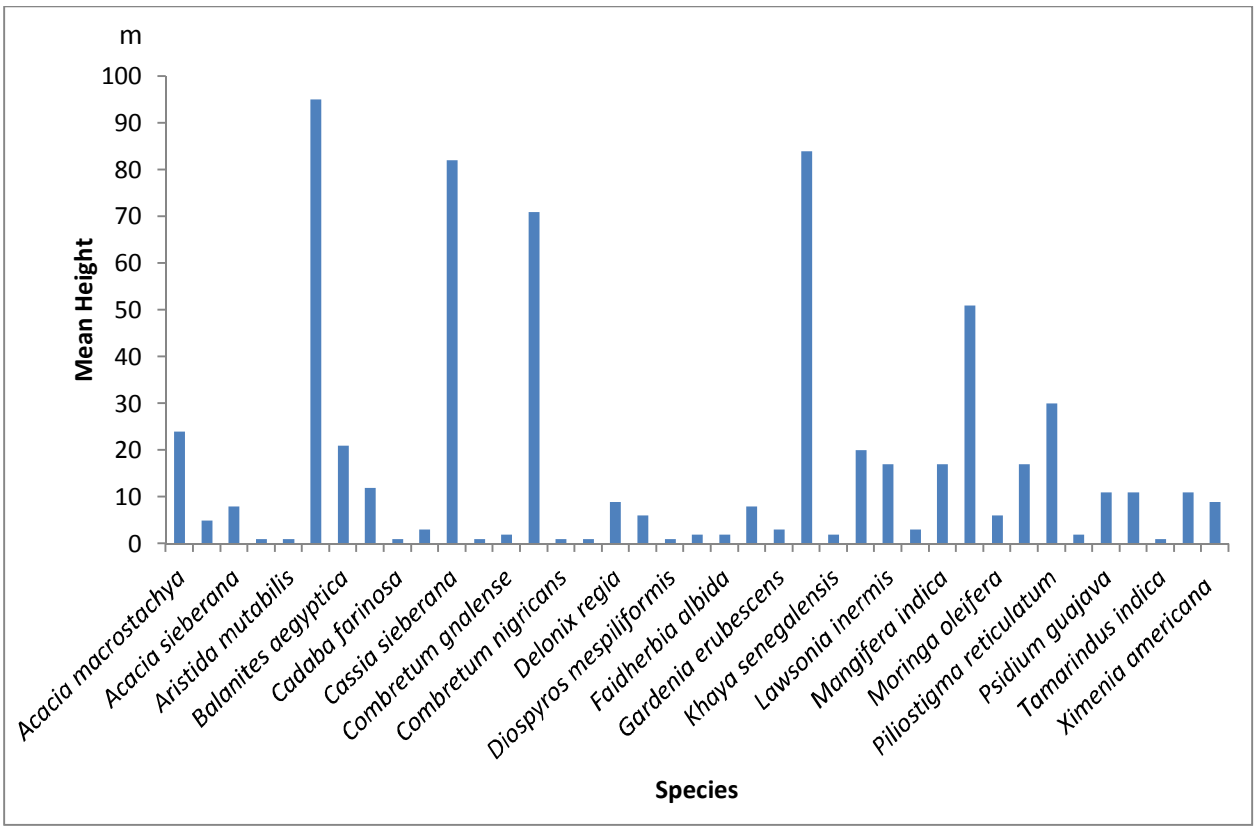


Figure 5.6: Mean Height of Woody Species

To analyze the vertical structure and stratification of woody species in the study area, species height was categorized into three classes – higher class with an average height of more than 15m, middle class with an average height of between 8m – 15m and the lower class of less than or equal to 8m high (Upadhaya *et al,* 2004). Species with a mean height of less than 8m are hereafter referred to as shrubs and small trees, those with a mean height of between 8m – 10m are the juvenile trees that are yet to reach maturity while those with a mean height of more than 15m are the full grown, matured trees. The study area comprises of 7.5% higher class, 50% middle class and 42.5% lower class species (Figure 5.7).

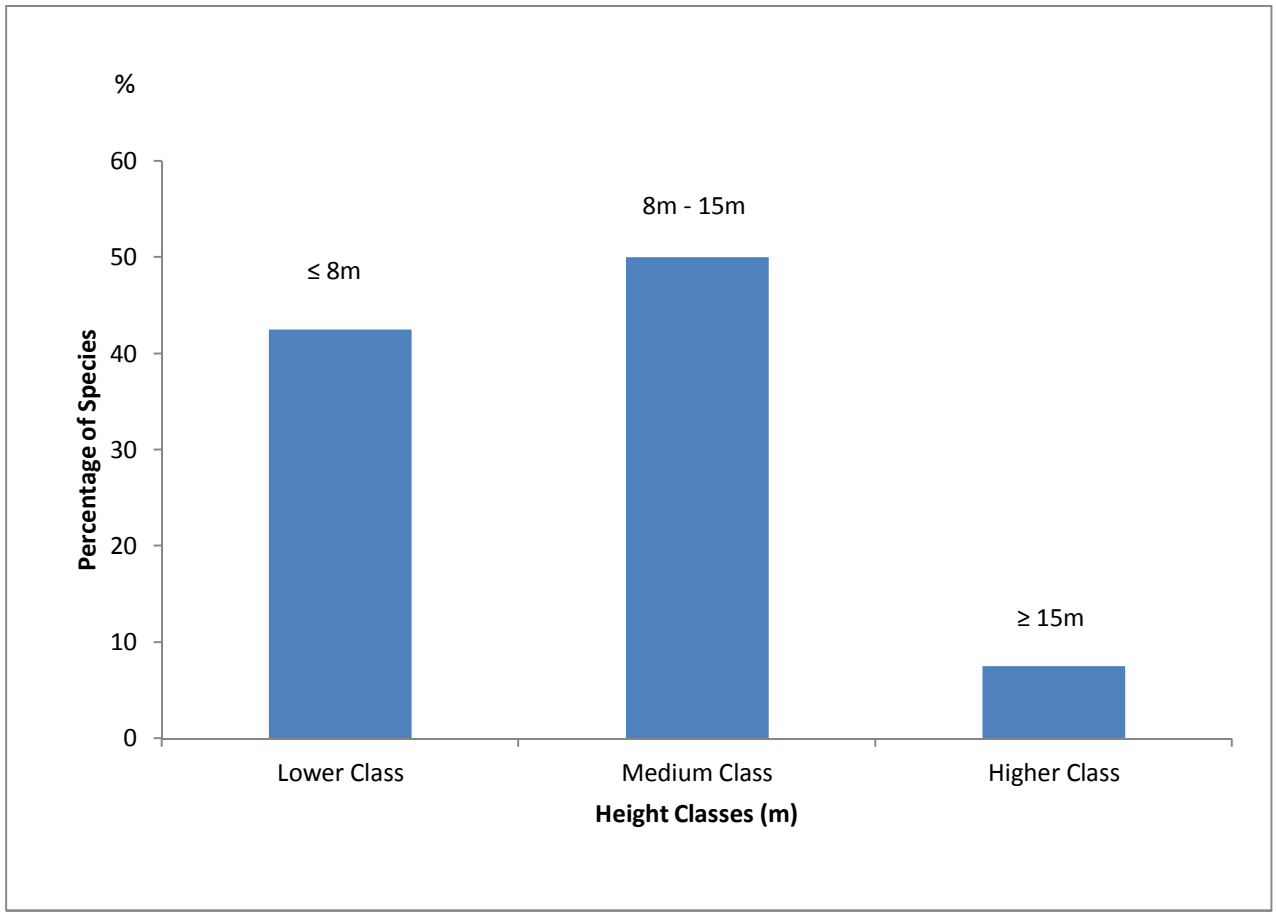


Figure 5.7: Vertical Structure of Woody Species

Analysis of the horizontal structure of species on the other hand shows that *Azadirachta indica* has the highest total DBH of 3789.2cm and highest total basal area of 162028.8cm^2. Therefore *Azadirachta indica* has the most outstanding horizontal structure in the study area and it is followed by *Senna Sieberiana* and *Parkia biglobosa*. *Senna Sieberiana* has a total DBH of 2130.8cm and total basal area of 62778.0cm^2 while *Parkia biglobosa* has a total DBH of 863.6cm and total basal area of 38465.8 cm^2. The species with the lowest DBH value (8.0cm) and lowest basal area (49.7 cm^2) on the other hand is *Aristida mutabilis*.

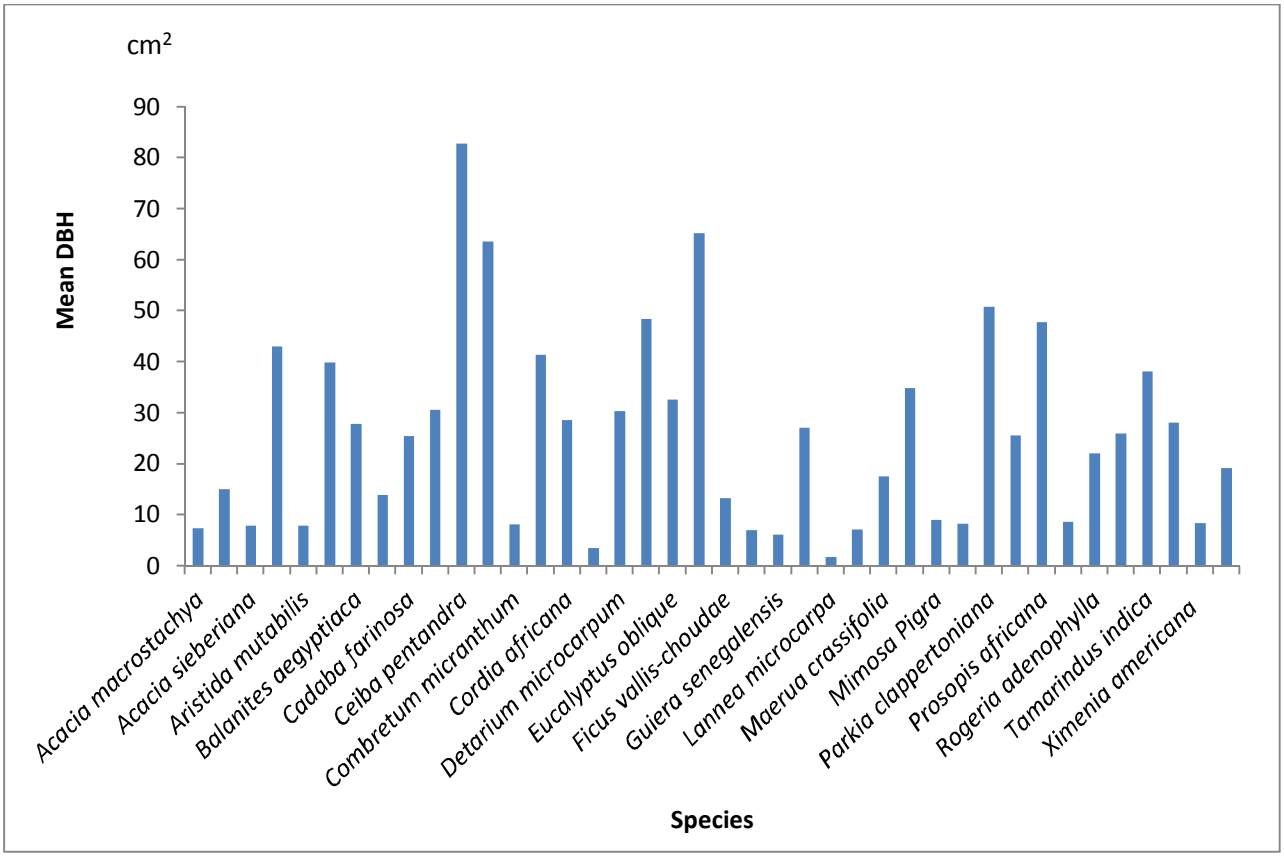


Figure 5.8: Variation of Mean Diameter at Breast Height

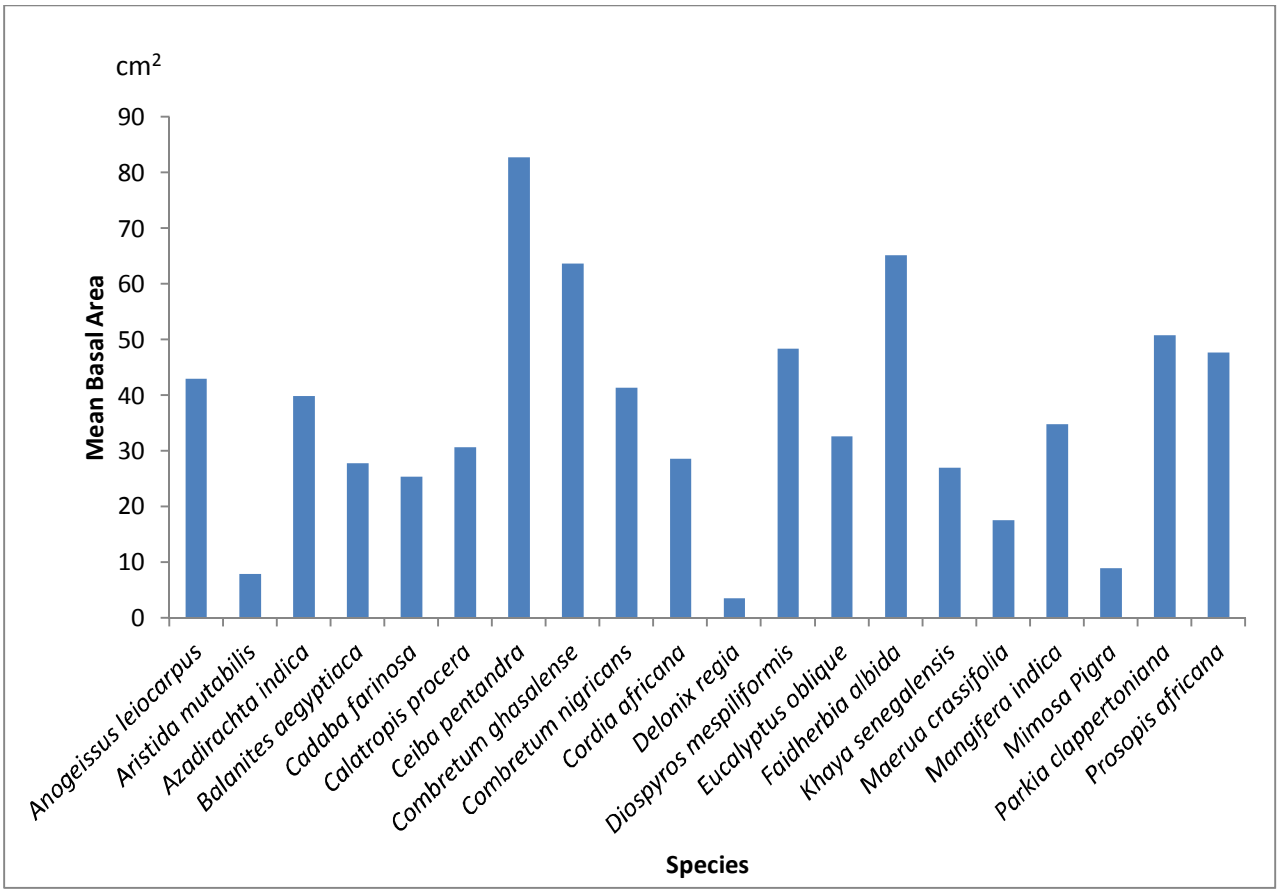


Figure 5.9: Variation of Mean Basal Area of Woody Species

To analyze the species horizontal structure, species were classified into 7 diameter classes: less than 10, 10-20, 21-30, 31-40, 41-50, 51-60, 61-70 and more than 70cm^2 diameter classes (Asteggiano, 2008). Figure 5.10 reveals that 32.5% of the species have a diameter of less than 10cm^2, 12.5% have a diameter of between 10cm^2 and 20cm^2, about 45% belong to 21cm^2- 50cm^2 while only about 10% have a diameter of more than 50cm^2.

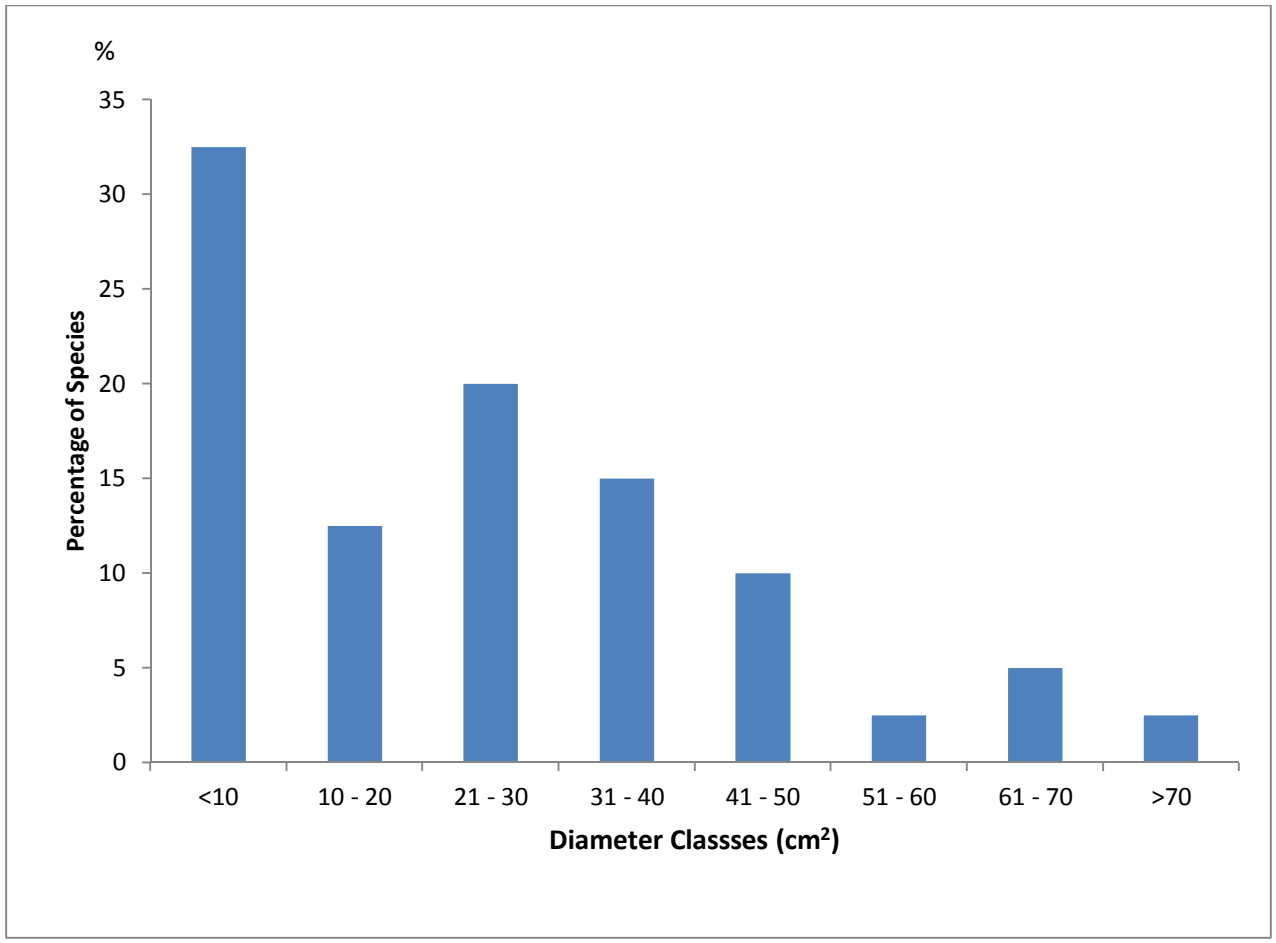


Figure 5.10: Horizontal Structure of Woody Species

The quantitative structure of species was determined by calculating specie's density per hectare. Species density is the number of individuals of a species in a given unit area, the value of which helps in determining the health of an ecosystem (ehow.com, 2012). In this study, species density was presented on per hectare basis (as obtained in Upadhaya *et al,* 2004; Demisse, 2006; Patrice *et al,* 2007 and Asteggiano, 2008).

Table 5.5: Per Hectare Stand Density of Woody Species

S/N	Species	Genus	Family	Local Name	Species Density Ha^{-}		
					Total	**D/Ha**	**RD**
1	*Acacia macrostachya*	*Acacia*	Fabaceae	Gardaye	24	96	3.58
2	*Acacia nilotica*	*Acacia*	Fabaceae	Bagaruwa	5	20	0.75
3	*Acacia Sieberiana*	*Acacia*	Fabaceae	Farar Kaya	8	32	1.19
4	*Anogeissus leiocarpus*	*Anogeissus*	Combretaceae	Marke	1	4	0.15
5	*Aristida mutabilis*	*Aristida*	Poacaea	Dashi	1	4	0.15
6	*Azadirachta indica*	*Azadirachta*	Meliaceae	Dogon Yaro	95	380	14.16
7	*Balanites Aegyptiaca*	*Balanites*	Balanitiaceae	Aduwa	21	84	3.13
8	*Boscia angustifolia*	*Boscia*	Capparidiaceae	Anza	12	48	1.79
9	*Cadaba farinosa*	*Cadaba*	Capparaceae	Bagaye	1	4	0.15
10	*Calotropis procera*	*Calotropis*	Apocynaceae	Tunfafiya	3	12	0.45
11	*Ceiba pentandra*	*Ceiba*	Malvaceae	Rini	1	4	0.15
12	*Combretum ghasalense*	*Combretum*	Combretaceae	Taramniya	2	8	0.30
13	*Combretum micranthum*	*Combretum*	Combretaceae	Geza	71	284	10.58
14	*Combretum nigricans*	*Combretum*	Combretaceae	Tsiriri	1	4	0.15
15	*Cordia africana*	*Cordia*	Fabaceae	Alilliba	1	4	0.15
16	*Delonix regia*	*Delonix*	Fabaceae	Dorowar Turawa	9	36	1.34
17	*Detarium microcarpum*	*Detarium*	Fabaceae	Taura	6	24	0.89
18	*Diospyros mesipiliformis*	*Diospyros*	Ebenacea	Kaiwa	1	4	0.15
19	*Eucalyptus obliqua*	*Eucalyptus*	Caesalpiniaceae	Zaiti	2	8	0.30
20	*Faidherbia albida*	*Faidherbia*	Myrtaceae	Gawo	2	8	0.30
21	*Ficus vallis-choudae*	*Ficus*	Fabaceae	Balgomi	8	32	1.19
22	*Gardenia erubescens*	*Gardenia*	Moraceae	Gaude	3	12	0.45
23	*Guiera senegalensis*	*Guiera*	Rubiaceae	Sabara	84	336	12.52
24	*Khaya senegalensis*	*Khaya*	Combretaceae	Madacci	2	8	0.30
25	*Lannea microcarpa*	*Lannea*	Anacardiaceae	Faru	20	80	2.98
26	*Lawsonia inermis*	*Lawsonia*	Rubiaceae	Lalle	17	68	2.53
27	*Maerua crassifolia*	*Maerua*	Meliaceae	Jirga	3	12	0.45
28	*Mangifera indica*	*Mangifera*	Capparaceae	Mangoro	17	68	2.53
29	*Mimosa pigra*	*Mimosa*	Anacardiaceae	Gumbi	51	204	7.60
30	*Moringa oleifera*	*Moringa*	Fabaceae	Zogale	6	24	0.89
31	*Parkia biglobosa*	*Parkia*	Fabaceae	Dorowa	17	68	2.53
32	*Piliostigma reticulatum*	*Piliostigma*	Leguminosae	Kalgo	30	120	4.47
33	*Prosopsis africana*	*Prosopsis*	Fabaceae	Kirya	2	8	0.30
34	*Psidium guajava*	*Psidium*	Myrtaceae	Gwaiba	11	44	1.64
35	*Rogeria adenophylla*	*Rogeria*	Pedaliaceae	Loda	11	44	1.64
36	*Senna Sieberiana*	*Senna*	Fabaceae	Malga	82	328	12.22
37	*Tamarindus indica*	*Tamarindus*	Fabaceae	Tsamiya	1	4	0.15
38	*Vitex doniana*	*Vitex*	Verbenaceae	Dunya	11	44	1.64
39	*Ximenia americana*	*Ximenia*	Olacaceae	Tsada	9	36	1.34
40	*Ziziphus abyssinica a*	*Ziziphus*	Rhamnaceae	Magarya	19	76	2.83
					671	2684	100.00

D/Ha^{-} = Density per Hectare: RD = Relative Density

The overall density of the species in the study area was 2684 (Table 5.5), a value which shows moderate density of woody species in the area. However, *Azadirachta indica* has the highest per hectare density of 380/ha^{-} followed by *Guiera senegalensis* and *Senna Sieberiana* which have a respective per hectare density of 336 and 328. *Combretum micranthum* has a density 284/ha^{-}. Species with the least density include *Anogeissus leiocarpus, Aristida mutabilis, Cadaba farinosa, Ceiba pentandra, Combretum nigricans, Cordia africana, Diospyros mesipiliformis* and *Tamarindus indica* each of which has a density of 4/ha^{-}.

5.2.4 Woody Biomass

Species biomass varied over land use types with the highest mean value of 3191.46Kg per tree recorded in the built-up area. The built-up area had the highest number of large trees and as such recorded the highest mean diameter at breast height and subsequently, higher biomass values.

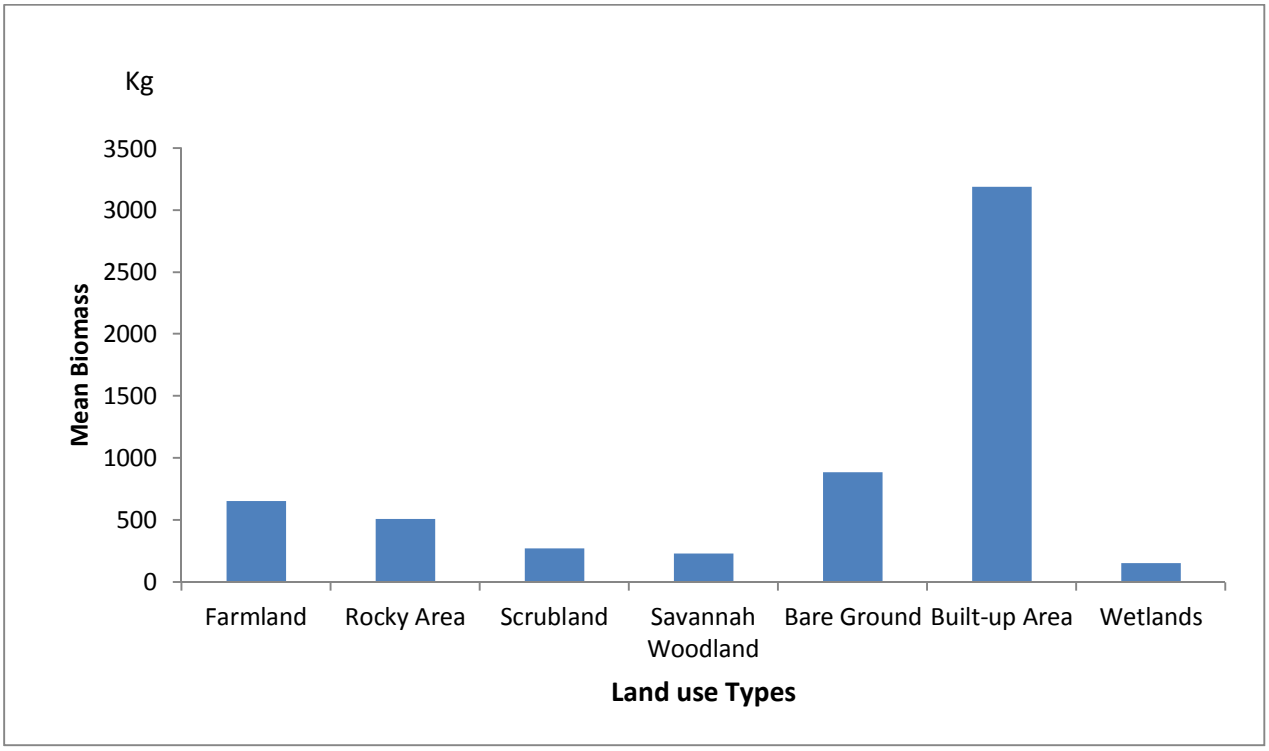


Figure 5.11: Variation of Woody Species Biomass over different land uses

Bare ground and farmland also recorded relatively high values of mean biomass of 884.6Kg and 655.81Kg per tree respectively. Although the areas had few woody species, the ones found are big and matured compared to other land use types. Similarly, although there are big species in the wetland, the land use type had the least mean biomass value of 152.1Kg per tree. This may be explained by the ratio of very thin woody species such as *Pteleopsis habeensis* and *Moringa oleifera* in the composition of species in the area. Since this analysis is based on mean values, the mean biomass would correspondingly be low.

5.2.5 Woody Species Diversity

Woody species diversity was computed within and between land use types using the Shannon Weiner's index (H). The more species a place may have, the more diverse it stands to be and the less species, the less diverse it may be. In this study, it was found out that the total species diversity in all land use types is 2.93 (Figure 5.12 and Appendix VI). This shows that the area is moderately diverse in woody species. However, the diversity of species varied remarkably among the species with *Azadirachta indica, Guiera senegalensis, Senna Sieberiana* and *Combretum micranthum* being the most diverse species with the highest H value of 0.27, 0.26, 0.25 and 0.23 respectively. *Anogeissus leiocarpus, Aristida mutabilis, Cadaba farinosa, Ceiba pentandra, Combretum nigricans, Cordia africana, Diospyros mesipiliformis* and *Tamarindus indica* on the other hand have an H value of less than 0.1 each; they therefore have the least diversity of species.

Diversity between land use types also varied (Figure 5.13). Savannah woodland has the highest H value of 2.62, followed by the farmland with an H value of 2.51 and the rocky area which has an H value of 2.49; these are therefore (in hierarchical order), the most diverse land use types in the

study area. Conversely, the built-up area has the least species diversity. This is because *Azadirachta indica* which is the dominant species in the land use type accounts for about 87% of the total species found thereon. Scrubland, Bare Ground and Wetlands on the other hand have moderate H values of 2.05, 1.97 and 1.79 respectively. This shows that while some areas in the study area have high woody species diversity, some have moderate and others have low species diversity.

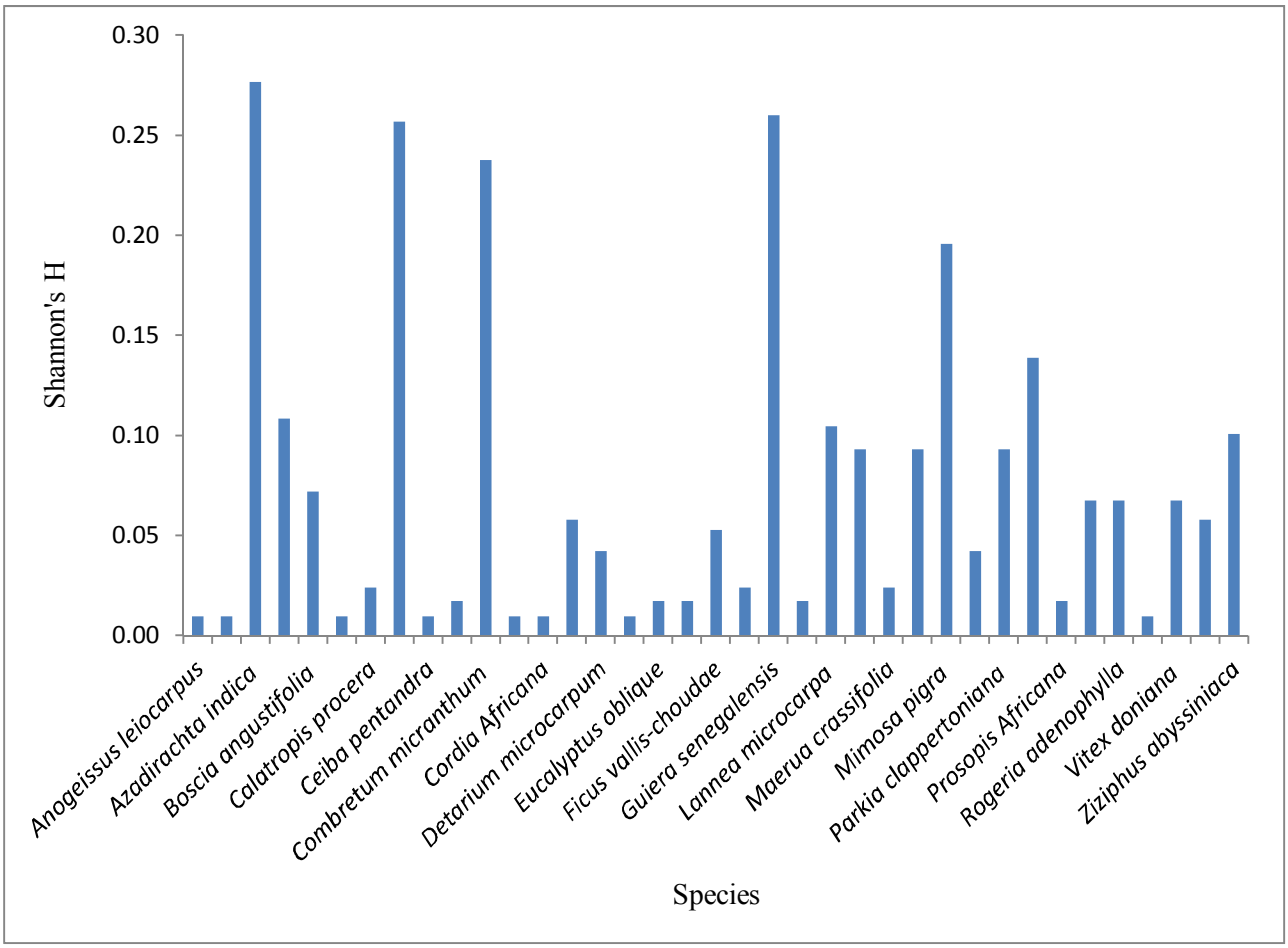


Figure 5.12: Woody Species Diversity (α) within Land use Types

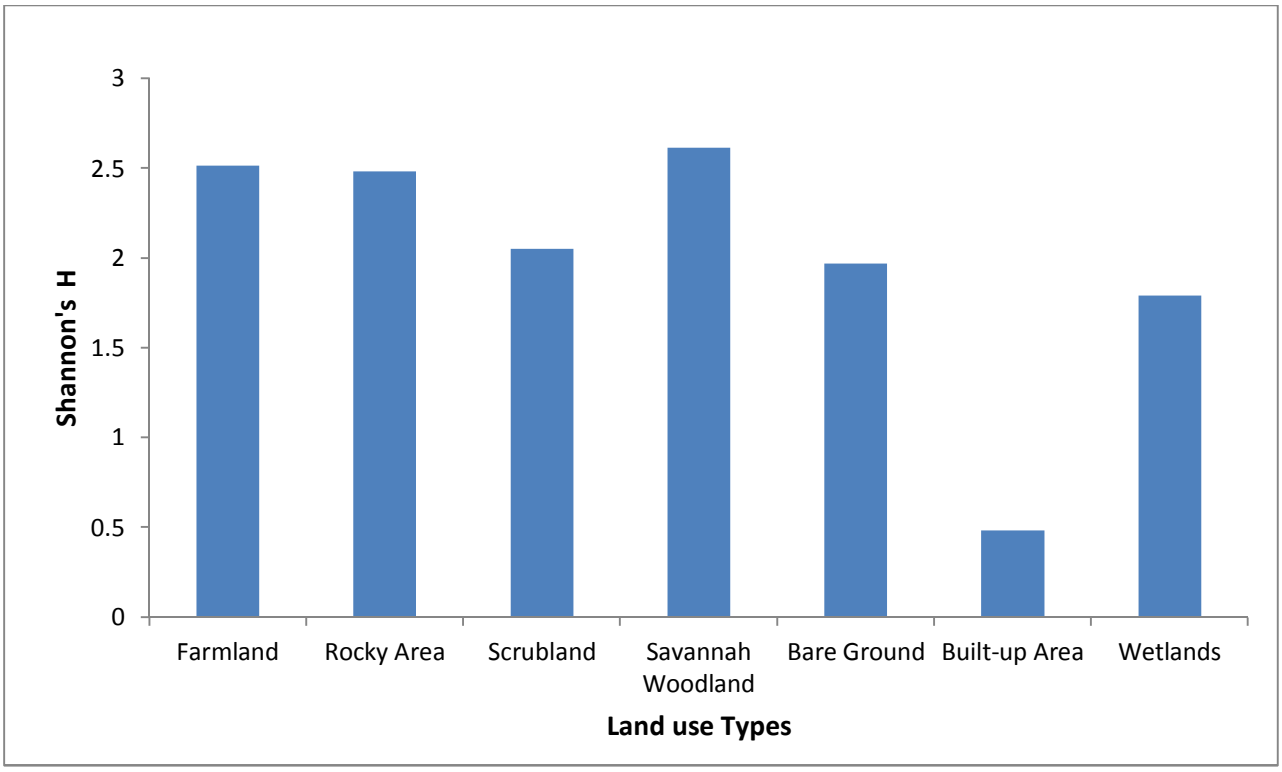


Figure 5.13: Woody Species Diversity (β) between Land use Types

5.3 SUMMARY OF SPATIAL VARIABILITY OF WOODY BIODIVERSITY

Table 5.6 summarizes the variability of the measured vegetation parameters over the different land use types. Vegetation parameters which include height, diameter at breast height (DBH), basal area (BA), density, diversity and biomass were analysed with Analysis of Variance (ANOVA) and Duncan Multiple Range Test (DMRT) at 0.05 level of significance.

Results of the analysis revealed that all the species' characteristics vary considerably within and among the different land use types in the study area. However, with a computed F value of 42.19, biomass is the species' parameter that varied most significantly while species' density has a computed F value of 2.25 and therefore insignificantly different amongst the different land uses. Other species characteristics – DBH, height, basal area and diversity have computed F values of 35.67, 12.00, 8.72 and 6.72 respectively.

Table 5.6: Variation of the Measured Woody Biodiversity Parameters within the Land use Types

S/N	Land use Type	No of Sample Plots		DBH (m)	Height (m)	BA (m)	Density (ha^{-})	Diversity	Biomass
1	Farmland	17	Mean	0.29^{c}	8.65^{b}	0.10^{b}	0.94^{b}	0.02^{bc}	655.81^{bc}
			SD	0.22	3.05	0.16	5.23	0.06	1132.25
2	Rocky Area	8	Mean	0.23^{cd}	7.80^{b}	0.08^{b}	2.0^{b}	0.05^{b}	509.97^{cd}
			SD	0.22	3.03	0.14	7.94	0.10	1033.77
3	Scrubland	6	Mean	0.15^{c}	7.53^{b}	0.04^{b}	2.67^{ab}	0.03^{bc}	200.51^{dc}
			SD	0.15	2.58	0.08	19.78	0.08	500.76
4	Savannah Woodland	5	Mean	0.17^{de}	8.30^{b}	0.04^{b}	2.67^{ab}	0.01^{c}	230.13^{de}
			SD	0.16	3.50	0.07	35.70	0.04	456.68
5	Bare Ground	6	Mean	0.37^{b}	8.65^{b}	2.79^{a}	2.67^{ab}	0.08^{a}	884.64^{b}
			SD	0.22	2.15	9.78	4.49	0.12	1024.99
6	Built-up Area	5	Mean	0.73^{a}	14.63^{a}	0.45^{b}	3.20^{ab}	0.03^{bc}	3191.46^{a}
			SD	0.21	5.26	0.22	8.48	0.07	1741.12
7	Wetlands	3	Mean	0.14^{c}	7.72^{b}	0.03^{b}	8.0^{a}	0.03^{b}	152.12^{e}
			SD	0.13	2.50	0.05	36.00	0.09	315.85
	ANOVA (F-ratio)			35.67**	2.25	8.72*	12.00*	6.72	42.19**

Significance level: * = 0.05level; * * = 0.01level

Means with the same letter(s) are not significantly different at 0.05 probability level

DBH = Diameter at Breast Height: BA = Basal Area: H = Height: Dn = Density: Dv = Diversity: Bm = Biomass: SD = Standard Deviation

The mean value of species diameter measured at breast height (DBH) was found to be highest in the built-up area and lowest in the scrubland and wetland area. Species suffer little or no disturbance and enjoy relative protection in the built-up area for the benefits people derive from them and for their ornamental value, hence the high mean DBH. In the scrubland, exploitation is very high and most of the species are shrubs that have a diameter of less than 2.5cm and as such, were not included in this study. Many of the species considered and measured in the scrubland were relatively thin and therefore, the mean DBH was low. Likewise in the wetlands, a considerably high number of thin species with low DBH values such as *Pteleopsis habeensis* and *Moringa oleifera* were found and recorded to warrant low mean DBH since the mean value takes members of a given population as equal entities. The Duncan Multiple Range Test (DMRT) revealed that the mean DBH of respective land use types is significantly different over the study area.

Species height was also found to be highest in the built-up area and lowest in the scrubland area. However, there is no remarkable variation of height in all other land use types as they have closely similar mean values. The pattern and intensity of woody species exploitation is higher in the scrubland than in the built-up area. This is because, while species in the built-up area are relatively protected, the scrubland is a no man's land devoid of adequate protection.

Only the bare ground surface has significantly different basal area compared to the other land use types. Analysis of variance thus did not reveal any significant difference amongst the various land uses. Some of the species on the bare ground such as *Azadirachta indica, Balanites aegyptiaca, Calotropis procera and Maerua crassifolia* are neither good source of fuel wood or of animal feed.

Their exploitation is therefore rather minimal. It was also shown that even though there are many large trees in the wetland area, preponderance of small or thin species made the average basal area to be lowest in the area.

The stand density shows considerable variation over the different land uses. The mean values are highest over the wetland area (8.0 stands per hectare) and built-up area (3.2 stands per hectare) and lowest over the rocky area (2.0 stands per hectare) and farmland area (0.94 stands per hectare). Analysis of variance thus revealed significant differences amongst the various land uses at the 0.05 level. In addition to favorable soil and moisture conditions, most species found in the wetland area, such as *Mangifera indica, Psidium guajava* and *Moringa oleifera,* are economic trees that cannot be freely exploited, hence the high density.

The species diversity also shows some variability with the land use types. The savannah woodland has the highest diversity value while bare ground and the farmland have the least. The other land use types have closely similar diversity levels.

Analysis of variance revealed significantly different biomass values amongst the different land uses. The built-up area exhibited higher mean species biomass (3191.5Kg/tree) while the wetland area showed lower mean species biomass (152.1Kg/tree) because species basal area is highest in the built-up area and lowest in the wetland area. Farmland and bare ground have similar but unequal biomass characteristics while other land use types are not significantly different in mean species biomass though the level of variability thereon differs.

Thus, overall, while the diameter at breast height, height, density and biomass revealed significantly different values amongst the different land uses, the basal area and species diversity did not. Consequently, the null hypothesis that guided the direction of the study that "there are no significant differences in the character of the woody biodiversity over the different land use types" is rejected except for the basal area and diversity parameters.

Table 5.7: The Pearson Correlation Coefficient Matrix of the Woody Vegetation Parameters

Woody Species Parameter DBH	Height	Basal Area	Density	Diversity	Biomass
Diameter at Breast Height (DBH)	0.67787	0.03318	0.00826	0.04500	0. 90811
	<.0001	0.3908	0.8308	0.2444	<.0001
Height		0.01683	-0.00141	0.00172	0.55821
		0.6634	0.9709	0.9645	<.0001
Basal Area			0.00548	0.09355	0.04458
			0.8872	0.0153	0.2489
Density				0.71064	0.01772
				<.0001	0.6469
Diversity					0.04304
					0.2656
Biomass					

< = Positive correlation between parameters

$\alpha = 0.05$

The Pearson correlation coefficient (Table 5.7) revealed that species diameter at breast height is positively correlated with their height and biomass. It also revealed that species biomass is positively correlated to species height while species diversity is positively correlated to species density. This implies that species biomass is a function of species height and diameter as found out

in the built-up area which did not only have the highest mean biomass but also the highest mean height and mean diameter. Conversely, a negative correlation exists between species biomass and species basal area, and between species diameter and species diversity. It was found in this study that although the built-up area had the highest mean species diameter, it had the least diversity values. The study also found out that no positive relationship exists between species basal area or species height and their density over a given study area. Therefore, the denser a particular area is in terms of species composition and richness, the lower its mean basal area and the more diverse it is likely to be.

5.4 DRIVERS OF WOODY BIODIVERSITY LOSS

Human pressure on woody species and biological diversity in general was observed to be enormous in the study area. There were indications of environmental deterioration everywhere. This situation is believed to have been caused by both natural and anthropogenic factors. The natural factors are to a large extent climatic though poor physical conditions of soils and vegetation also play contributory roles. According to Smeins *et al.* (1997), woody plants have always increased and decreased with fluctuations in climate over the past 20,000 years. As the rainy season in the area is generally brief (about 3 months) and usually unpredictable, lack of adequate rainfall and high temperature exposes the environment to a situation of high evapo-transpiration and as such, moisture deficit.

Similarly, the history of the sudano-sahelian zone of Nigeria to which present study area is part of is replete with severe and prolonged drought events some of which lasted several years. These series of severe and prolonged droughts as witnessed since the 1950s made the already fragile

sudano-sahelian environment to become more vulnerable than ever (FGN, 2005). Furthermore, scarcity during drought years leads to enhanced grazing pressure by the livestock which accentuates the problem of loss of vegetative cover. This devastating situation was also confirmed by Jibrin (2009) to be one of the major causes of the reduction in plants cover and which adversely affect the development, productivity and the general wellbeing of woody species in Kpashimi forest reserve, Nigeria.

Species such as *Guiera senegalensis, Combretum micranthum, Ficus vallis-choudae, Ximenia americana* and *Ziziphus abyssinica* therefore become in a state of dormancy when moisture levels are low to adapt to the situation. Similarly, *Acacia macrostachya, Lannea microcarpa, Acacia nilotica, Detarium microcarpum, Lannea microcarpa, Rogeria adenophylla,,* and a host of others shed their leaves to cope with the condition of moisture deficit.

Human factors are the results of the various human activities. Indiscriminate fuel wood extraction is the most common human activity that causes massive loss of woody species in the area (Plate 5.8 and 5.9). With very restricted alternative energy source and construction materials in Nigeria, the demand for woody species as fuel wood has been on steady increase, despite existing Felling of Trees (Control) Edict in the various States. Much of the energy for cooking is sourced from fuel wood and this consumption is considerably higher than what can sustainably be removed from the forests (FGN, 2005).



Plate 5.8: Fuel wood transportation in the study area



Plate 5.9: Fuel wood marketing in the study area

Another important driver of woody biodiversity loss in the area is agricultural activity. With the growth of human population and its attendant expansion of farming areas, large areas of land are continuously being cleared and converted to agricultural use as a result of which, many woody species are invariably destroyed. The scrubland and savannah woodland which harbor most of the woody species are in this case most vulnerable (Plate 5.10).



Plate 5.10: Expansion of Farmlands leads to clearance of Woody Species

Continuous and free grazing by animals also hinders the continuity of woody species. The Northern part of the country generally supports much of the country's livestock economy, hosting about 90% of the 16 million cattle population, about two-thirds of the 26 million goats and 13.5 million sheep and almost all donkeys, camels and horses (FGN, 2012). The nomadic herdsmen graze their livestock freely throughout the area and are constantly in search of suitable pastures.

This scenario as affirmed by Scholes and Walker (1993) is one of the most important anthropogenic disturbances that affect savannah vegetation (cited in Sawadogo *et al*., 2007). Degradation of savanna woodlands due to overgrazing, fire and wood cutting was also found to be a serious environmental concern in Burkina Faso just as it is in many tropical countries (Fries and Heermans, 1992).



Plate 5.11: Cattle Rearing in the Area

Bush burning and exploitation of woody species for medicinal purpose are two very important drivers of woody biodiversity loss. While burning damages plants cells and tissues, exploitation of species for medicinal purposes exterminates the species. This is because while some herbal medical practitioners use woody species' leaves and barks in their medicinal preparations, others use the roots. Exploiting the barks and roots interrupts the systemic flow of water and nutrients and as such, kills the plant.

Like in many parts of the developing world, constructions and settlement expansion also account for a considerable loss of woody species in the area. Woody species are cleared to make way for residential, commercial or institutional structures as well as roads and communication networks.



Plate 5.12: Clearing Woody Species for Construction purpose

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 SUMMARY OF FINDINGS

This study was carried out to assess the diversity and spatial variability of woody species over the major land use and land cover types in Yabo area of Sokoto state. The study reveals that the study area comprises of seven major land use/land cover types which are rather not equal in terms of their spatial coverage. It also revealed that the dominant land use in the study area is the agricultural land use.

The study enumerated a total of six hundred and seventy one (671) individual woody species stands from the prevailing land use types; their distributions are to forty (40) species, thirty five (35) genera and twenty one (21) families. From this distribution, eight species and seven families were found to be the dominant ones. The dominant species include *Azadirachta indica, Balanites aegyptiaca, Senna Sieberiana, Combretum micranthum, Guiera senegalensis,Mimosa pigra, Parkia biglobosa and Piliostigma reticulatum* while the dominant families are *Anacardiaceae, Balanitiaceae, Caesalpiniaceae, Leguminosae, Meliaceae, Fabaceae* and *Combretaceae.* When the result obtained from the field survey was projected to cover the entire study area, the result shows 171,600 woody stands in all. This translates to an average of fifty four (54) stands per hectare.

The composition and spatial pattern of species distribution in the area is highly variable. On the whole, the savannah woodland has the highest number of individual species stand and accounts for about 40.4% of the total stands in the area while the lowest number of stands was recorded in the built-up area which accounted for only about 2.2% of the total species stand in the area.

From the analysis of woody species structure in the area, about 42.5% (285) belonged to the lower height class (≤ 8m), 50% (336) belonged to the middle height class (8m-15m) and only 7.5% (50) belonged to the higher height class (>15m). For the diameter distribution, about 32.5% (218) of the species belonged to <10cm diameter class, 12.5% (84) to 10cm – 20cm diameter class, 20% (134) to 21cm -30cm diameter class, 15% (101) to 31cm 40cm diameter class, 10% (67) to 41cm – 50cm diameter class, 2.5% (17) to 51cm – 60cm diameter class, 5% (34) to 61cm – 70cm diameter class and 2.5% (17) to >70cm diameter class. From the analysis also, *Azadirachta indica, Guiera senegalensis*, *Senna Sieberiana* and *Combretum micranthum* were assessed as species having the highest density per hectare while *Anogeissus leiocarpus, Aristida mutabilis, Cadaba farinosa, Ceiba pentandra, Combretum nigricans, Cordia africana, Diospyros mesipiliformis* and *Tamarindus indica* have the lowest density per hectare. The species structure therefore is short to moderate height and small to medium diameter width while density per hectare of species is relatively low in the area.

Analysis of woody species biomass also revealed high variability. The built-up area which has the highest number of large trees was also found to have the highest level of biomass in the study area. Conversely, the scrubland area has the lowest biomass level. Although there are relatively few species in the bare ground area, this land use type recorded a surprisingly high biomass level. This was attributed to the fact that the few trees found there were rather matured and big.

The study area was found to be moderately diverse in its species composition. However, diversity (H) across the study area varied remarkably. *Azadirachta indica, Guiera senegalensis, Senna Sieberiana* and *Combretum micranthum* were found to have the highest H value and therefore the

most diverse woody species in the area. Similarly, the savannah woodland was found to be the most diverse land use type while the built-up area was the least diverse land use type. The various woody biodiversity parameters between the different land use types in the study area were tested by the use of F-ratio and were found to be statistically significant at 0.05 significance level.

Drivers of woody biodiversity loss were summarized under natural and human factors. Natural factors were mainly the erratic climatic condition, poor soil and meager vegetation. Human factors on the other hand include fuel wood extraction, agricultural expansion, uncontrolled grazing, bush burning, and exploitation for medicinal purpose, constructions and settlements expansion.

6.2 CONCLUSION

This study has clearly demonstrated that woody species in the study area show considerable variability. Factors responsible for such variability include the nature and intensity of exploitation; the economic and ecological value of species, species adaptability to environmental conditions and their tolerance to disturbance as well as difference in soil nutrients and moisture in a given area. Overall however, the species and actual number of tree stands are low suggesting severe land degradation in the area. The major driver of woody biodiversity loss in the area is human through fuel wood extraction, agricultural activities and settlement. The urgent need to halt the degradation trend is therefore stressed.

This information the study thus provide could form a basis for further research on the state of biological diversity and in developing conservation strategies in the study area.

6.3 RECOMMENDATIONS

To improve upon the wellbeing of woody species in the area and biological diversity in general, the following recommendations are made.

i. Awareness campaigns and intensive public enlightenment on the values of woody species in particular and biological diversity in general as well as their role in environmental protection and conservation are highly desirable.

ii. The existing conservation laws in the state should be modified and strengthened to ensure conservation of the available species. The laws should be backed by adequate commitment as well as appropriate and uniform application of penalties.

iii. Demarcation of a protected area is highly recommended in the area as none exists. This will go a long way in restricting excessive exploitation of natural resources by the people.

iv. Government should provide alternative, cheap and readily available sources of domestic energy such as cooking coal, cooking gas, kerosene and biogas at affordable prices so that the rate at which fuel wood is exploited and used as domestic energy would be reduced to the barest minimal.

v. Local and regional authorities as well as citizens should be integrated in conservation programmes because the success of biodiversity conservation depends on the contribution of all and sundry. In this sense, farmers and other stake holders in the environment should be encouraged to plant and nurse economic trees at homes and in the farms. This is because individual efforts in raising and protecting tree species has proved to be effective as

observed in the built-up area and the wetlands where species are well protected to reach their maturity.

vi. Further research on the state and conservation status of woody species in particular and biodiversity in general is also recommended.

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APPENDICES

Appendix I: Field Vegetation Data Collection Form

Plot Number_____

Coordinates_____

Name of Cluster_____

S/N	Species	Family	DBH	Height

Date……..

Appendix II: Sample Plots Studied and their Lat/Long

SN	Plot Title	Land use Type	Coordinates
1	BG1	Bare Ground	12.72822N - 5.01075E
2	BG2	Bare Ground	12.73804N - 5.00184E
3	BG3	Bare Ground	12.74100N - 5.00830E
4	BG4	Bare Ground	12.72988N - 5.03015E
5	BG5	Bare Ground	12.73134N - 5.00366E
6	BG6	Bare Ground	12.70944N - 4.99834E
7	BUA1	Built-up Area	12.72122N - 5.01094E
8	BUA2	Built-up Area	12.71452N - 5.01909E
9	BUA3	Built-up Area	12.72822N - 5.01075E
10	BUA4	Built-up Area	12.72999N - 5.00408E
11	BUA5	Built-up Area	12.73259N - 5.00554E
12	FL1	Farmland	12.70382N - 5.03127E
13	FL2	Farmland	12.71028N - 4.99601E
14	FL3	Farmland	12.70668N - 5.01909E
15	FL4	Farmland	12.70361N - 5.00607E
16	FL5	Farmland	12.69905N - 4.99443E
17	FL6	Farmland	12.70838N - 5.01592E
18	FL7	Farmland	12.71272N - 5.00427E
19	FL8	Farmland	12.71961N - 4.99443E
20	FL9	Farmland	12.72119N - 4.98469E
21	FL10	Farmland	12.70022N - 4.98702E
22	FL11	Farmland	12.71198N - 4.98585E
23	FL12	Farmland	12.72530N - 5.02139E
24	FL13	Farmland	12.70711N - 5.02534E
25	FL14	Farmland	12.73920N - 4.99104E
26	FL15	Farmland	12.71304N - 5.01698E
27	FL16	Farmland	12.73124N - 4.99394E
28	FL17	Farmland	12.73082N - 4.98479E
29	RA1	Rocky Area	12.70499N - 4.99909E
30	RA2	Rocky Area	12.71028N - 5.00978E
31	RA3	Rocky Area	12.71833N - 5.02862E
32	RA4	Rocky Area	12.71855N - 5.00057E
33	RA5	Rocky Area	12.72119N - 5.02354E
34	RA6	Rocky Area	12.73158N - 5.03211E
35	RA7	Rocky Area	12.73560N - 5.02502E
36	RA8	Rocky Area	12.73761N - 5.02343E
37	SCR1	Scrubland	12.70329N - 5.01899E
38	SCR2	Scrubland	12.71399N - 5.03190E
39	SCR3	Scrubland	12.72098N - 5.02354E
40	SCR4	Scrubland	12.73311N - 5.00053E
41	SCR5	Scrubland	12.73656N - 4.98437E

42	SCR6	Scrubland	12.73942N - 4.98670E
43	SW1	Savannah Woodland	12.70202N - 5.02375E
44	SW2	Savannah Woodland	12.70223N - 5.01338E
45	SW3	Savannah Woodland	12.71325N - 4.99739E
46	SW4	Savannah Woodland	12.72024N - 5.02756E
47	SW5	Savannah Woodland	12.74116N - 5.01211E
48	WL1	Wetlands	12.70753N - 4.98913E
49	WL2	Wetlands	12.71537N - 4.99136E
50	WL3	Wetlands	12.72744N - 4.99384E

Appendix III: Distribution of Woody Species over the Study Area

S/N	Species	Land Use Types								
		Farm Land	Rocky Area	Scrubland	Savannah Woodland	Bare Ground	Built-up Area	Wetlands	TOTAL	%
1	*Acacia macrostachya*	3	0	0	21	0	0	0	24	3.6
2	*Acacia nilotica*	1	0	3	0	0	0	1	5	0.7
3	*Acacia Sieberiana*	0	5	0	3	0	0	0	8	1.2
4	*Anogeissus leiocarpus*	1	0	0	0	0	0	0	1	0.1
5	*Aristida mutabilis*	0	1	0	0	0	0	0	1	0.1
6	*Azadirachta indica*	15	14	6	33	3	13	11	95	14.2
7	*Balanites Aegyptiaca*	6	1	1	11	1	1	0	21	3.1
8	*Boscia angustifolia*	0	2	6	4	0	0	0	12	1.8
9	*Cadaba farinosa*	0	1	0	0	0	0	0	1	0.1
10	*Calotropis procera*	0	0	0	0	3	0	0	3	0.4
11	*Senna Sieberiana*	18	10	23	25	6	0	0	82	12.2
12	*Ceiba pentandra*	0	0	0	0	0	1	0	1	0.1
13	*Combretum ghasalense*	0	0	0	2	0	0	0	2	0.3
14	*Combretum micranthum*	4	0	15	49	3	0	0	71	10.6
15	*Combretum nigricans*	0	1	0	0	0	0	0	1	0.1
16	*Cordia africana*	0	0	0	1	0	0	0	1	0.1
17	*Delonix regia*	0	0	0	9	0	0	0	9	1.3
18	*Detarium microcarpum*	0	2	0	4	0	0	0	6	0.9

Appendix III: Distribution of Woody Species over the Study Area (cont'd)

19	*Diospyros mesipiliformis*	0	0	0	1	0	0	0	1	0.1
20	*Eucalyptus oblique*	0	0	0	2	0	0	0	2	0.3
21	*Faidherbia albida*	2	0	0	0	0	0	0	2	0.3
22	*Ficus vallis-choudae*	2	0	4	2	0	0	0	8	1.2
23	*Gardenia erubescens*	0	0	0	3	0	0	0	3	0.4
24	*Guiera senegalensis*	9	12	38	23	2	0	0	84	12.5
25	*Khaya senegalensis*	2	0	0	0	0	0	0	2	0.3
26	*Lannea microcarpa*	10	1	3	2	4	0	0	20	3.0
27	*Lawsonia inermis*	0	0	0	6	0	0	11	17	2.5
28	*Maerua crassifolia*	0	1	0	0	2	0	0	3	0.4
29	*Mangifera indica*	3	0	0	0	0	0	14	17	2.5
30	*Mimosa pigra*	6	0	6	39	0	0	0	51	7.6
31	*Moringa oleifera*	0	0	0	0	0	0	6	6	0.9
32	*Parkia biglobosa*	12	0	0	3	0	0	2	17	2.5
33	*Piliostigma reticulatum*	19	2	0	9	0	0	0	30	4.5
34	*Prosopsis africana*	1	0	1	0	0	0	0	2	0.3
35	*Psidium guajava*	0	0	0	0	0	0	11	11	1.6
36	*Rogeria adenophylla*	9	0	1	1	0	0	0	11	1.6
37	*Tamarindus indica*	1	0	0	0	0	0	0	1	0.1
38	*Vitex doniana*	10	0	0	0	0	0	1	11	1.6
39	*Ximenia americana*	0	1	2	6	0	0	0	9	1.3
40	*Ziziphus abyssinica*	3	0	4	12	0	0	0	19	2.8
		137	54	113	271	24	15	57	671	100.0

Appendix IV: Species Frequency

S/N	Species	No of Plots	Frequency (%)	Relative Frequency
1	*Acacia macrostachya*	4	8	1.81
2	*Acacia nilotica*	3	6	1.36
3	*Acacia Sieberiana*	2	4	0.90
4	*Anogeissus leiocarpus*	1	2	0.45
5	*Aristida mutabilis*	1	2	0.45
6	*Azadirachta indica*	27	54	12.22
7	*Balanites Aegyptiaca*	13	26	5.88
8	*Boscia angustifolia*	10	20	4.52
9	*Cadaba farinosa*	1	2	0.45
10	*Calotropis procera*	3	6	1.36
11	*Senna Sieberiana*	22	44	9.95
12	*Ceiba pentandra*	1	2	0.45
13	*Combretum ghasalense*	1	2	0.45
14	*Combretum micranthum*	13	26	5.88
15	*Combretum nigricans*	1	2	0.45
16	*Cordia africana*	1	2	0.45
17	*Delonix regia*	4	2	0.45
18	*Detarium microcarpum*	4	8	1.81
19	*Diospyros mesipiliformis*	1	2	0.45
20	*Eucalyptus oblique*	1	2	0.45
21	*Faidherbia albida*	1	2	0.45
22	*Ficus vallis-choudae*	5	10	2.26
23	*Gardenia erubescens*	2	4	0.90
24	*Guiera senegalensis*	16	32	7.24
25	*Khaya senegalensis*	1	2	0.45
26	*Lannea microcarpa*	14	28	6.33
27	*Maerua crassifolia*	2	4	0.90
28	*Mangifera indica*	4	8	1.81
29	*Mimosa pigra*	10	20	4.52
30	*Moringa oleifera*	2	4	0.90
31	*Parkia biglobosa*	10	20	4.52
32	*Piliostigma reticulatum*	15	30	6.79
33	*Prosopsis africana*	2	4	0.90
34	*Psidium guajava*	2	4	0.90
35	*Lawsonia inermis*	4	8	1.81
36	*Rogeria adenophylla*	5	10	2.26
37	*Tamarindus indica*	1	2	0.45
38	*Vitex doniana*	3	6	1.36
39	*Ximenia americana*	4	8	1.81
40	*Ziziphus abyssinica*	7	14	3.17
			442	

Appendix V: Structure of Woody Species

S/N	Species	Total	MDBH (cm)	MH (m)	MBA (cm3)	RF	RD	RBA	IVI (SD)
1	*Acacia macrostachya*	24	7.4	6.7	71.6	1.81	3.58	0.40	5.78
2	*Acacia nilotica*	5	15.1	9.4	183.5	1.36	0.75	0.21	2.31
3	*Acacia Sieberiana*	8	8.0	7.2	56.7	0.90	1.19	0.10	2.20
4	*Anogeissus leiocarpus*	1	43.0	9.6	1450.3	0.45	0.15	0.33	0.94
5	*Aristida mutabilis*	1	8.0	6.0	49.7	0.45	0.15	0.01	0.61
6	*Azadirachta indica*	95	39.9	11.4	1705.6	12.22	14.16	37.34	63.71
7	*Balanites Aegyptiaca*	21	27.9	7.8	788.4	5.88	3.13	3.82	12.83
8	*Boscia angustifolia*	12	14.0	5.9	169.5	4.52	1.79	0.47	6.78
9	*Cadaba farinosa*	1	25.5	9.8	509.3	0.45	0.15	0.12	0.72
10	*Calotropis procera*	3	30.7	11.1	746.3	1.36	0.45	0.52	2.32
11	*Senna Sieberiana*	82	26.0	9.0	765.6	9.95	12.22	14.47	36.64
12	*Ceiba pentandra*	1	82.8	24.9	5379.4	0.45	0.15	1.24	1.84
13	*Combretum ghasalense*	2	63.7	12.6	3254.7	0.45	0.30	1.50	2.25
14	*Combretum micranthum*	71	8.1	6.2	72.3	5.88	10.58	1.18	17.65
15	*Combretum nigricans*	1	41.4	11.0	1344.9	0.45	0.15	0.31	0.91
16	*Cordia africana*	1	28.6	13.8	644.6	0.45	0.15	0.15	0.75
17	*Delonix regia*	9	3.5	12.4	920.5	0.45	1.34	1.91	3.70
18	*Detarium microcarpum*	6	30.3	9.2	831.8	1.81	0.89	1.15	3.85
19	*Diospyros mesipiliformis*	1	48.4	14.0	1838.6	0.45	0.15	0.42	1.03
20	*Eucalyptus obliqua*	2	32.6	17.5	848.5	0.45	0.30	0.39	1.14
21	*Faidherbia albida*	2	65.3	15.1	3394.0	0.45	0.30	1.56	2.31
22	*Ficus vallis-choudae*	8	13.2	7.9	179.6	2.26	1.19	0.33	3.79
23	*Gardenia erubescens*	3	7.0	5.3	44.2	0.90	0.45	0.03	1.38
24	*Guiera senegalensis*	84	6.1	5.8	39.0	7.24	12.52	0.75	20.51
25	*Khaya senegalensis*	2	27.1	9.5	592.9	0.45	0.30	0.27	1.02
26	*Lannea microcarpa*	20	1.7	8.8	57.9	6.33	2.98	0.27	9.58
27	*Lawsonia inermis*	17	7.2	5.9	89.5	1.81	2.53	0.35	4.69
28	*Maerua crassifolia*	3	17.6	8.0	255.6	0.90	0.45	0.18	1.53
29	*Mangifera indica*	17	34.9	10.2	1391.3	1.81	2.53	5.45	9.79
30	*Mimosa Pigra*	51	9.0	8.5	129.9	4.52	7.60	1.53	13.65
31	*Moringa oleifera*	6	8.2	6.9	60.0	0.90	0.89	0.08	1.88
32	*Parkia biglobosa*	17	50.8	11.8	2262.7	4.52	2.53	8.86	15.92
33	*Piliostigma reticulatum*	30	25.5	7.6	701.4	6.79	4.47	4.85	16.11
34	*Prosopsis africana*	2	47.7	10.8	2299.8	0.90	0.30	1.06	2.26
35	*Psidium guajava*	11	8.7	6.3	64.7	0.90	1.64	0.16	2.71
36	*Rogeria adenophylla*	11	22.1	7.4	482.0	2.26	1.64	1.22	5.12
37	*Tamarindus indica*	1	38.2	8.5	1145.9	0.45	0.15	0.26	0.87
38	*Vitex doniana*	11	28.1	6.8	912.2	1.36	1.64	2.31	5.31
39	*Ximenia americana*	9	8.3	6.2	60.7	1.81	1.34	0.13	3.28
40	*Ziziphus abyssinica*	19	19.2	7.7	980.2	3.17	2.83	4.29	10.29
		671				100.0	100.0	100.0	300.00

MDBH = Mean Diameter at Breast Height: MH = Mean Height: MBA = Mean Basal Area
RF = Relative Frequency: RD = Relative Density: RBA = Relative Basal Area:
IVI = Importance Value Index

Appendix VI: Diversity of Woody Species

S/N	Species	Genus	Family	Local Name	Total	Shannon's H		
						Pi	logPi	H
1	*Acacia macrostachya*	*Acacia*	Fabaceae	Gardaye	24	0.035767511	-3.330715307	0.119131397
2	*Acacia nilotica*	*Acacia*	Fabaceae	Bagaruwa	5	0.007451565	-4.899331225	0.036507684
3	*Acacia Sieberiana*	*Acacia*	Fabaceae	Farar Kaya	8	0.011922504	-4.429327595	0.052808675
4	*Anogeissus leiocarpus*	*Anogeissus*	Combretaceae	Marke	1	0.001490313	-6.508769137	0.009700103
5	*Aristida mutabilis*	*Aristida*	Poacaea	Dashi	1	0.001490313	-6.508769137	0.009700103
6	*Azadirachta indica*	*Azadirachta*	Meliaceae	Dogon Yaro	95	0.141579732	-1.954892245	0.27677312
7	*Balanites Aegyptiaca*	*Balanites*	Balanitiaceae	Aduwa	21	0.031296572	-3.464246699	0.108419047
8	*Boscia angustifolia*	*Boscia*	Capparidiaceae	Anza	12	0.017883756	-4.023862487	0.071961773
9	*Cadaba farinosa*	*Cadaba*	Capparaceae	Bagaye	1	0.001490313	-6.508769137	0.009700103
10	*Calotropis procera*	*Calotropis*	Apocynaceae	Tunfafiya	3	0.004470939	-5.410156848	0.024188481
11	*Senna Sieberiana*	*Senna*	Fabaceae	Malga	82	0.122205663	-2.10204989	0.256882401
12	*Ceiba pentandra*	*Ceiba*	Malvaceae	Rini	1	0.001490313	-6.508769137	0.009700103
13	*Combretum ghasalense*	*Combretum*	Combretaceae	Taramniya	2	0.002980626	-5.815621956	0.017334194
14	*Combretum micranthum*	*Combretum*	Combretaceae	Geza	71	0.105812221	-2.24608926	0.237663692
15	*Combretum nigricans*	*Combretum*	Combretaceae	Tsiriri	1	0.001490313	-6.508769137	0.009700103
16	*Cordia africana*	*Cordia*	Fabaceae	Alilliba	1	0.001490313	-6.508769137	0.009700103
17	*Delonix regia*	*Delonix*	Fabaceae	Dorowar Turawa	9	0.013412817	-4.31154456	0.057829957
18	*Detarium microcarpum*	*Detarium*	Caesalpiniaceae	Taura	6	0.008941878	-4.717009668	0.042178924
19	*Diospyros mesipiliformis*	*Diospyros*	Ebenacea	Kaiwa	1	0.001490313	-6.508769137	0.009700103
20	*Eucalyptus oblique*	*Eucalyptus*	Myrtaceae	Zaiti	2	0.002980626	-5.815621956	0.017334194

Appendix VII: Diversity of Woody Species (cont'd)

S/N	Species	Genus	Family	Local Name	Total	Shannon's H		
						Pi	logPi	H
21	*Faidherbia albida*	*Faidherbia*	Fabaceae	Gawo	2	0.00298063	-5.815622	0.01733419
22	*Ficus vallis-choudae*	*Ficus*	Moraceae	Balgomi	8	0.0119225	-4.429328	0.05280867
23	*Gardenia erubescens*	*Gardenia*	Rubiaceae	Gaude	3	0.00447094	-5.410157	0.02418848
24	*Guiera senegalensis*	*Guiera*	Combretaceae	Sabara	84	0.12518629	-2.077952	0.26013114
25	*Khaya senegalensis*	*Khaya*	Meliaceae	Madacci	2	0.00298063	-5.815622	0.01733419
26	*Lannea microcarpa*	*Lannea*	Anacardiaceae	Faru	20	0.02980626	-3.513037	0.10471049
27	*Lawsonia inermis*	*Lawsonia*	Rubiaceae	Lalle	17	0.02533532	-3.675556	0.09312138
28	*Maerua crassifolia*	*Maerua*	Capparaceae	Jirga	3	0.00447094	-5.410157	0.02418848
29	*Mangifera indica*	*Mangifera*	Anacardiaceae	Mangoro	17	0.02533532	-3.675556	0.09312138
30	*Mimosa pigra*	*Mimosa*	Fabaceae	Gumbi	51	0.07600596	-2.576944	0.19586307
31	*Moringa oleifera*	*Moringa*	Fabaceae	Zogale	6	0.00894188	-4.71701	0.04217892
32	*Parkia biglobosa*	*Parkia*	Leguminosae	Dorowa	17	0.02533532	-3.675556	0.09312138
33	*Piliostigma reticulatum*	*Piliostigma*	Caesalpiniaceae	Kalgo	30	0.04470939	-3.107572	0.13893763
34	*Prosopsis africana*	*Prosopsis*	Fabaceae	Kirya	2	0.00298063	-5.815622	0.01733419
35	*Psidium guajava*	*Psidium*	Myrtaceae	Gwaiba	11	0.01639344	-4.110874	0.06739137
36	*Rogeria adenophylla*	*Rogeria*	Pedaliaceae	Loda	11	0.01639344	-4.110874	0.06739137
37	*Tamarindus indica*	*Tamarindus*	Fabaceae	Tsamiya	1	0.00149031	-6.508769	0.0097001
38	*Vitex doniana*	*Vitex*	Verbenaceae	Dunya	11	0.01639344	-4.110874	0.06739137
39	*Ximenia americana*	*Ximenia*	Olacaceae	Tsada	9	0.01341282	-4.311545	0.05782996
40	*Ziziphus abyssinica*	*Ziziphus*	Rhamnaceae	Magarya	19	0.02831595	-3.56433	0.10092738
					671	1	-184.5148	2.93191945