CHAPTER ONE

1.1 INTRODUCTION

In every land, and in all ages, trees have had an influence of great magnitude on the progress and welfare of man kind. The progress from primitive cave dwellers to the present civilized state cannot be told without frequent reference to forests and their products. Trees provided these early inhabitants with food, medicines, fuel, shelter, protection, shade, tools and other needs. Today over ten thousand products are reportedly made of and from forests. It is the raw material from which forest industries manufacture countless products, for the home, factory and office. A forest is a living, complexly interrelated community of trees and associated plants and animals. Within the community, plants and animals grow old and die. From the soil, trees take up moisture and nitrogen, and with the aid of sunlight, they manufacture wood and other products used by humans.

Deforestation is the conversion of forested areas to non-forest land use such as arable land, urban use, wasteland or pasture. Anambra State is seriously threatened by deforestation. The 2006 national population and housing survey put the population of Anambra State at 4,182,032 and the population density at 863/Km^2 (Ezike, 2011).The quest for more land to meet the needs of the rapidly expanding population in the state as well as the unfavorable economic downturn of many people is socio-economic propellants of deforestation in the state. This increase in population has reduced the fallow periods in the state, consequently little time is allowed for the soil to replenish its nutrients with the result that more forests are cleared for farmlands. The high rate, at which forests are currently converted to agriculture, indicates that the economic return from agriculture is higher than from forests, at least in the short term, and that the land is more valuable deforested than forested [Gaston *et al*. 1998]. As population increases, the demand for wood continually increases. Trees are harvested for multiple uses ranging from lumber to wood for fuel. The rate of deforestation currently significantly exceeds the rate of forest renewal in Anambra state.

According to Okafor, (1979) when fallow periods are long enough to permit full vegetation regeneration and soil fertility restoration, this cultivation is recognized as ecologically balanced, economically attractive, and culturally integrated. It has been pointed out that certain woody species such as *Dialium guineense, Anthonata macrophylla, Alchornea cordifolia,* dominate the natural fallow system in the humid zone of southeastern Nigeria, where population density is high, the fallow period short, and the soil acid [Obi and Tuley 1973; Okigbo 1982; Getahun *et al*. 1982].

According to Padock *et al.,* (1985), Forestry is the art and science of managing forests so as to yield, on a continuous basis, a maximum in quantity and quality of forest products and services. It is in a sense, the handling of forest lands to satisfy people’s needs. It includes the logging, manufacturing, marketing and use of wood products. Forests can be managed for single or multiple purposes to include protection of watersheds, production of timber, provision of wildlife habitat and recreation, regulation of stream flow, control of erosion, medicinal purposes and general aesthetics. It would be impossible for our country to maintain the standard of living it enjoys without the products and services which emanate from forests (Padock *et al.* 1985).

The scientific study of forest species and their interaction with the environment is referred to as forest ecology, while the management of forests is often referred to as forestry (Padoek *et al.* 1985). Primack (1991), noted that forest management has changed considerably over the last few centuries, with rapid changes from the 1980s onwards culminating into a practice now referred to as sustainable forest management. Forest ecologists concentrate on forest patterns and processes, usually with the aim of elucidating cause and effect relationships. Foresters who practice sustainable forest management focus on the integration of ecological, social and economic values, often in consultation with local communities and other stakeholders (Primack, 1991).

Anthropogenic factors that can affect forests include logging, urban sprawl, human-caused forest fires, acid rain, invasive species, and the slash and burn practices of swidden agriculture or shifting cultivation (Wong, 1992). The loss and re-growth of forest leads to a distinction between two broad types of forest, primary or old-growth forest and secondary forest. FAO (1991) reported that, there are also many natural factors that can cause changes in forests over time including forest fires, insects, diseases, weather, competition between species, etc. In 1997, the World Resources Institute recorded that only 20% of the world's original forests remained in large intact tracts of undisturbed forest. More than 75% of these intact forests lie in three countries - the Boreal forests of Russia and Canada and the rainforest of Brazil. In 2006 this information on intact forests was updated using latest available satellite imagery (Ramesteiner, 1998).

Canada has about 4,020,000 square kilometres (1,550,000sq mi) of forest land (Michon *et al.*, 1994). According to the same source, more than 90% of forest land is publicly owned and about 50% of the total forest area is allocated for harvesting. These allocated areas are managed using the principles of sustainable forest management, which includes extensive consultation with local stakeholders (Michon *et al.*, 1994). About eight percent of Canada's forest is legally protected from resource development. Much more forest land -about 40 percent of the total forest land base - is subject to varying degrees of protection through processes such as integrated land use planning or defined management areas such as certified forests (Michon *et al.*, 1994).

Bass (1998), in his works with forest certification, projected that, by December 2006, over 1,237,000 square kilometers of forest land in Canada (about half the global total) would have been certified as being sustainably managed. Also, the Canadian Sustainable Forestry Certification Coalition, quoted in Bass (1998) reported that, clearcutting, first used in the latter half of the 20th century, is less expensive, but devastating to the environment and companies are required by law to ensure that harvested areas are adequately regenerated. Most Canadian provinces have regulations limiting the size of clearcuts, although some older clearcuts can range upwards of 110 square kilometres (27,000 acres) in size which were cut over several years. China instituted a ban on logging, beginning in 1998, due to the destruction caused by clearcutting. Selective cutting avoids the erosion, and flooding, that result from clear cutting (Korang, 1986).

In the United States, most forests have historically been affected by humans to some degree, though in recent years improved forestry practices has helped regulate or moderate large scale or severe impacts. However, Leakey and Newton (1994) stated that, the United States Forest Service estimates a net loss of about 2 million hectares (4,942,000 acres), US forests will occur between 1997 and 2020; this estimate includes conversion of forest land to other uses, including urban and suburban development, as well as afforestation and natural reversion of abandoned crop and pasture land to forest. However, in many areas of the United States, the area of forest is stable or increasing, particularly in many northern states. The opposite problem from flooding has plagued national forests, with loggers complaining that a lack of thinning and proper forest management has resulted in large forest fires (Leakey and Newton, 1994).

Old-growth forest contains mainly natural patterns of biodiversity in established seral patterns, and they contain mainly species native to the region and habitat. The natural formations and processes have not been affected by humans with a frequency or intensity to change the natural structure and components of the habitat. Secondary forest contains significant elements of species which were originally from other regions or habitats (Elliot, 1992).

Smaller areas of woodland in cities may be managed as urban forestry, sometimes within public parks. These are often created for human benefits; Kashio, (1994) stated that, Attention Restoration Theory argues that spending time in nature reduces stress and improves health, while forest schools and kindergartens help young people to develop social as well as scientific skills in forests. These typically need to be close to where the children live, for practical logistics. South-eastern Nigeria has been blessed with a warm climate, abundant rainfall, a long growing season and soils which make rapid tree growth. Less time is required to raise a tree crop in the south-east than any other region in the Nation (Okafor, 1999, Enunwonye 1983). When the first white settlers came to Africa, they found extensive forests that were both a help and a hindrance to them. From the forest they secured materials to build their log cabins and sheds for their livestock and the wood with which to keep warm. Block houses and stockades to which they fled in times of danger, also came from materials in the forests. Ajayi, (1983) stated that much of their food, clothing and medicine were supplied from this source.

Nevertheless, forests in this period (white man's invasion of Africa) were a hindrance to crop production and defense. Therefore some of the reasons for clearing land occupied by trees were: to grow crops, to provide grass for livestock, to rid areas of wide beast and to eliminate a hiding place for hoodlums. There was no economic justification for sparing them (Ajayi, 1983). While there are variations in the activities performed by the several forestry agencies, Ezike, (2011) noted that, each state has the responsibility for the development of forest policy as it relates to state and private forest lands within its boundaries. Programmes generally include forest fire control, operation of trees nurseries, assistance to small woodland owners in timber management problems, research, and operation of state forests and general education of the public. Apart from the direct benefits which forests provide in the way of products, other values are derived from the trees. Some of the beneficial influences are often overlooked and their values under estimated (Dunn 1975).

Okafor (1979) stated that, during a rain storm, the leaves and branches of trees break the impact of rain, causing the moisture to drip rather than reach the earth with a force. Upon reaching the forest floor, the ground litter and the humus absorb the water and reduce surface runoff. Of most important however, is the effect of the litter and humus in keeping the soil mellow, porous and permeable, allowing seepage of water into the substratum where nature stores water. Much of it subsequently appears at the surface in the form of springs. Thus forests help regulate stream flow and the process acts as natural filtering agents. In contrast, surface runoff in urban areas is high and contributes to peak flow of water. More so, Clement and Villachica (1994) observed that, in treeless areas such as in western Oklahoma and western Texas, wind breaks are established to reduce the harmful effects of the wind in drying out and blowing the soil, as protection against drifting snow, and to protect crops, livestock, homes and barns from cold or hot wind. In other regions of the world, plantings of this nature have been made, to some extent, where wind exposure is a problem. Wind in treeless areas, remove fertile top soil, results in an increase in evaporation, and blows sand over fertile soil. Research has shown that properly established windbreaks reduce wind speed relation to the height of the trees.

Forest vegetation that shades water courses from the full heat of the sun contributes towards the prevention of excess stream temperatures. In certain areas of the Nigerian nation, the removal of trees from creeks and streams resulted in warm water that was undesirable for the continued existence of eastern brook trout. Forests also help to produce clear streams most desirable for fish life. In forest watersheds where management is carefully practiced, extremes of water flow in winter and summer are avoided, thus aiding in flood control. In contrast, where poor land management is practiced and forests are depleted on the head water basins, the resulting discharge following rain carries topsoil downstream in flash floods, affecting aquatic life and reducing the productivity of streams and rivers for many years. Forest streams usually have a minimum amount of sediment even during periods of high stream flow (Clement and Villachica 1994).

Many kinds of wildlife are found in the forests where they obtain shelter and food. Some kinds of wildlife disappear when forest trees are removed. Other kinds of wildlife dependent on shrubs, weeds and young trees may occupy the area where the tree habitat is restored. The original kinds of habitat may return. When trees and other kinds of forest vegetation are destroyed, all wildlife may disappear for a long time (Ajayi 1983). On bare soil the amount of water that can be absorbed from a heavy rainfall is less than in a forested land. The result is rapid runoff over the land surface. In the process, soil particles are packed up by the water as it travels. The result is quick accumulation of muddy water in streams and rivers. In contrast, water that moves through forested soils does so more slowly and stays free of sediments.

While the role of trees in cleansing the air is not yet fully understood, there seems to be no doubt that trees do take in pollutants from the air during their normal gas exchange. Small amount of sulfur dioxide, for example could possibly be taken in and used in metabolism by the trees. There is also the view that trees may take up various soil and water pollutants through the roots and thus aid cleansing soil and water. However the leaves of trees aid in the removal matter. When such material is deposited upon leaves, particularly hairy leaves, the leaves usually hold onto the particles until the particles are washed to the ground by the rain. Additionally, trees can also reduce the velocity of the wind in a given area, allowing the dust particles in the air to settle to the ground by gravity.

Koran (1986) noted that, there can be no doubt that noise can be abated through the proper use of trees and other plants. Even a few trees can be effective if placed between the noise source and people. However, hard wood trees which drop their leaves are not much help in winter. Trees, to be effective in noise abatement, should be close to the source of the noise. Greenbelts, made up of trees and other plants are becoming increasingly important in urban planning. Aside from the aesthetic and social values which greenbelts provide, their recognition as moisture storage zones is becoming evident. Water diverted from street is directed into these storage zones which do affect the quality and quantity of runoff.

Oyakhilome (1985) observed that, the better known values of forests are the social benefits which they provide for outdoor recreation. Hunting, fishing, bird watching, nature study, camping, picnicking, hiking and scenic or aesthetic values are but a few. Often overlooked is the fact that a forest is made up of all kinds of plants, some of which offer a lot of potential for financial return. During the Christmas season, a market is available for Christmas trees; mistletoe; uncoloured or coloured pine cones of all species; branches of evergreens such as longleaf pine and holly and sweet gum balls. Galex an evergreen herb, is used by florists for decorations One cannot deny the fact that the greatest contribution forests make is the forest products derived from trees. Too frequently, their value is overlooked. Ours is a wood-oriented society, wood is a most important part of houses, and wood is important in the construction of apartment building and many other industrial and commercial structures (Okafor, 1977). There is wood in the morning paper, in cereal boxes, in sports equipment and in furniture. Where ever one looks there is a wood product. Trees from forests are made into lumber, pulpwood, veneer, poles, railroad ties, and piling to name but a few. Lumber is further used in the production of furniture and other manufactured items. Pulpwood is used to manufacture a multitude of products, including paper. Today, through chemistry, wood is providing a variety of products, including rayon, cellophane, plastics and other well known products. Wood is likely to play an increasingly important role in supplying some of the nation's energy needs through the production of biomass from timber.

1.2 Statement of the Problem

Deforestation and cropping have caused a great deal of damage in Anambra State. This uncontrolled deforestation usually accompanied by poor soil management has led to land degradation and ecological imbalance in many parts of the state. Clearing and burning are deforestation methods employed by farmers and hunters in the state. The land clearing and post-clearing soil management methods employed in the state has affected the role of forests as carbon sequestration sites. Large scale deforestation in the state has also occurred as a result of construction works by the local, state and federal governments. Urbanization is another cause of deforestation in the state. The migration of people to urban areas has led to the clearing of forests for residential and other purposes. The citing of industries without recourse to the impact on the environment is also a problem in some parts of the state. Development initiatives such as road and building constructions are supplemented by growing encroachment and illegal logging has further increased the risk of deforestation in the state. The effects of deforestation include loss of soil nutrients, loss of valuable species of economic/medicinal value, siltation of rivers, species extinction, reduced biological diversity, reduced ecosystem stability, reduced plant biomass, and broken food chain. Increased rates of soil erosion have a potential of leading to a rise in river beds and hence increased frequency of flooding, threatening settlements and cultivable land. A major effect of deforestation in the state is increased soil erosion which has displaced people from their native homes, led to destruction of lives and property and collapse of infrastructural facilities in some parts of the state.

Activities such as agriculture, logging, bush meat hunting, over exploitation of medicinal plants, minerals and oil extraction have direct impacts on forests and wildlife. Population growth, conflict and disease, governance problems, lack of forest management capacity, a shortage of funding and a lack of awareness are some of the factors that facilitate the decline of forest resources. A growing problem has been road-building by logging companies, which gives bush meat hunters access to the heart of previously remote forests. This has led to extreme over-hunting of vulnerable and endangered species such as the western lowland gorilla, elephant and leopard (Ajayi 1983). Fiber board and particle-board consumption in tropical Africa has been rising fairly rapidly in recent years, but in individual countries, the demand is still below the quantities on which an industry can reasonably be based. Once conditions warrant the establishment of an industry, raw material needs as far as wood is concerned should be ample throughout the state or region (ITTC 1990). Paper consumption has also been rising rapidly and in a number of tropical African countries the situation is approaching where it may be possible to base pulp and paper production on domestic needs (Agbelusi and Afolayan1987).

With the approaching exhaustion of areas being felled for agriculture in West Africa, it seems probable that West African timber removals and production will decline in the future in some of the major producing areas, unless production from reserves coupled with improved sylvicultural techniques can make up for the deficit. It is significant that in Nigeria it is even being forecast that within the next two decades or so the export trade in timber will have virtually ended (Ajayi, 1983). The situation will undoubtedly direct attention to secondary timbers now in poor demand, and also to hitherto somewhat neglected areas, such as Liberia and eastern Nigeria. It is also certain that a larger local demand will develop as a consequence of the rising living standards of a rapidly increasing population, and that this will lead to an increase in local sawmilling. However, Agbelusi and Afolayan, (1987) stated that, over the past decades, the annual increase in timber exports by value, mostly from West Africa has exceeded 12 percent, and local and external demands are certain to increase further. The availability of commercial timber in forests at present in use is diminishing but there are possibilities of bringing untapped areas into production. Sustainable management of the forests that can meet the standard of the Millennium Development Goals is therefore sacrosanct.

1.3 Justification for the Research

- The justification for this research emanated from the fact that, the magnificient variety of plant species and wildlife in these forests are heritage that are unique, not just to Anambra state, but also to Nigeria and Africa as a whole.
- Anambra State has the second smallest land area in Nigeria with high human populaton and alarming rate of deforestation and forest degradation because of human economic activities.
- With the current rate of deforestation and forest degradation in the state, the forest that provide goods and services to the people will soon varnish with the goods and services they provide, so the need for this study.
- Trees are an important natural resource that helps a city's environment, health, and overall quality of life. Therefore, having a good understanding of the composition of the forest is essential to maintaining this resource.
- This research has become necessary in view of the fact that it will give the stakeholders and concerned agencies a clue of what the current status of the forest resources of the state entailed.

1.4 Aim and Objectives

Aim

The aim of this work was to ecologically characterize and evaluate the forests of Anambra State.

Objectives

The specific objectives are to:

1. Determine the floristic composition and diversity of forests in Anambra State;
2. Determine the soil physicochemical properties of the forests;
3. Determine the relationships between species diversity and the physicochemical parameters of the forests.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 African Forests and their Development

Deforestation occurs because of many reasons. Trees are used as or sold for fuel. Amous (1999) stated that the share of wood fuels in African primary energy consumption represents on average 86% of total African energy consumption. One reason for forest depletion in West Africa is to plant cash crops such as cotton, cocoa, rubber, kolanuts, gum and oil palm for export. Large-scale deforestation occurs in Anambra State as a result of ignorance of intrinsic value, inadequate environmental laws, lack of ascribed value and poor forest management practices. The reliance on area expansion to meet the needs of rapidly increasing human populations has also resulted in increased deforestation in Anambra State. Deforestation is a serious cause of environmental problems in the state. These problems include erosion, loss of soil fertility, loss of forest products like medicinal plants and fruits, extinction of species, changes in climatic conditions, and displacement of indigenous people. Poverty is an important factor of deforestation in most African countries. The New York Times (2009) reports that among countries with a per capita GDP of at least US$4,600, net deforestation rates have ceased to increase.

According to Dagogo (1981), experience in Africa has shown that, in the absence of careful forestry planning, in the broad context of general land-use planning, the nations' forest resources will not be used to best advantage and may be dissipated by unwise exploitation or neglect. In some African countries, the forest capital is already being rapidly depleted, a fact hitherto largely obscured.

Addey, (1982) observed that, the disappearance of the forest can be seen where communities clear the land on the forest edge, and where crops are introduced even on steep hillsides as in the montane regions of Kenya, Nyasaland and Southern Rhodesia, or in bordering savanna areas where the sub desert encroaches. Future field work will undoubtedly indicate what modifications are necessary in tropical Africa to principles for forest protection accepted in other regions.

Throughout the Sahelian zone, from Senegal to Sudan, Amposay-Agyemang, (1980) stated that, the shrub and thorny forest along the desert fringes may be of relatively limited value in themselves, but to their value should be added the much more important ability to reduce the force and to check the sting of the desert winds, to check shifting sands and the advance of sub desert, and to restore conditions favorable to human life and grazing. The destruction of *Acacia* and *Commiphora* forests and their replacement by pure but thin grass cover represents in itself a change towards more desiccated conditions and erosion. Land-use planning should provide where essential for the maintenance of tree vegetation, since the new establishment of a tree cover in semi-arid zones with long periods of drought is most difficult and costly (Osei-Owusu 1981).

In the Sudanian and Guinean zones of the Upper Volta and north Ghana, the need for the useful protective effects of tree cover is particularly evident. Sound management of the Volta watershed can help to achieve regular stream flow, limit flood damage, check river bank erosion, and reduce the silting of reservoirs for the hydroelectric industry and irrigation. "Gallery forests" along African rivers should be subjected to a very strong conservation effort (Forestry Department of Ghana 1975).

Shiembo, (1986) agreed that, the protective effect of tree plantations as shelterbelts to reduce wind erosion and evaporation is well understood in humid areas, in drier regions of Africa, in the miombo and mopane woodlands in the eastern and central plateau, it is well to remember that in some circumstances the trees themselves may use, or cause the evaporation of, more water than grass cover. In Kenya, the question of water control in both aspects, run-off and evaporation, is being studied for forests in comparison with tea plantations.

For the land use policy in these drier tropical parts of Africa, Adeola and Decker (1987) noted that, it is important to distinguish between plantations which have dominant protective functions and plantations which are established for purely production purposes, such as timber and fuel supply, or for fodder supplement. Although the latter plantations afford protection this is not their main function and they can be harvested solely on economic grounds, e.g., highest yield per rotation. On the other hand, natural protection forests, for instance, large areas in Uganda, and protective plantations must be managed with the objective of improving water yields, stabilizing soil and conserving its properties, and preventing erosion and desiccation. The protective forests and plantations have to be maintained permanently and the harvesting of the timber and fuel must be only a secondary consideration (Adeola and Decker, 1987).

Coming to the closed forest formation, a major planning task must be to define clearly the forest areas to be set aside on the one hand for production and on the other as protection forests although in most cases these two roles can be combined. Gouyon *et al*. (1993) stated that, a particular case arises in Ghana and other West African countries, where maintenance of a certain minimum forest cover is essential to preserve the microclimate necessary for the proper growth of cocoa. An estimate for tropical Africa would be that at present some 60 million hectares have been classified as forest reserves, Diop (1993) posited. These reserves should be extended to at least 100 million hectares, which have proved to be productive, and which is the figure of the forest area that is actually in use in tropical Africa today (Diop, 1993). But in determining the extent of forest reserves the existing reserves should be re-examined make sure that they conform to present-day standards of land-use planning. Such planning must also extend to the 650 million hectares of what was once forest land and is now under some form of shifting cultivation.

The term "reserve" should not be misinterpreted. These forest areas represent demarcated forest; where proper forest management and utilization are planned. Asibey (l989) stated that, they have both productive and protective functions. It's also necessary to get some idea of the intensity of management and utilization. It may not be possible for an African country to secure all this information for all its forests in a first inventory survey.

In regard to the use of forest land the First Session of the FAO African Forestry commission (Ibadan, Nigeria) stressed that:

(a) Systematic forestry can be satisfactorily practiced only in areas specifically and permanently set aside for that purpose. Their location, extent and nature depend upon the forest's protective and productive roles.

(b) Where the retention or extension of forest cover is necessary for the maintenance of land stability and climatic conditions, and for the regulation of water supplies, this becomes the overriding consideration.

(c) As to the productive role of the forest, the satisfaction of present and future local and national requirements, and the provision for export of timber and other produce derived from natural forest or tree cover and plantations on a sustained yield basis must largely determine the distribution and size of such areas.

(d) On land outside such areas, the role of trees in providing additional sources of fodder, fruit, fuel and other produce of value to the agricultural and pastoral communities should be maintained and encouraged (FAO, 1991).

In practice, Asamoah (1985) noted that, the most suitable percentage of forest land in relation to agriculture and other non-forest land will be influenced by topography, climate and soils; by population density and settlement pattern; by economic circumstances including the infrastructure of the region; and of course the condition of the forest itself - accessibility, growing stock, net growth and allowable cut. It is not possible to specify a minimum forest area as a percentage of the total land area of a country or region. Only the consideration of all factors can lead to a proper distribution of the tree cover and to a sound land-use pattern (Boamah 1986).

There are other measures necessary for the formulation and implementation of forest policy, especially forest resources inventories and timber trends studies. Ntiamoa-Baidu (1987) agreed that, a national forest policy cannot be formulated unless the basic facts are known on the location and extent of the forest stands; their ownership; the volume of standing timber; the potential productivity (annual growth less losses); and their importance for protective purposes.

In Liberia, for example, a country in the closed rain forest belt, Annegers 1973 stated that, the national forests have been delineated (1.6 million hectares - 17 percent of the total land area), based on the interpretation of aerial photographs. The second step is the inventory of these national forests; as they will not all come immediately into use, the inventory will be organized in two phases. First, a low percentage of stratified random samplings will delimit the more valuable areas with regard to species; secondly, a higher percentage enumeration to produce improved data for the more accessible areas of economic timber. It is estimated that another 1.6 million hectares of primary and secondary forests are located outside the national forests. Under the new forest land-use policy, an inventory of this area has to be undertaken by the forest industry (concessionaires) and reported to the Bureau of Forestry before utilization can start (Engel, 1984).

It is interesting to note that also in the neighboring Ivory Coast, where forests cover some 50 percent of the country, 17 percent of the total land area has been classified as forest reserves (Abbiw, 1989). When considering how much money a country should spend on forest inventories, Abbiw (1989) stressed that, it is necessary to take into account the capital value of the forests as a national asset, the money to be spent on their development, the income to be derived from them and the losses that would result from faulty planning.

In his research on plant and tradition in Africa, Abbiw (2000) reported that, the demand for forest products grows with increasing population and rising standards of living and the pattern of requirements changes. Timber trends studies establish orders of magnitude for the principal trends of timber requirements and possibilities of supply, and are basic to the planned development of a forest industry. They set out the pattern of wood consumption; they assess forest resources and their utilization by geographic areas; they forecast trends of timber utilization and of losses in the forest; and they assess net balances between prospective requirements and supply, and appraise the resulting problems (Abbiw, 1989). Studies of this kind have been made by government agencies in some of the more advanced countries, and by FAO for Europe, the Far East and Latin America. F AO, in conjunction with ECA, has completed or nearly completed studies of this type in Uganda, Kenya and Tanzania and is soon to undertake one in Sudan. Ghana has requested a similar study. However, the entire African continent will not be covered by such country studies for some years to come (Abbiw, 1989).

2.2 Forestry Production and Forest Industries

According to Agbor, (1986) Africa has 17 percent of the forest area of the world, but only 9 percent of the world forest area in use. These forests contribute only 7 percent of the total forest removals and a mere 1.5 percent of the industrial wood output of the world.

The three classical methods of increasing forest production fit in well with the African picture:

1. Bringing forest into use and production. This means on the one hand making accessible more of the closed rain forests and managing and using them properly; on the other hand, establishing new forest plantations in the savanna;

2. Growing more on the forest land already in use. This means improving existing stands and creating more quick-growing plantations as part of an already productive forest area;

3. Making better use of forest products. This means establishing modem integrated wood-using industries and using fully all removals from the forests and plantations, by employing the latest techniques for making particle boards, fiber boards, pulp and paper, and so on (Ahmed *et al*.,1971).

They also posited that, experience in more advanced parts of the world shows that all three ways can be employed together; By means of higher agricultural yields per unit area, the area of marginal arable and grazing land, especially lands highly susceptible to erosion, can be reduced and the surplus changed back to forest. Better forest techniques can lead to higher increment per unit of area. Mechanized extraction can bring into use previously inaccessible forest resources. Improved mechanical and chemical methods of processing can lessen waste and manpower and achieve higher outputs of forest products.

2.3 Forest Classification

According to Abbiw (1987), forests can be classified in different ways and to different degrees of specificity. One such way is in terms of the "biome" in which they exist, combined with leaf longevity of the dominant species (whether they are evergreen or deciduous). He noted that another distinction is whether the forests composed predominantly of broadleaf trees, coniferous (needle-leaved) trees, or mixed.

Boreal forests occupy the subarctic zone and are generally evergreen and coniferous. Temperate zones support both broadleaf deciduous forests (e.g., temperate deciduous forest) and evergreen coniferous forests (e.g., temperate coniferous forests and temperate rainforests). Warm temperate zones support broadleaf evergreen forests, including laurel forests. Tropical and subtropical forests include tropical and subtropical moist forests, tropical and subtropical dry forests, and tropical and subtropical coniferous forests. Physiognomy classifies forests based on their overall physical structure or developmental stage (e.g. old growth vs. second growth). Forests can also be classified more specifically based on the climate and the dominant tree species present, resulting in numerous different forest types (e.g., *Ponderosa* Pine/Douglas-Fir forest).

Brookfield (1994) agreed that, a number of global forest classification systems have been proposed, but none has gained universal acceptance. UNEP- WCMC's forest category classification system is a simplification of other more complex systems (e.g. UNESCO's forest and woodland 'subformations'). This system divides the world's forests into 26 major types, which reflect climatic zones as well as the principal types of trees. Brookfield (1994) stated that, these 26 major types can be reclassified into 6 broader categories: temperate needleleaf; temperate broadleaf and mixed; tropical moist; tropical dry; sparse trees and parkland; and forest plantations. Each category is described as a separate section below.

2.3.1 Tropical Moist Forest

Tropical moist forests include many different forest types. The best known and most extensive are the lowland evergreen broadleaf rainforests include, for example: the seasonally inundated varzea and igapo forests and the terra firma forests of the Amazon Basin; the peat swamp forests and moist dipterocarp forests of Southeast Asia; and the high forests of the Congo Basin (Howard, 1998). The forests of tropical mountains are also included in this broad category, generally divided into upper and lower montane formations on the basis of their physiognomy, which varies with altitude. The montane forests include cloud forest, those forests at middle to high altitude, which derive a significant part of their water budget from cloud, and support a rich abundance of vascular and nonvascular epiphytes. Mangrove forests also fall within this broad category, as do most of the tropical coniferous forests of Central America.

2.3.2 Tropical Dry Forest

Hong (1989) stated that, tropical dry forests are characteristic of areas in the tropics affected by seasonal drought. The seasonality of rainfall is usually reflected in the deciduousness of the forest canopy, with most trees being leafless for several months of the year. However, under some conditions, e.g. less fertile soils or less predictable drought regimes, the proportion of evergreen species increases and the forests are characterised as "sclerophyllous". Thorn forest, a dense forest of low stature with a high frequency of thorny or spiny species, is found where drought is prolonged, and especially where grazing animals are plentiful. On very poor soils, and especially where fire is a recurrent phenomenon, woody savannas develop.

2.3.3 Sparse Trees and Parkland

Taiga forest near Saranpaul in the northeast Ural Mountains Khanty-Mansiysk Autonomous, Okrug Russia depicts this. The trees include *Picea obovata* (dominant on right bank), *Larix sibirica*, *Pinus sibirica*, and *Betula pendula*. Sparse trees and parkland are forests with open canopies of 10-30% crown cover. They occur principally in areas of transition from forested to non-forested landscapes. The two major zones in which these ecosystems occur are in the boreal region and in the seasonally dry tropics. At high latitudes, north of the main zone of boreal forest or taiga, growing conditions are not adequate to maintain a continuous closed forest cover, so tree cover is both sparse and discontinuous. This vegetation is variously called open taiga, open lichen woodland, and forest tundra. It is species-poor, has high bryophyte cover, and is frequently affected by fire (FAO, 1995).

2.3.4 Forest Plantations

Forest plantations, generally intended for the production of timber and pulpwood increase the total area of forest worldwide. Commonly mono-specific and/or composed of introduced tree species, these ecosystems are not generally important as habitat for native biodiversity. However, they can be managed in ways that enhance their biodiversity protection functions and they are important providers of ecosystem services such as maintaining nutrient capital, protecting watersheds and soil structure as well as storing carbon. They may also play an important role in alleviating pressure on natural forests for timber and fuelwood production (Brookfield, 1994).

2.4 Forest Categories

According to Dunn (1975), 15 tropical forest categories are used to enable the translation of forest types from national and regional classification systems to a harmonised global one. They include:

1. Lowland evergreen broadleaf rain forest - Natural forests with > 30% canopy cover, below 1,200 m (3,937 ft) altitude that display little or no seasonality, the canopy being> 75% evergreen broadleaf.
2. Lower montane forest - Natural forests with> 30% canopy cover, between 1200-1800 m altitude, with any seasonality regime and leaf type mixture.
3. Upper montane forest - Natural forests with> 30% canopy cover, above 1,800 m (5,906 ft) altitude, with any seasonality regime and leaf type mixture.
4. Freshwater swamp forest - Natural forests with> 30% canopy cover, below 1,200 m (3,937 ft) altitude, composed of trees with any mixture of leaf type and seasonality, but in which the predominant environmental characteristic is a waterlogged soil.
5. Semi-evergreen moist broadleaf forest - Natural forests with> 30% canopy cover, below 1,200 m (3,937 ft) altitude in which between 50-75% of the canopy is evergreen, > 75% are broadleaves, and the trees display seasonality of flowering and fruiting.
6. Mixed broad leaf/needle leaf forest - Natural forests with> 30% canopy cover, below 1,200 m (3,937 ft) altitude, in which the canopy is composed of a more or less even mixture of needle leaf and broadleaf crowns (between 50:50% and 25:75%).
7. Needleleaf forest - Natural forest with> 30% canopy cover, below 1,200 m (3,937 ft) altitude, in which the canopy is predominantly (> 75%) needle leaf.
8. Mangroves - Natural forests with> 30% canopy cover, composed of species of mangrove tree, generally along coasts in or near brackish or seawater.
9. Disturbed natural forest - Any forest type above that has in its interior significant areas of disturbance by people, including clearing, felling for wood extraction, anthropogenic fires, road construction, etc.
10. Deciduous/semi-deciduous broadleaf forest - Natural forests with > 30% canopy cover, below 1,200 m (3,937 ft) altitude in which between 50-100% of the canopy is deciduous and broadleaves predominate (> 75% of canopy cover).

11. Sclerophyllous dry forest - Natural forests with> 30% canopy cover, below 1,200 m (3,937 ft) altitude, in which the canopy is mainly composed of sclerophyllous broadleaves and is> 75% evergreen.

12. Thorn forest - Natural forests with> 30% canopy cover, below 1,200 m (3,937 ft) altitude, in which the canopy is mainly composed of deciduous trees with thorns and succulent phanerophytes with thorns, may be frequent.

13. Sparse trees and parkland - Natural forests in which the tree canopy cover is between 10-30%, such as in the savannah regions of the world. Trees of any type (e.g., needle leaf, broadleaf, palms).

14. Exotic species plantation - Intensively managed forests with> 30% canopy cover, which have been planted by people with species not naturally occurring in that country.

15. Native species plantation - Intensively managed forests with> 30% canopy cover, which have been planted by people with species that occur naturally in that country(Dunn, 1975).

2.5 Distribution and geographical ranges of Forests

Forests can be found in all regions capable of sustaining tree growth, at altitudes up to the tree line, except where natural fire frequency or other disturbance is too high, or where the environment has been altered by human activity.

The latitudes 10° north and south of the Equator are mostly covered in tropical rainforest, and the latitudes between 53°N and 67°N have boreal forest. As a general rule, forests dominated by angiosperms (broadleaf forests) are more species-rich than those dominated by gymnosperms (conifer, montane, or needleleaf forests), although exceptions exist (Michon and Bompard, 1987).

Forests sometimes contain many tree species only within a small area (as in tropical rain and temperate deciduous forests), or relatively few species over large areas (e.g., taiga and arid montane coniferous forests). Aumeerudy (1993) noted that, forests are often home to many animal and plant species, and biomass per unit area is high compared to other vegetation communities. Much of this biomass occurs below ground in the root systems and as partially decomposed plant detritus. The woody component of a forest contains lignin, which is relatively slow to decompose compared with other orgamc materials such as cellulose or carbohydrate.

According to Cashman (1987), forests are differentiated from woodlands by the extent of canopy coverage: in a forest, the branches and the foliage of separate trees often meet or interlock, although there can be gaps of varying sizes within an area referred to as forest. Woodland has a more continuously open canopy, with trees spaced further apart, which allows more sunlight to penetrate to the ground between them.

Among the major forested biomes are:

- rain forest·(tropical and temperate)
- taigas
- temperate hardwood forest
- tropical dry forest

2.6 Sustainable forest management

According to Michon *et al.* (1996), the term 'sustainable forest management' can be traced to the non-binding 'Forest Principles' which were prominent outputs of the United Nations Conference on Environment and Development (UNCED) in June 1992. The guiding objective of the Forest Principles is to contribute to the management, conservation and sustainable development of all types of forests and to provide for their multiple and complementary functions and uses. Principle 2b specifically states, "Forest resources and forest lands should be sustainably managed to meet the social, economic, ecological, cultural and spiritual needs of present and future generations."

Momberg (1992) posited that, the concept of sustainable forest management has continued to evolve since 1992 through international forest policy dialogue within the Intergovernmental Panel on Forests (IPF), the Intergovernmental Forum on Forests (IFF) and the United Nations Forum on Forests (UNFF) - and through a large number of country-led and ecoregional initiatives aimed at translating the concept into practice. These include the development of criteria for and indicators of sustainable forest management supported by international organizations including FAO, the International Tropical Timber Organization (ITTO), the United Nations Environment Programme (UNEP) and other members of the Collaborative Partnership on Forests (CPF) (Momberg, 1992).

Sustainable forest management is also the main theme of the FAO Strategic Plan for Forestry (FAO, 1991), whose mission is "to enhance human well-being through support to member countries in the sustainable management of the world's trees and forests". Despite, or perhaps because of, the long maturing process of the sustainable forest management concept, it is difficult to define explicitly what sustainable forest management is. Following the Kotka IV recommendation to use the sustainable forest management concept as a reporting framework, same basic attributes were developed in collaboration with the FRA advisory group and national correspondents (FAO, 1991).

2.7 Improving forest Production

Since commercial timber cuttings in the closed rain forests in Africa are generally "selective," involving the removal of the few best merchantable species, Akinyele and Atinmo (1983), there are two main ways in which production can be improved. The first is to increase the proportion of species now recognized as valuable; the second is to find ways of using economically a larger number of species.

Recognized methods of achieving the first aim are:

(a) Encouragement of indigenous economic species by appropriate management and silvicultural treatment (like the tropical shelter wood system, essentially natural regeneration);

(b) Enrichment of existing forest by planting (artificial regeneration) in blocks, groups, lines, or other patterns of valuable indigenous or exotic species;

(c) Replacement of the original forest or "broken bush" and Forestation of former forest land by plantations of commercially valuable species, often in connection with agricultural crops (Huston, 1994).

On the second way of improving productivity, It is encouraging to note that progress in marketing and processing of timber is leading to the use of many for merry un-merchantable species. Thirty years ago, Bass (1998) noted that, African forest exploitation was linked with trade names like mahogany and okoume. *Triplochiton scleroxylon*, a West African timber (trade names: obeche, wawa, samba, ayous), did not begin to play an important role on the world market until the last decade.

To achieve the greatest value of these closed forests, Ajayi (1978), noted that, the primary natural stands have to be encouraged and enriched - as described above -by the improvement of existing stands and the gradual conversion of mixed forests plantations of quick-growing species within the environment of the natural forests, which can provide intensive production of a uniform raw material for the wood-using industry. If, as in western and eastern Nigeria, the pressure on the closed rain forest area is so great that parts of the forest proper must be converted into cropland, it is often sound land use for areas of lower agricultural potential, generally former forest land, to be made available for forest plantations, together with an allotment of funds. Ajayi (1978), agreed that, this is one of the obvious examples where a change in land use can provide for a fuller use of natural resources.

Burkhill, (1985) stated that, a good example of development of forests comes from Gabon; as supplies of okoume are vital for the maintenance of future production at the present level, it is necessary to carry out a planting programme. Okoume plantations are being established at the rate of 2,000 hectares per year based on a target yield of 300 tons per hectare in a 60-year rotation which would provide 600,000 tons of okoume annually. Furthermore, naturally regenerated okoume stands are subject to silvicultural improvement operations to arrive at an average yield of 50 tons of timber per hectare, against 10 to 15 tons per hectare in unimproved natural forests.

Another example of possible yields comes from Liberia. The National Forest Service made estimates that the volume of merchantable wood of the primary and secondary forests is 4,000 board feet per acre (56 cubic meters per hectare). Thus the 9 million acres (365,000 hectares) of that forest represent a stumpage income for the government of U.S. $ 144 million. The average stumpage price is $4 per 1,000 board feet (5.6 cubic meters). In addition, yearly land use taxes of 6 to 10 U.S. cents per acre (15 to 25 U.S. cents per hectare) and 25 percent income tax over net profits are paid to the government by the wood industry (Coates, 1987).

The price obtainable for timber in effect rules what can be spent on its extraction, so that extraction costs vary with species and markets served. Ingels, (1988) stated that, timber logging and transportation costs in general form the major item in extraction costs and in most cases may represent 70 percent or more of the total cost. It is for this reason that improvements to roads, railways and waterways, as well as to carriers - trucks, railway engines and tugs - are so necessary for an extension of the economic zone from which timber can be extracted. Railway improvement have been largely responsible for the rapid postwar development of production in Ghana and improved roads in the case of Ivory Coast (Ingels, 1988,).

According to Okafor, (1977), in Nigeria and Gabon, where the waterways play an important part, the improvement of tugs and rafting systems has helped, while the advent of the diesel truck has lengthened the economic haulage distance from the forest to the launching point on the rivers. The effect of the improvements is noticeable not only in the expansion of the area for extraction, but also in the range of species extracted. He further stated that, the notable postwar rise in volume of production of utility species such as *Triplochiton* has been made possible by transport improvements, together with the application of timber preservatives to protect logs vulnerable to insect and fungal attack.

2.8 Biological Diversity

'Biological diversity' encompasses the variety of existing life forms, the ecological roles they perform and the genetic diversity they contain (FAG, 1989). In forests, biological diversity allows species to adapt continuously to dynamically evolving environmental conditions, to maintain the potential for tree breeding and improvement (to meet human needs for goods and services and changing end-use requirements), and to support their ecosystem functions. While timber production often dominated the way in which forests were managed in the twentieth century, FAO (1982) reported that, new pressures in the twenty-first century drive a more balanced approach, calling for delivery of multiple goods and services. The process towards sustainable forest management is now considered consistent with the conservation of biological diversity.

The FAO (1975) report stated that, assessing, monitoring and reporting on biological diversity are important activities aimed at guiding sustainable forest management. Monitoring of biological diversity and of the changes caused by forestry practices is important in assessing the effectiveness of management and the cumulative changes brought about by forest use. However, there are conceptual and practical difficulties in doing so. These are not unique to biological diversity per se, but are general inventory problems related to target parameters that are complex and highly variable.

The values derived from biological diversity are associated with different scales that require different assessment methodologies. These include ecosystems, landscapes, species, populations, individuals and genes. Varying and complex interactions exist among all these levels (Hardly and Kartawinata 1993).

Because biological diversity encompasses the complexity of all life forms, Merry and Carter, (1997) agreed that, assessment and monitoring is only possible for specific aspects or particular, defined goals. There is no single, objective measure of biological diversity, only proxy measures appropriate for specified and, by necessity, restricted purposes. Species richness, for example, has a very wide natural vanation from boreal to tropical forests. For policy and monitoring purposes, it is the change in biodiversity that is important, which implies identifying a few relevant indicators and then monitoring them over time. Upton and Bass (l995) stated that, so far this has not been achieved for forest ecosystems on a wide scale (National or Continental), but they noted that, FRA has attempted to establish a baseline for forest ecosystems worldwide, and to provide input into wider biodiversity monitoring work.

FAO (2003a) reported that, most local forest inventories are conducted to estimate harvestable volumes of wood and sometimes non-wood forest products, rather than to monitor biological diversity. An immediate need exists to categorize and substantially improve the understanding of biological diversity with a view to measuring trends, particularly on regional scales. In this respect, the work carried out in the framework of criteria and indicators processes, which all address biological diversity, is an important contribution.

FAO (2006b) stated that, the variables measured in FRA 2005 with relevance to forest biological diversity include:

- Area of primary forests;
- Forest area designated for conservation of biodiversity;
- Composition of forests;
- Number of native tree species;
- Threatened forest tree species.

Biological diversity results suggest, however, that the total area of primary forests exceeds 1.3 billion hectares or 36 percent of all forests, and that the ten countries with the largest area of primary forest account for 88.2 percent of the total area of primary forest in the world (FAO, 2006b).

Great variation exists in terms of the distribution of primary forest, with limited areas reported from the Caribbean, Eastern and Southern Africa, Europe (not including the Russian Federation), North Africa and the arid zones of Western and Central Asia. The largest expanse of primary forest is found in South America (the Amazon Basin). Countries in North and Central America and the Russian Federation have also classified a relatively high proportion of their forests as primary (Leakey and Newton, 1994). The estimated annual net decrease in primary forests of 6 million hectares is alarmingly high. FAO, (2000), reported that, this decrease reflects not only a complete loss of these forests, but also changes within the forest, for instance when primary forests move into the category of modified natural forests due to selective logging. Some countries, notably in Europe and Japan, are reporting an increase in their areas of primary forests, because natural forests have been set aside as 'no intervention' areas.

In 2005, globally, more than 400 million hectares of forests, or 11 percent of total forest area, were designated for the conservation of biological diversity as the primary function. The area of forest devoted to conservation of biodiversity has increased by at least 96 million hectares, or 32 percent, since 1990. This increasing trend is evident in all regions and sub-regions except Northern, Eastern and Southern Africa (FAO, 2006a). Information on the total area of forest, that has conservation of biological diversity designated as one of the functions and management objectives is of considerable interest to the forest conservation community, but information was lacking from many countries. To improve the potential value of this variable, it would be worth refining and simplifying its estimation. This might improve the level of reporting, which was especially low in Africa and Oceania (Vaschuren 1983).

Forest composition is a valuable indicator of biological diversity. Although a significant number of countries reported on the composition of their forests in terms of growing stock, FAO (1997a) reported that, information was unavailable for many countries, which makes a detailed analysis of the value of the indicator difficult. Fried and Sardjono (1992) stated that, there is also great variation in terms of forest tree species diversity, from limited numbers of individual species in boreal ecosystems to high species richness per area unit in Central and South America, South and Southeast Asia, and Western and Central Africa. Boreal forests tend to harbour the lowest species diversity. On average, the ten most common tree species in a country account for 76 percent of total growing stock.

The exceptions by region are found in Central America, South and Southeast Asia and Western and Central Africa, where percentages range from 22 to 47 percent. In Europe and Western and Central Asia, the ten most common tree species account for more than 90 percent of total growing stock (Poulsen, 1981). Information was missing from many countries in South America (including Brazil) and from most of the countries in the Congo Basin, both areas of known high species diversity.

According to FAO (1995), the combined list of the ten most common tree species from all countries contained 445 different species. Five genera (*Pinus*, *Quercus*, *Picea*, *Abies* and *Fagus*) make up almost one-third of the number of species reported as being most common. This may be influenced by the fact that Asia and Europe are over-represented, in terms of the number of countries that reported on this topic, relative to their total forest area. FAO, (2001 b) reported that, no change in the relative importance of different species was found between 1990 and 2000; nor were major changes noticed in the share of growing stock occupied by the three most common species.

The theme concerns the conservation and management of biological diversity at ecosystem (landscape), species and genetic levels. Such conservation, including the protection of areas with fragile ecosystems, ensures that diversity of life is maintained, and provides opportunities to develop new products in the future, including medicines (FAO 2000). Genetic improvement is also a means of increasing forest productivity, for example to ensure high wood production levels in intensively managed forests. The five most forest-rich countries (the Russian Federation, Brazil, Canada, the United States and China) account for more than half of total forest area (2,097 million hectares or 53 percent) (FAO 2003b). Forests need to be managed so that the risks and impacts of unwanted disturbances are minimized, including wildfires, airborne pollution, storm felling, invasive species, pests, diseases and insects. Such disturbances may impact social and economic as well as environmental dimensions of forestry (Weinstock 1983).

Forest area provides the first indication of the relative importance of forests in a country or region, while estimates of forest area change over time provide an indication of the demand for land for forestry and other land uses, and may also illustrate the impact of significant environmental disasters and disturbances on forest ecosystems. Forest area is relatively easy to measure, and this variable has therefore been selected as one of the 48 indicators for monitoring progress towards the Millennium Development Goals agreed by the United Nations (particularly Goal 7 - Ensuring environmental sustainability) (FAO 2002c). Data on the status of and trends in area of forest are crucial to decisions related to forest and land-use policies and resource allocations, but they need to be combined with information on the health and vitality of forests and their socio-economic and environmental functions and values, the report stated.

It should also be kept in mind that primary forests fulfill many essential functions other than the conservation of biological diversity: soil and water conservation, carbon sequestration and the preservation of aesthetic, cultural and religious values. Dove (1993a) observed that, as forests shrink, wildlife disappears and economies sputter, one business keeps booming in the Congo Basin forests: logging. Along with pressures caused by population growth over the last decades, unregulated and often illegal extraction of timber puts wildlife, local people and economies at risk.

2.13 Rising demographics and the implications for forests

The greatest loss of forests in recent years has occurred in countries with a high population growth. This demographic trend has led to increases in shifting cultivation (a form of subsistence farming), natural forests being converted into plantations and cash crops contributing to forest loss in the region (Dove, 1993). Ansa (1986) stated that, there's a more serious factor affecting the prospects of the Congo Basin forests: unrelenting timber demand from around the world. China, Europe and the US are importing vast quantities of wood products from the forests of Gabon and Cameroon. These are powerful incentives for the continued extraction of wood from the Congo Basin forests. The chimpanzee, recently shown to be the potential source of the HIV 1 virus in humans, is also endangered. Its forest home is being logged and it continues to be hunted and sold as food in and around the Congo Basin forests.

Also, Ansa (1996) in his works noted that, with human populations growing at 2% to 3 % and subsistence agriculture still the main source of food and income for most people in the Congo River Basin, habitat loss, bushmeat trade and climate change are likely to be the most significant long-term threats to biodiversity. Continuing global demand for the timber resources of the region's forests will also make conservation efforts particularly challenging. To understand the situation in today's Congo River Basin, one must go back in time to the era of foreign colonization. When the region's countries gained their independence, Momberg (1992), stated that, the colonial powers in Central Africa left an unstable and flawed foundation upon which to build modem states. Economic structures favoured foreign investment, particularly in the extractive industry, and little had been achieved to empower and build the capacity of citizens.

The political division of African territories may have facilitated resource extraction and tax collection, but it also seriously disrupted traditional governance, land use, trade networks and population movements (Ardayfio, 1986). Today, environmental issues are just one of the items on the 'to-do' list of several Congo River Basin countries. Better education and infrastructure, employment opportunities, improved public services, more foreign investments are some of the many priorities vying for support. Clearly, environmental concerns need to be well integrated in all of these areas if they are to be successful.

2.10 Plantation (reserves) Forestry as a Solution

Timber shortages are clearly either real or in prospect, posing a severe threat to both entrepreneurship and employment. Given a low rate of success with enrichment planting, growing emphasis is now being placed on plantation forestry to ensure future supply. Though some planting was done on a small scale in the 1970s, the first serious effort began in Sabah in 1983, initially with pines. Other fastgrowing exotics are now mainly used, principally *Acacia mangium*, *Paraserianthes falcataria*, *Gmelina arborea*, and, sometimes, *Eucalyptus deglupta*. The sites are cleared completely, but without destumping; weeding is required until the seedlings have become young trees and developed a shading canopy. The result, however, should be a forest composed entirely of useful timber, with a high rate of production. In the Peninsula, a sustainable yield on a cycle as short as 15 years is anticipated (Addo-Ashong, 1987). In general, most areas to be employed are among those already heavily degraded by earlier logging.

With the exception of *Gmelina arborea,* which makes reasonable furniture, the fast-growing timber is suitable only for construction purposes and as pulpwood or as fillers in plywood. In timber-short Sabah, plans for the five years 1991-1995 included 3,200 km2 of new forest plantations (Dove, 1994). This is in addition to the large area designated for enrichment planting. It seems likely that much of the new effort will be in areas burned in 1983, 85 per cent of which had been logged (Whitmore, 1999). By contrast, only 420 km2 are planned for the Peninsula, where the principal reliance continues to be placed on tighter forest management. In Sarawak, forest plantations hardly exist, and plans for the five years 1991-1995 included only 200 km2, yet for some badly degraded areas in western and west-central Sarawak they could be a very suitable use of land.

FAO, (1995) reported that, Indonesia has already stepped up its reforestation efforts using mainly *Acacia mangium*, with a view to the future establishment of pulp and paper mills. There have been experimental plantings going back more than a decade on one huge concession in East Kalimantan. At Pulau Laut, off the south-east coast, problems of insect infestation and inappropriate varieties have been encountered and overcome. The selective logging system is now termed the "selective logging and planting system" and, in a new move to encourage investment, the government has permitted areas quite separate from the concessions to be leased for plantation forestry for 35year periods (FAO, 1997). Although reforestation is supposedly practiced on a part of every concession, little has been developed. This is almost everywhere the case, even in the better-managed Peninsula (Coates, 1987).

In Indonesia moreover, a new type of transmigrant settlement, called HTI (Hutan Tanaman Industri)- Trans, aims at supplying 30,000 Javanese families to West Kalimantan as a labour force for the total replanting programme, estimated to cover 300,000 hectares in 1992/93. These workers, who had previously been engaged on two year contracts for development of tree-crop settlements, will extend these contracts to work on tree planting (FAO 2001a).

2.11 Ecological risk in plantation forests

Plantation establishment are still regarded as highrisk ventures, with a considerable degree of skill required in monitoring and management (Shiembo, 1986). Moreover, there is risk of disease and pest invasion owing to the narrow genetic base; it is acknowledged that the whole stock of *Acacia mangium* in Sabah for example, comes from a single Australian parent (Michon *et al*, 1994). It has been reported from several sources that up to one-third of *Acacia mangium* in some plantations are affected by a rot that causes hollow boles, making the timber of no use for any purpose but wood chipping and pulping, and adding to the danger when felling (Hadley and Kartawinata, 1993; Hashim, 1991). Most certainly, biodiversity within plantation forests will be extremely low.

Moreover, in areas where drought is a recurrent hazard, important questions arise regarding the drought-tolerance of the planted species. Most have little fire resistance, and there is the additional risk that repeated fire could lead to abandonment and conversion of the sites to Imperata cylindrica grassland (FAO, 2002a). Fire risk is most serious where the preexisting vegetation is already grassland. The grass bums readily in the dry season and, even in normal years, some of the new plantings have already been lost. There are risks and· the social problems associated with these replanting. FAO, (2003b) reported that, this rapid decrease stems not only from deforestation, but also from modification of forests due to selective logging and other human interventions - whereby primary forests move into the class of modified natural forests. The rate of loss of primary forests is stable or slightly decreasing in most sub-regions, but is increasing in South America and, to a lesser extent, in North America. Brazil and Indonesia alone account for an annual loss of primary forest of 4.9 million hectares. The data collected do not permit an analysis of how much of this net loss is due to deforestation and how much is owing to areas of forest moving into the modified natural forest class (FAO, 2002b).

2.12 Initiatives on the Sustained Ability of Forest

The expansion of sustainable development initiatives in the 1990's reflected an emphasis on integrated solutions to economic development, sociopolitical stability and environmental health in the global community. The Brundtland Commission (Vincent, 1988) and the 1992 Earth Summit in Rio de Janeiro, Brazil, formed the springboards for many of today's initiatives (Gouyon *et al.,* 1993). In the forestry sector, a myriad of efforts to achieve sustainable management of forest resources have emerged. It is perhaps a subjective and debatable endeavor to assign a level of quality to any type of resource management system; yet, one such initiative, timber certification, has been put forth as a viable alternative to existing regulations, codes and practices which strive to do so. Upton and Bass, (1995) stated that, although sustainability has many definitions, in most cases it reflects a development paradigm to balance the temporal and spatial existence of resources and the needs of a society to use those resources. They maintained that, the potential impact of timber certification on the sustainability of forest resources is difficult to predict; however, the emergence of timber certification into the forest policy and forest management arenas around the world is indisputable and requires examination.

Timber certification involves the evaluation, monitoring and labeling of wood production from stump to end use. First, the management of a forest area must be certified according to a set of standards or principles of sustainable forestry for a particular forest region. This process is known as forest certification (Upton and Bass, 1995). The production and distribution of products from the stump to the final consumer must be confirmed through the chain-of-custody associated with the final product. Finally, the label attached to the final product must reflect the degree or scope of the certification proclaimed. Given that worldwide, forest products trade was valued at more than USD 128 bill in 1995 (FAO 1997a), the potential impacts of certification on markets cannot be ignored.

2.13 Functional Roles of Forests

2.13.1 Riparian Forests

Okafor, (1983) stated that, protecting stream and river banks from undue horizontal erosion is only one function of a buffer zone of trees along both sides of a watercourse. The buffer area also acts as a filter and depository for sediment, pesticides and fertilizers from upslope land use. It may also reduce water temperatures through shading, thereby improving conditions for many forms of aquatic life. Several countries find this protective function so compelling that they have established 'green stream corridors' or they protect such corridors through zoning regulations, including mandatory practices in logging. This trend merits being continued and accelerated.

2.13.2 Forests Mitigating Salinity

Secondary salinity, as opposed to natural (or primary) salinity, can be caused by the removal of forests. Reduction of the evapo-transpiration of deep-rooted trees causes a rise in the water table. In areas in which salts are present in the lower layers of the soil, this higher water table can bring salts into the root zone and adversely affect plant growth, even proving toxic. This is especially critical where clearing and establishment of crops is attempted. It is estimated that perhaps 7 percent of the agricultural area of Western Australia is suffering from such secondary salinization in lands formerly forested (Ghassemi, *et al.*, 1995). Moreover, saline water draining from such areas can adversely impact downstream or downslope usefulness of water. Reforestation in these areas has made salinized land useful once again. Forests are thus playing a protective role in areas prone to soil salinization. Wood harvesting, followed by regeneration, should not result in salinity as long as clear-felled areas are not extensive.

2.13.3 Productive Functions of Forest Resources

Forests and trees outside forests provide a wide range of wood and non-wood forest products. (FAO 2000) noted that, this theme expresses the ambition to maintain an ample and valuable supply of primary forest products, while at the same time ensuring that production and harvesting are sustainable and do not compromise the management options of future generations. Forests and trees outside forests provide a wide range of wood and non-wood forest products. The productive function of forest resources is a common thematic element of all the eco-regional criteria and indicator processes. This reflects an ambition to maintain an ample, valuable supply of primary forest products, while at the same time ensuring that production and harvesting are sustainable and do not compromise the management options of future generations (FAO 2004a; 2005c; 2003a). Describing the forest resource as a provider of goods has traditionally been one of the main objectives of global forest resources assessments. Earlier assessments focused on timber supply, but the concept of forest production has since widened to encompass all types of wood and non-wood forest products.

Forest plantations - a subset of all planted forests are defined as forests of introduced species and in some cases native species, established through planting or seeding, with few species, even spacing and/or even-aged stands. Productive forest plantations are defined as forest plantations predominantly intended for the provision of wood, fiber and non-wood forest products (Leakey 1996). Productive plantations can also provide protective, recreational, amenity and other functions, which are not precluded by the harvesting of products. Some forests classified as semi-natural include planted trees of native species, most of which are used for productive purposes. As these forests do not fall under the forest plantation definition, they are not included in this analysis. The FRA 2005 thematic study on planted forests provides a more detailed analysis of both forest plantations and the planted forest component of semi-natural forests (FAO 2006b).

2.13.4 Protective Functions of Forest

The theme addresses the role of forests and trees outside forests in moderating soil, hydrological and aquatic systems, maintaining clean water (including healthy fish populations) and reducing the risks and impacts of floods, avalanches, erosion and drought. Okafor (1997) stated that, protective functions of forest resources also contribute to ecosystem conservation efforts and have strong cross-sectoral aspects, because the benefits to agriculture' and rural livelihoods are high. Recognizing the important protective role of forests, many countries have planted substantial areas of forests and trees for this purpose. These range from large-scale forest plantations to stabilize sand dunes and combat desertification to windbreaks and individual trees planted to provide shade. For FRA 2005, countries were asked to characterize their forests in five classes: primary, modified, natural, semi-natural, protective plantation and productive plantation (FAO 2006a). Protective forest plantations are defined as those with introduced species and in some cases native species, established through planting or seeding, with few species, even spacing and or even-aged stands, predominantly for the provision of services such as protection of soil and water, rehabilitation of degraded lands, combating desertification, etc (Dunn 1975) .

Some countries had difficulty in differentiating whether the purpose of a forest plantation was predominantly productive or protective because of forest plantation management policies for multipurpose or multiple functionality. Protective forest plantations do not totally preclude some harvesting of wood, fiber and other products. It should be noted that this category only captures a subset of all the forests and trees planted for protective purposes. It does not include, for instance, the planted component of semi-natural forests (sown or planted native species), windbreaks with a width of less than 20 m or an area of less than 0.5 ha or individual trees or groups of trees (Padock ., 1985).

2.13.5 Socio-Economic Functions Forests

The theme covers the contributions of forest resources to the overall economy, for example through employment, values generated through processing and marketing of forest products, and energy, trade and investment in the forest sector. It also addresses the important forest function of hosting and protecting sites and landscapes (FAO 1989). Forests provide a wide range of economic and social benefits to humankind. These include contributions to the overall economy - for example through employment, processing and trade of forest products and energy - and investments in the forest sector. They also include the hosting and protection of sites and landscapes of high cultural, spiritual or recreational value. Maintaining and enhancing these functions is an integral part of sustainable forest management (Dove 1993a).

Information on the status of and trends in socio-economic benefits is thus essential in evaluating progress towards sustainable forest management, together with the more usual statistics on the predominantly environmental values considered under the other themes. Economic benefits are usually measured in monetary terms and may include: income from employment in the sector; the value of the production of goods and services from forests; and the contribution of the sector to the national economy, energy supplies and international trade. In addition, Okafor (1977) stated that, the economic viability or sustainability of the sector can be assessed by measures such as the profitability of forest enterprises or the level of investment. The social functions of forests are often more difficult to measure and can vary considerably among countries, depending on their level of development and traditions.

For example, Addey (1982) stated that, in developed, post-industrial societies, the benefits of forests for recreation and amenity values or the maintenance of a rural way of life may be most important, while in developing countries, the area of forests available for subsistence activities or the number of people employed in the sector may be a better indication of their social value. Given the difficulties of measuring the social benefits of forests, Watanabe (1990) asserted that, social functions are often measured in terms of inputs rather than outputs (e.g. the area or proportion of forests used to provide various social functions). A wide variety of variables may be measured: production and consumption; recreation and tourism; funding and investment in the forest sector; cultural, social and spiritual needs and values; forestry employment; health and safety; and community needs (FAO 2000).

In FRA 2005, countries provided information on four measures of socio-economic functions: Value of wood and non-wood forest product removals. FRA 2005 examines the production of primary products, excluding the benefits of downstream processing (FAO 2006b). In general, FAO (2006b) the measures presented in FRA 2005 are more restrictive than those proposed in some international criteria and indicators processes because they refer to benefits from forests only (rather than benefits from the whole forestry sector, which include downstream processing). The availability of information was highest for the area of forest designated for different functions and ownership of forests and lowest for the value of NWFP removals.

2.13.6 The Emergency or Buffer Role of Forests

Forests have traditionally provided food and marketable products during emergency periods of food shortages, illness or death. This function is well illustrated in stories from the region in which trees are portrayed as providers during famines. Early works, such as Bukhill (1985) study on the emergency uses of forest products, also illustrate the former importance of forests as a buffer source of food supplies. He relates that forest tubers, roots and rhizomes were the main source of energy during famine times. It is not however clear, from recent accounts, whether and how this function has changed in the last few decades. Forest resources have declined, so too has people's knowledge of their varied resources. In addition, the commercialised rural economies and food aid programmes may, in some cases, substitute for the food buffer forests once provided. It can be postulated that marketable and processed forest products provide a means for earning cash income during emergencies, although no information has been found on this issue (Coates 1987).

2.14 Assessing the Value of Forest Resources by Their Functions

There are a multitude of household uses for forests. Some are region specific, while others are specific to a group of people, or even a household. In examining the uses of resources by individual households, and in assessing their importance at a regional level, it is more useful to focus on the functions they serve rather than the specific species exploited (Herren-Gemmill 1988). People are not concerned with trees themselves; they value functions such as cooking, warmth, food, medicine and shelter. Information on the functions of forest resources can be found in anthropological and geographic household-level studies, as well as in studies evaluating the uses of farm fallow trees (Asamoah 1985, Boamah 1986, Dagogo 1981, Nwoboshi 1986, Herren-Gemmill 1988, Okafor 1979). In regions where the natural forests have disappeared, useful trees are often incorporated into the farming systems (Okafor 1983, Oyakhilome 1985). For this reason studies of on-farm trees often reveal information on the functions that forest resources once served. Poulsen (1981), also suggests that forest products can be classified by function.)

This study has identified many of the common functions forest products serve in households throughout the West African forest region:

* Food (both animals and plants) to supplement the diet and meet seasonal shortages;

* Drinks: palm wine and alcohol, "water";

* Food and cash buffers or insurance in emergency hardship periods;

* Medicines and dental chewing sticks;

* Fuel, for all household and enterprise needs;

* Marketable products exploitable for cash income (e.g. cola nut);

* Material for house construction: poles, bark, liana, palm roof tiles and other roof leaves, wattle slats, timber;

* Material for household, agriculture, hunting and fishing equipment;

* Yam and other crop stakes;

* Materials for crop storage containers;

* Fencing and boundary markings;

* Fodder

* Shade

* Inputs for processing enterprises (e.g. fuelwood);

* Locations for social, religious and healing ceremonies;

* Symbols of cultural and religious identity and importance (Okafor 1983).

By focusing on the functions of forest products the role of these products can be examined and information from different areas of the region can be compared. In addition, this focus allows one to examine how uses change over time and by setting. For example, in examining the function of foods gathered from forest areas, Okafor (1979) noted that, similarities can be seen across the region: forest foods provide dietary staples and supplements; fill in seasonal and emergency food shortfalls; and provide specific nutrients and culturally symbolic foods. Forest leaves, nuts and wild animals are used in sauces which accompany main meal staples. Forest fruits and insects are consumed largely as snacks, especially by children and during periods when agricultural work is most time-consuming. Mushrooms are consumed as meat substitutes, and are generally available only during the rains. Forest foods may have particular cultural value (such as the cola nut, a sign of welcome in many parts of the region). Some forest foods provide regular supplements to the diet, others are consumed seasonally, when staple food supplies dwindle or during peak labour periods when little time is left for cooking. Still other forest foods are used only in emergency periods when no other foods are available. These generally differ from regularly consumed products; they are more energy-rich but require lengthy processing (Umeh 1987; Okafor 1977; Olawonye and Ajayi 1975). What is important about the focus on function is that discussions move beyond species descriptions.

The changing uses of forest resources can also be viewed in terms of their evolving functions. For example, in some cases forest foods may no longer provide the diverse range of produce which they once did. But culturally important foods may still be widely consumed. In other instances, Agbor (1986) asserted that, the growing market for some forest foods (e.g. *Irvingia gabonensis* seeds) may have changed their role in rural areas; trees may now be valued as a source of cash income. Concomitant with these changing functions, changes in the ways in which these products are valued and managed may ensue. In southern Benin, for example, a new technology for palm alcohol distilling was introduced which changed the way the raphia palms were used and valued. Formerly they had served a great range of household functions and had been used by anyone in the community, but with the introduction of this new technology, they were rapidly overexploited because of the nearby urban market for palm alcohol (Bukhill 1985).

There can be little doubt that the functions of forests will change for households in the rural regions of southern West Africa. Adeola and Decker (1987) observed that, the relative importance of different forest products may also change: this can already be seen as some products take on more of a commercial value. But, for most of the functions listed above, contemporary evidence suggests that forest products are still important for the majority of rural households. Although substitutes exist for many non-timber forest products, few people have the resources to buy them. Perhaps for this reason, of those noted above only "material for household, hunting, and fishing equipment", "foods as a buffer during emergencies", and "drinks" appear to be of declining importance throughout the region as a whole (Dines and Kalbar 1992).

Many different factors work together to limit or alter the way forest resources are used. Widespread forest degradation caused by expanding agricultural land clearing, conversion to plantations (cocoa and timber), and timber exploitation all diminish people's access to forest products (Okafor, 1977). In addition, migration from rural areas to urban centers has created larger markets for some forest products. Increased commercialization of rural economies in conjunction with increasing populations and degradation of the forest resource base, have served to increase the pressure on dwindling resources.

2.15 The Impact of Forest Degradation on Forest ResourceUse

In some regions formerly plentiful supplies of wildlife, medicines and supplementary foods have practically disappeared. This is not to suggest that decline substitutes are not adopted or that cleared forest lands reap no harvests. The degradation of the forest quite naturally leads to an in resource use. However, in the West African region there are some forest "products" which cannot be readily replaced; those that serve cultural or symbolic functions are especially important (e.g. bushmeat, medicines, and housing material). For example, in Korang (1986) study of the impact of forest conversion on surrounding residents, a diminished supply of locally valued forest resources was noted. These losses had not been replaced with substitute products from the plantations. Thus people had lost a source of income (sale of canes and chewing sticks), food (bushmeat), and medicine.

In some cases, deforestation has reduced the extent to which forest resources are used. Jost (2007) noted that, among the Ando in Cote d'Ivoire a decline in knowledge regarding medicinal plants and their uses has resulted from a decline in actual forest resources. In the case of plant medicines this loss of knowledge is particularly troubling, as traditional medicine is the only health care available to the majority of those living in rural areas of this West African region. In Western Cameroon, Korang (1986) noted that, there are many forest foods which are decreasingly exploited. He adds that almost all of the region's natural vegetation has disappeared. Traditional supplemental foods are not available in exploitable quantities and new foods that are imported from other regions have taken their place. Forest foods with particular social value are still consumed on ceremonial occasions though these products are often specially protected or produced on farms for such occasions.

The greatest amount of information on the impact of forest degradation comes from studies of wildlife decline. Several studies have shown that bushmeat consumption is limited by the supply of wildlife (Ajayi 1971, Asibey 1977, Ntiamoa-Baidu 1987, Huston 1994). In southern Cameroon, Gouyon *et al*. (1993) asserted that the decline in bushmeat consumption, caused by reduced supply of wild animals, has resulted in deterioration in the quality of people's diets. The risks associated with a continued decline in supply become particularity great when it is realised that, as discussed earlier, it is difficult to substitute for wild animals; livestock production is difficult in this region. Fuelwood scarcity has led to a range of different problems. In the southern regions of Ghana, Ardayfio (1986) has found that fuel wood scarcity has forced households to purchase fuel at the expense of food (in one village household, fuelwood expenditures rose from 1 % to 16% of total expenditures within a few months), cooking time is being reduced and, in some cases, different foods are being used.

The additional time that must be spent collecting fuel wood has increased the negative health effects of fuelwood gathering, and women's income earning activities which require high fuelwood energy inputs, have, in some cases, been curtailed because the fuel costs have become prohibitive.

2.16 Use of Forest Tree Species on Farm Lands

In some areas the combination of declining forest resources and increasing market demand for certain products has resulted in increased use of forest trees on farm lands. This is occurring, to different degrees, throughout humid West Africa. Its predominance depends upon the amount of land pressure that exists, the quality of nearby forest resources, traditional tenure regulations, the extent of commercialisation, and the markets for forest products. In Nigeria, on-farm trees are valued for cash income, shade, fruit, fuelwood, wood for building material and agricultural implements, soil conservation, and palm wine (Okafor, 1979). As nearby forests disappear it is not only trees with marketable products which are increasingly left on farms, trees with food crops or particular household uses such as those used for medicine production, are also being preserved and supplemented (Umeh 1987).

Generally it is believed that many of the West Africans from the region do not plant trees. Trees on farm lands are most commonly those that have been left and protected during forest fallow and cultivation periods, or transplanted wildlings. But, tree planting on farm lands is increasing. In southern Nigeria, where land pressure is at perhaps its highest in the West African region, the number of trees being planted on farm and fallow lands is increasing (Okafor 1979). Currently approximately 37% of the farm and fallow land trees were planted Okafor also noted. In southeastern Nigeria, there is a considerable amount of research evaluating trees on farm lands. One hundred and seventy-one (171) common farm and fallow land forest tree species with edible products have been identified; the density of these species is often far greater on farm lands than in natural forests (Okafor 1977). On-farm trees serve a multitude of household functions while providing support to agricultural production (e.g. yam stakes and mulch) and a source of cash income. Okafor (1983) found that the tree species with the greatest number of household uses were often incorporated into compound farms while less frequently used species were found in outlying fields.

Okafor also examined the relative predominance of tree planting and protection. His analysis showed that more *Dacryodes edulis* and *Irvingia gabonensis* were planted than were protected. On the other hand, *Treculia africana* and *Pentaclethra macrophylla* were generally protected rather than being planted. At the Anambra State Forestry Research Station *Irvingia gabonensis* and *Dacroydes edulis* seedling demand far exceeds supply (Okafor 1983). Both of these species have valued traditional uses as well as an important market value. In other parts of West Africa, tree planting also appears to be of growing importance. In Western Cameroon, Engel (1984) notes that natural vegetation has almost disappeared. He finds that many useful forest species are protected and planted in hedgerows, especially those with market value. In Sierra Leone, Engel (1984) has also found that most farmers are interested in planting trees on their farms. The most valued species for planting are oil palm and other food trees.

Fruit trees are of growing importance. In an examination of agroforestry systems in southeastern Nigeria, Njoku (1983) found that trees (especially fruit trees) were being incorporated into farms with increasing frequency. Trees were generally protected as wildlings though they were planted as boundary demarcations; generally those with long gestation periods were selected for this purpose, (e.g. *Mansonia altissima* and *Nauclea diderriehii*). In the Ho district (Ghana), approximately 75% of the fallow field tree species have medicinal uses (Asamoah 1985). In Nigeria medicinally valued trees are also predominant on farm and fallow lands (Okafor 1983). For example, the leaves of *Jatropha curcas* are used for treating ringworm (the seeds are used as a soup ingredient).

Okafor (1983) found that at least half of the produce gathered from on-farm and fallow land trees was consumed by the household rather than being marketed, though strong markets for these tree products did exist. Another study in southeastern Nigeria echoes Okafor's (1983) findings. It reveals that a great portion of the tree product harvest is consumed by the household rather than being sold: for example, 78% of the *Irvingia gabonensis* fruit and seeds harvested from compounds are consumed by the household (Njoku 1983). In addition to planting trees, changes in the commercial value of forest products has, in some cases, led to changes in traditional regulations over tree products. For example, in a rural community near Accra, in Ghana, Shiembo (1986) found that the increasing market value of fuelwood led to severe exploitation of the woody vegetation, and changes in the rules associated with resource use. Fuelwood became a privatized commodity, and could now only be collected from people's own farm lands. Thus landless people in the community were forced to purchase their fuel.

In some instances changes in tree tenure systems may reflect increasing market demand for certain forest products and a rapid decline in resources themselves. This may be the case in Casamance, Senegal, where FAO (1976) reported that, the traditional rights associated with forest products have changed with the decline of forest resources. Formerly, access to forests was "open", then rights to forest areas surrounding farm fields and especially the vast array of palm products from them, were restricted. Increased tree planting can also be a sign of increased privatization as it is traditionally a sign of ownership in some parts of humid West Africa. The introduction of a new technology for palm alcohol production in southern Benin catalyzed changes in the management and value of raphia swamp resources. In village areas with considerable raphia resources a system of communal management has developed. However, in villages with good access to the Cotonou urban market, excessive overexploitation has sometimes led to privatization of raphia groves (Addo-Ashong 1987).

In many cases, raphia groves have been divided among villagers who have been given permanent rights to parcels of grove. By tradition, raphia is never planted; it is seen as a gift of God. However, since the privatization of these areas people have begun to plant young seedlings (Enunwaonye 1983). Good seed trees are now protected and their seeds are distributed among the villagers who raise and transport them into the groves. In some cases the privatization has led to clearing of the raphia groves for vegetable cultivation which, because it can be undertaken in the dry season, leads to higher profits. In both cases the increased marketability of a forest product has led to changes in the management of a formerly "free" resource. As forest resources decline, their utility and value to local people may diminish. Some authors suggest that loss of knowledge about traditional foods, medicines and uses of surrounding resources are indications of cultural disintegration and impoverishment (Okafor, 1999). There is, however, little concrete information on either the changing uses of forest resources or the differential uses of different forest types. The examples presented in this section highlight some apparent trends. They suggest that it may be possible to manage both forest and fallow land in such a way that the production of increasingly valued (both commercially and domestically) forest products is supplemented.

There can be little doubt that the rapid changes to the environment which are occurring throughout the West African humid zone affect the ways these forest resources are used. In some cases new products introduced from urban areas (and foreign markets) are replacing traditional forest goods. In other cases, however, Agbor (1986) observed that, commercialisation and resource decline have placed a high market value on forest products, especially those that cannot be replaced for cultural (e.g. Irvingia seeds), environmental (e.g. bushmeat), or economic (e.g. medicines) reasons. While the expansion of agriculture and human settlements into formerly uncleared forest areas has destroyed many forest resources, it has also created new habitats for other commonly used resources (e.g. grasscutter). Clearing and forest fallow cycles favour much-used species such as oil palms.

2.17 The Value of Forest Products at local and National leves

The information that is needed to assess the importance of forests and forest resources at the rural household level differs from the information that is needed to assess their national or regional importance. At a national and regional level relevant information can include: the number of people employed in forest-related activities; the forest products with an export market; the uses of forest resources by regional and national enterprises; the availability of raw materials from the forest; the number of small forest based enterprises; and extrapolations of the quantities of forest resources exploited over a region (FAO 1995). However, at the local level, Ajayi, (1971) stated that, the importance of forests and forest resources can best be determined through more detailed examination of information about people's values and daily needs. As was noted at the outset, little information exists in the literature to directly assess the value people place on forests and forest products. There is however, a great deal of indicative information which can be used to assess the local importance of forest resources. The following discussion draws on some of these examples in order to illuminate different ways in which the value of local resources can be assessed (Ajayi 1978).

The local value of forest resources is perhaps most insightfully assessed by reviewing studies which examine either people's responses to abrupt changes in their forest environment or the impact of development projects that change either the forest or people's access to the forest (Okafor 1983, Nigeria; Engel 1984, Cameroon). Korang (1986) conducted an interesting study on the local impact of the Subri development project in Ghana. The Subri project converted a large forest area to a *Gmelina arborea* pulp and fuel wood plantation. People from the surrounding area said that the project provided employment and improved roads. However, at the same time their supply of forest products diminished and housing and food prices increased. Ninety-four percent of 'those interviewed complained that the project reduced the supply or their access to forest resources. In their view the most important losses were bushmeat, chewsticks, canes, poles and other housing materials, and condiments. Korang noted that for many local residents the formerly abundant supplies of chewing sticks and canes had provided a source of income (these products were gathered and sold to wholesale traders).

A study (Boamah 1986) of an agricultural development project in Northern Sierra Leone provides another example. The project, a rice production scheme, parcelled out areas of formerly common land. As a result of these allocations, the study asserts, non-project farmers no longer had access to raphia palm groves, their source of building materials, food, wine, and raw materials for basketry and furniture making. As was the case in the preceding Ghanaian example, the project had not considered the value of these forest resources for local consumption and income earning opportunity.

2.18 Seasonal Variation in the Use and Importance of Forest Products

Perhaps one of the most crucial functions of forests is that they provide products for consumption and sale during seasons when other foods and sources of income are less prevalent (Okafor 1979). Although the seasonal variations may not be as pronounced in the humid zone when compared to more arid regions, forest product use still complements the seasonal agricultural cycle. Many smallscale enterprises are run seasonally, when labour is available. In rural Sierra Leone fuel wood collection for market sale is concentrated in the off-peak agricultural season, thereby providing income in a period when food supplies are generally at their lowest (Asamoah 1985). Similarly, palm oil processing takes place when cash is needed for food purchases. The palm fruit and kernels are processed as soon as they are harvested, despite the fact that returns would be higher if they were saved and processed later in the season (a result of seasonal variations in selling prices) (Engel 1984). The income earned in forest based processing and gathering activities often plays an essential part in the agricultural cycle. In rural Sierra Leone, income from fuelwood sales (the first returns from cleared lands) is often used to purchase agricultural inputs such as seeds or equipment (Ansa 1986). Similarly in Ghana, the income that is earned from bushmeat sales is often invested in agricultural production (Asibey 1989b).

Many forest products are gathered and consumed seasonally. In most cases this reflects a seasonal need for food supplements. However, in some instances forest foods are only available in specific seasons. Perhaps the most popular examples are snails and mushrooms which are both generally only available at the beginning of the rains in a review of bush foods consumed in southern Cameroon, Engel (1984) found that plant foods gathered from wild areas (notably forests) were most valued when other food sources were unavailable - at the end of the dry season. Michon *et al*., (1994) more recent study in Banen, Cameroon reiterates these findings suggesting that forest foods are still very important during the off-peak agricultural season. Okafor's study (1983) on forest foods in markets in southern Nigeria reveals that many are available in seasons when cultivated varieties are in short supply. He notes that these foods are only available in the dry season because they are gathered from the forest. In some cases forest species are cultivated (e.g. *Gnetum* sp.), but these cultivars do not produce for as long a period into the dry season as those found in forest habitats.

Throughout West Africa consumption of bushmeat is generally higher during the rainy season. In some communities, hunting is an important off-season activity. In southern Cameroon, trapping is common during the rainy season (Amat 1972). And among the pygmies from southern Cameroon the species hunted as well as hunting techniques vary by season (Ajayi 1978).

2.19 The Importance of Forest Resources to Women and the Rural Poor

This discussion has focused largely on common forest products and their use. Little has been said about who within the rural community relies most on forest resources. While forests are exploited for a variety of products and functions, they are especially important for those with access to fewer resources, most notably the rural poor, many of whom are women. This is of particular importance as many development projects are geared towards improving the lives of the rural poor (Ajayi 1978). In most communities in the region, exploitation of forests has traditionally been open to all for subsistence needs. Forest foods are particularly important for poor households as they provide an available, accessible source of a diverse range of foods. Especially important are fish and wild animals, leaves, nuts and mushrooms. For some forest foods such as bushmeat, consumption is limited by supply. In these cases, the poor's access to these products may decline as they become scarce luxuries. In other cases, forest foods may be considered poor man's food. In these instances people may attempt to purchase substitute foods whenever possible. In both situations forest food consumption may decline. However, there is little information from the region which specifically addresses the changing dietary patterns of the rural poor, or which focuses on their changing consumption of forest foods (Abbiw 1989; Okafor 1977; Addey 1982).

Forest-based activities, such as gathering and processing non-timber forest products (NTFPs) often provide important employment opportunities in rural regions. Gathering of forest products for sale is often dominated by the rural poor. In Sierra Leone, for example, it is the poorer households within the rural community who rely on sale of fuelwood (Ardayfio 1986). Similarly, poorer women often dominate the gathering and trade of forest leaves (Okafor 1979). While forest based activities may provide numerous opportunities for the rural poor, the earning potential varies substantially (e.g. basket-making versus wood-carving). Generally, activities which are dominated by the poor reap the lowest returns. In some cases income earned from forest based activities can be invested in agricultural assets (such as implements, or livestock). In these cases forests offer the poor a means of investing in their future.

2.20 Management of Natural Forest Areas for Wildlife and Other Products

There is great potential for the management of natural forest areas for their NTFPs, as these resources are appreciated by resident populations. However, in light of growing population pressure and changing markets, forest managers are faced with a problem: how can they protect forests from over-exploitation while maintaining an interest in them through sustained use? The answer lies in flexible and positive management (Ahmed *et al.*, 1971). In the past, management has often entailed collection of taxes and statistics. A clear understanding of how forest resources are currently used, can help in the development of a system to protect and develop (e.g. through selection) locally important forest resources. A system of usury rights which is geared to meeting local people's needs should also be developed; they opined. There is great scope for traditional as well as community forest management.

Many authors such as Okafor 1983, Ahmed *et al*. 1971 and Ardayfio 1986, noted that while forest products are commonly exploited, their density in natural areas is generally low. Research is needed on ways of increasing the density and productivity of locally exploited forest species. Some attempts are being made to this end. However, they generally focus on creating "new" resource sources through game ranches, domestication of animals, and increased tree planting on farms (Abbiw 2000). The costs in terms of labour and capital may be too great for many rural people. One of the salient features of forests is that their products are readily available with little input (with the notable exception of gathering time). Thus, management plans that focus on improving existing resources can draw on local people's knowledge and focus on products which are familiar and needed. Nwoboshi (1986) asserts that, Foods, medicines and products with cash value are perhaps those products that most need programmes of diversified management.

For the West African region as a whole, the need for forest management for bushmeat is most pressing (Dunn 1975). Techniques are required to help restore and sustain wild animal populations. These need to be as simple and cheap as possible, the more expensive the method, the more expensive the final meat product. It appears that the most common approach to forest management for wild animal production entails creation of small patch clearings in the forests and selection for wild animals' food resources. Ajayi (1971) noted that, hunting regulations which account for seasonal patterns of labour demand (most notably for agricultural tasks), seasonal food needs and animal population cycles are also needed.

There is very little information on the ways to manage forests to yield a diversity of products. Some information can be gleaned from botanical and ecological studies. In addition, anthropological and ethno botanical studies sometimes include information relevant for forest management. (For example, Kumar (1983) study of raphia palms and their use in southern Benin includes a description of communal management techniques.

More information is needed regarding ways to increase the productivity and density of locally valued plant species in natural forest stands. As forests have not been managed for NTFPs in the past (by foresters), little is known. The most promising information may come from farmers who have been managing useful trees on their farms or fallow lands. For example, in her study of fallow management in southwestern Nigeria, Herren-Gemmill (1988) relates that farmers often protect some forest species when they clear land for crop production, others (e.g. *Triplochiton superba*) are allowed to germinate and grow during the cultivation period, while some are deliberately planted. Some interesting work has also been carried out in southeastern Nigeria by Okafor (1977; 1983). He has focused on improving popular forest food species and has found that protection and enrichment planting greatly increase density.

There are no examples of community forestry activities designed to enhance pre-existing forest resources in the region (south-eastern Nigeria). There are a few examples of "indigenous" management by communities, but it is not clear how these systems are changing. One forest area called Yapo reserve, in southern Cote d'Ivoire, is currently being managed for its secondary as well as timber products (Adeola and Decker 1987). The managers note that the revenues from secondary products (mainly fuelwood, charcoal, chewing sticks, ornamental plant materials and wood sold for matchstick making) in 1987 was 6,750,000 FCFA (US$ I = FCFA 260) (Adeola and Decker 1987). They add that the revenues earned from these products are available on a continual basis and thus, have helped defray the management costs of the forest. There are only a few examples like this one. However, forest management for these products must rely on local knowledge, and management goals should be directed by local people's needs and interests. The potential for community management of forest areas for NTFPs is therefore great.

2.21 Management of Fallow Lands and Farm Trees

Many authors note that intensification of management of fallow lands for forest products will relieve some of the pressure placed on forest areas (Ajayi 1979, Asibey 1987b, Poulsen 1981). In some regions that suffer from high population pressure, the use of fallow and farm areas has already intensified. Trees have become more important on farms, and in some cases products formerly gathered from forests are now found on farms. There are many opportunities for development in this area. Intensive production of valued foods, medicines, building materials and marketable goods may be possible. Fallow areas can perhaps be managed for production of wild game, mushroom, medicine, or raw materials for rural enterprises.

There may be problems associated with introducing wild animals 'into farming systems, even in fallow land areas. The introduction of new species can result in serious pest problems. However, as several authors have noted, if simple pest control technologies are developed, such as mist nets, gum, and other traps, the nutritional and monetary benefits gained from the captured animals may far outweigh any possible crop damage (as long as species are kept from reaching pest levels) (Asibey 1987b, Ntiamoa-Baidu 1987).

Ntiamoa-Baidu (1987) noted that, the amount of damage actually caused by different species is unknown. She asserts that many damage claims by farmers are an attempt to justify killing animals for meat (reflecting the great demand). The possibility of incorporating bushmeat into farm management is evident. There are (no animals which are not considered food by different West African groups, but the absence of affordable control techniques (or protection laws) prevent people from effectively exploiting this food resource. In one area of northern Ghana, mist nets were used to try to control bird pests on irrigated rice fields. Over a six week period, 80,000 birds were caught, providing a regular source of meat to farmers over that period.

While there appears to be great potential for managing forest fallow areas for wild animals (e.g. encouraging wild animal food plants), no examples from this region were found in the literature. One example from the Peruvian Amazon region illustrates the potential for this kind of management, especially where markets for bushmeat are strong. In this region fallow areas are selectively managed for fruit and other game food trees. Late in the fallow cycle hunting platforms are set up near aging fruit trees in order to watch for and capture game which comes in to feed as fruit ripens. Most of the meat is then consumed by the household, and income is also earned from bushmeat and skin sales (which contribute an average 9% of the average annual cash income) (Padoch *et al*., 1985).

2.22 Forest plantations and non-timber forest products

Forest and tree crop plantations are generally believed to destroy non-timber forest product supplies, most notably wild animal habitats. While this is certainly the case for products which are cleared to make way for plantation crops, it may be possible to incorporate local product needs into plantation management plans. For example, at some stages of development, plantations may favour some wild animal populations. Asibey (1987b) notes for example, that grasscutter and antelope populations increase in the early stages of oil palm plantations. As plantations develop, the food supply dwindles and the animal populations decline. Simple management techniques, such as leaving patches of forest vegetation, may help sustain the wild animal populations. Other possibilities might include creating hedgerows of mixed vegetation to increase food and habitat diversity and encourage settlement of desired animal populations. There is also the opportunity to draw on work of those focusing on "ecological engineering" and "restoration ecology". These two areas of research focus on planting and management of a broad range of products (Nwoboshi 1987). As was noted above, returns from management for "secondary" forest products often provide a steady source of revenue (as opposed to that gained from timber harvest) which can contribute to the costs of plantation management.

2.23 The Export of Forest and Tree Resources

In comparison with other regions of the world (e.g. Asia and the Pacific) the export of non-timber forest products from the West African humid forest zone is small. Though NTFPs are exported, information on these markets is scanty. Plant medicines and wild animal products are commonly exported within the region. The Cameroonian Forest Service reports that medicinal plants were the most commonly recorded secondary forest products collected from Forestry Department lands (Adeo1a and Decker 1987). They are primarily collected for the export market, and the most common species are: *Prunus africanum* (729 tonnes exported in 1984), *Pausinystalia johimbe* (229 tonnes in 1982), *Strophanthus* sp. (25 tonnes in 1982) and *Voacanga africana* (30 tonnes in 1982) (Hong 1989). In his study on traditional plant medicines in the Guinea Republic, Jeffry (1977) discusses the export of medicinal plants. Plant materials are generally collected by paid collectors who sell the unprocessed plant material to foreign companies through an agent. For example, *Combretum micranthum* is exported to France where it is processed and used as a diuretic and in hepatitis treatments; and *Rauvolfia vomitoria* (the source of reserpine) is exported to Europe and Japan.

The impact of this trade on local and regional economies is quite large. In an assessment of resource use in the Oku Mountain region of Cameroon, Macleod (1987) includes a discussion of the importance of plant medicine collection to rural inhabitants of the region. She notes that Oku is a center for *Prunus africanum* bark collection. The bark is sought after by several large pharmaceutical companies who use it to produce drugs for prostate gland treatments. She estimates that over 2000 tonnes of bark are extracted annually by one company alone. This industry provides an important source of off-farm income for local residents: approximately half the bark is collected by paid workers and the rest is gathered by small enterprises. Macleod (1987) estimates that a third of the people from the region supplement their income with bark collection and other artisanal activities. Wild animals (e.g. parrots) and wild animal products (e.g. ivory) are also important export products. Most governments collect statistics on the export of wild animals; however, they are considered quite unreliable because of the large quantity of trade which goes unrecorded. In Ghana, Ntiamoa-Baidu (1987) reported that US$ 344,000 worth of wild animals were exported in 1985 (the most important trade animal was the gray parrot; 9500 were traded in 1985). In Nigeria, Ajayi (1979) reported that 4.4 million dollars worth of wild animal products were exported in 1965 (of greatest value were hides and skins).

2.24 Soil Productivity

Soil is the fundamental resource of the forest (MFRC 2007). Without it or its productive capacity, the other resources of the forest are diminished. For example, soil productivity influences what plants can grow on a site and how well they grow; maintaining soil productivity will facilitate the regeneration, survival, and long-term growth of desired vegetation; and productive soils sustain a variety of forest values such as timber harvesting, wildlife habitat and biodiversity.

Growing and harvesting biomass has the potential to impact the following aspects of soils (MFCR 2007).

- Physical properties, including soil structure, texture, porosity, density, drainage, and surface hydrology,
- Chemical status, including nutrient status and pH, and
- Biological characteristics of soils (i.e., the organisms that live in the soil)

Management activities may impact soil physical and chemical properties which will eventually affect soil nutrients, organic matter and moisture-holding capacity (Torbert and Burger 2000).

Increased trafficking increases the potential for soil displacement, compaction and rutting, erosion, nutrient depletion and erosion. Soil compaction increases soil strength which commonly slows root penetration and reduces the regeneration and growth of trees (Sweigard *et al.*, 2007; Gregorrich *et al.*, 1988), reduces soil infiltration rates, increases the potential for erosion, changes landscape hydrology (Bonde *et al.,* 1992). Water tables can rise after a biomass harvesting operation as tree removal reduces stand water uptake and evaporative loss.

Where woody biomass is removed under a two-pass system (i.e., the harvesting and recovery of round wood and biomass occur in separate passes), increased trafficking occurs across the harvested site. This additional trafficking can result in more compaction across the site.

Mechanical site preparation techniques such as tillage, raking, windrowing, disking and piling can lead to reductions in soil organic matter which is important for maintaining soil microbial communities, forming soil structure, soil carbon storage, nutrient cycling and regulation of soil hydrological processes (Rochester *et al.*, 1991). A reduction in soil organic matter and soil carbon storage will reduce the total capital and availability of nutrients especially nitrogen (N), phosphorus (P), potassium (K) and calcium (Ca).

Soil biological processes are generally decreased through compaction, exposure of mineral soils, drying, and accumulation of toxic elements, and extreme temperatures that may be caused by removal of downed and dead wood from the forest floor (Norman *et al.,* 1982, Chase *et al.,* 1989).

Where root suckering or coppice regeneration (i.e., a cycle where trees are cut to ground level every few years and then regrow from the stumps into a clump of stems) is planned, it is especially important to avoid damaging the root systems through compaction and rutting.

2.25 Soil Quality and Soil Productivity in Africa

More than four decades of research and development work in Africa have not resulted in the 3-5 % annual increase in agricultural growth (Anderson and Paul, 1984) that is necessary for most African countries to ensure sustainability of agriculture and the promise of food security in the next decade. Sluggish or zero growth is likely because of the cumulative effect of many factors but with strong bearings on soil productivity. Agriculture production is not merely the managing of the biophysical resources; it is also strongly controlled by the socioeconomic milieu. The opening of national markets to world trade has induced new stresses in the on-farm socioeconomic situation. The resource poor farmers of Africa have few options today to enhance their agricultural productivity. The challenge to African governments and the international community is to enhance the farmer's ability to effectively participate in the national and global economy and a prerequisite is the improvement of the productivity of the millions of small farms. The traditional low-input agriculture practiced by many of the farmers in the absence of replenishment of mineral nutrients, is slowly reducing many of the soils to almost inert systems (Sweigard *et al*., 2007). As many of the soils also have low resilience, future corrective measures may be exorbitantly expensive.

The study of Cheshire *et al.,* (1990) indicates that soils on about 5 million ha of land in Africa are degraded to a point where their original biotic functions have been fully destroyed and resilience reduced to such a level that rehabilitation to make them productive may be economically prohibitive. This empirical assessment based on the judgment of many persons and often made in the absence of supporting data, points to the magnitude of the problem. With reliable resource inventories and monitoring of the resource base, better assessments and projections can be made. Such knowledge is as important as helping national planners and farmers to enhance their agricultural productivity.

2.26 Soil Quality

Quality is the essential character, distinguishing feature or property of an object. It identifies that feature which, makes the thing useful or perform a task in a beneficial way. Most persons refer to soil quality in a similar way and look for attributes that enable the soil to perform its functions in an acceptable manner. Larson and Pierce (1991) view soil quality as the capacity of a soil to function within its ecosystem boundaries and interact positively with the environment external to that ecosystem. They link soil quality to the four sustain.ability objectives of -- agronomic, ecological, micro- and macro-economic sustainability (Chase *et al.*, 1989).

A more formal definition, of Larson and Pierce (1991) and many others are, " the capacity of the soil, as an integral part of the ecosystem to perform the functions of:

- enabling life to thrive in or on it;
- acting as an ecosystem source, sink, and a filter reducing contaminants affecting water and other resources;
- providing the foundation for buildings and other structures, and space for rooting and support for plants;
- Buffering the life support system against thermal, chemical, gaseous, and/or other stresses; and regulating microclimate through its hydrological function of controlling water flowing over or in it."

Soil quality and productivity have emerged as a unifying concept to address the larger issue of sustainability of ecosystems in general and agriculture in particular. Sweigard *et al*., 2007) noted that, USDA Natural Resources Conservation Service (NRCS) is utilizing an "Ecosystems Based Approach" for its technology development and transfer program with soil quality being one of the basic criteria for the many decisions that have to be made with respect to sustainable land management. From the point of land use and land management decision making, soil quality:

- provides a quantitative basis for evaluating different land use options and impacts of technology;
- furnishes parameters for quantifying ecosystem interactions;
- evaluates status and impacts of soil conditions over given periods of time;
- provides a basis for targeting conservation programs;

- enables environmental assessment, or specific assessments related to biodiversity, chemical loads, bio-contaminants, etc., as it is a measurable component of the environment;
- serves as a critical parameter for evaluating sustainable agriculture and forestry;
- serves as one of the tools for evaluating conservation programs, levels of compliance, effects of conservation practices, and targeting high risk areas for conservation reserve activities, and
- Provides a basis for identifying tension zones and serves as a triggering mechanism for implementation of mitigating strategies (when indicators suggest that critical soil quality thresholds are exceeded or ecosystem collapse is imminent).

Sweigard *et al*., 2007) state that agriculture in sub-Saharan Africa, more than in any other part of the world is in crisis. The low-input low-output systems of agriculture which maintained Africa at subsistence levels is no longer able to feed the people. In addition, there are the associated problems of land degradation accelerated by low-input systems which in some instances has exceeded the resilience threshold of soils. Naturally low quality and human-induced low quality soils now characterize much of the African landscape; however there are areas where high levels of productivity are still possible.

The challenge of enhancing the productivity of well endowed lands and reducing the pressures on the fragile ecosystems is the solution to putting Africa on the path to sustainability development. With appropriate capital infusion and support services, the efficiency of resource-poor farmers of Africa can be raised and the seeds to another Green Revolution sown.

2. 27. The Forests in Anambra State

2.27. 1. Forestry and Agriculture in Anambra State

Anambra State has high potentials for agricultural development, because of stretches of fertile land on the plains in Ogbaru, Ayamelum, Oyi, Awka and Orumba Local Government Areas. These areas support healthy crops of yam, maize, cassava, rice, and vegetables. The Ifite Ogwari Dam on the Anambra River provides water for 3,500 hectares of irrigated land at Omor for the cultivation of rice, maize, and out of season vegetables. This project, with a target of 5, 000 hectare of irrigated land, is a joint venture between the Federal Government and a Japanese consortium (Nwosu 2003).

The Omor rice farms, together with the Ogboji-Ezira rice lands of Orumba, and Odoekpe rice fields in Ogbaru, earn for Anambra State the third richest rice potentials area in Nigeria. Large private farms, such as the Ekenedilichukwu Farms, Arnak Farms, and Pokobros are located in the rich hydromorphic soil regions of Anambra and Ayamelum LGAs. Nwosu (2003) also stated that, forest reserves in the Mamu river basin, Akpaka and Ajali-Umeje reserves, provide valuable forest products, protect the watersheds and maintain ecological balance, thereby helping to prevent sheet and gully erosions. Services and programmes geared towards increased agricultural production and forestry, including the organization of farm groups.

2.27.2 Mineral Resources:

Anambra State is not too rich in mineral resources; and some, known to exist, are not yet to be exploited. For example, tungsten at Oba and large deposits of lignite in Onitsha, Idemili, and Nnewi LGAs are yet to be exploited. Kaolin is mined in the Ukpor Ihembosi axis for the ceramic industry at Umuahia in Abia State; while the deposits at Afuleri and EnuguAgidi await exploitation. Sandstones of Ameke Formation are quarried in several places, particularly at Abagana and Nsugbe for construction purposes (Egboka 1993). Natural gas has been discovered at Ebenebe Ridge, southeast of Ebenebe town, and preliminary prospecting indicated that crude oil exists in commercial quantities in the state.

2.27.3 Geology and Natural Endowments:

Egboka, (1993) stated that, Anambra State lies in the Anambra Basin, the first region where intensive oil exploration was carried out in Nigeria. The Anambra basin has about 6,000 m of sedimentary rocks. The sedimentary rocks comprise ancient Cretaceous deltas, somewhat similar to the Niger Delta, with the Nkporo Shale, the Mamu Formation, the Ajali sandstone and the Nsukka Formation as the main deposits. On the surface the dominant sedimentary rocks are the Imo Shale a sequence of grey shales, occasional clay iron stones and Sandstone beds.

The Imo Shale underlies the eastern part of the state, particularly in Ayamelum, Awka North, and Orumba North LGAs. Next in the geological sequence, is the Ameke Formation, which includes Nanka Sands, laid down in the Eocene. Egboka (1993) noted that, its rock types are sandstone, calcareous shale, and shelly limestone in thin bands. Outcrops of the sandstone occur at various places on the higher cuesta, such as at Abagana and Nsugbe, where they are quarried for construction purposes. There is also Nanka sand out crop mainly at Nanka and Oko in Orumba North LGA. Lignite was deposited in the Oligocene to Miocene; and it alternates with gritty clays in places. Outcrops of lignite occur in Onitsha and Nnewi. The latest of the tour geological formations is the Benin Formation or the coastal plain sands deposited from Miocene to pleistocene. The Benin Formation consists of yellow and white sands. The formation underlies much of Ihiala LGA. Thick deposits of alluvium were laid down in the western parts of the state, south and north of Onitsha in the Niger and Anambra river floodplains (Egboka 1993).

2.27.4 Landforms and Drainage:

Egboka (1993), Anambra State falls into two main landform regions: a highland region of moderate elevation that covers much of the state south of the Anambra River, and low plains to the west, north, and east of the highlands. The highland region is a low asymmetrical ridge or cuesta in the northern portion of the Awka Orlu Uplands, which trend roughly southeast to north- west, in line with the geological formations that underlie it. Egboka noted that, it is highest in the southeast, about 410 m above mean sea level, and gradually decreases in height to only 33 m in the northwest on the banks of the Anambra River and the Niger. At Onitsha and Otuocha, the cuesta provides well drained low land, very close to the river, thereby enabling settlements to extend to the banks of the river.

The cuesta has confined the wide and braided channel of the Niger to a comparatively narrow valley bed at the southern part of Onitsha, making an appropriate location for the construction of bridge across the river. The highland consist two cuestas, a lower and a higher one, each with east facing escarpment. The two cuestas merge south of Nanka. The lower cuesta, formed by the more resister sandstone rocks of the Imo Shale, rises to only 150 m above mean sea level at Umuawulu and decreases in height northwestward to only 100 m at Achalla. Its escarpment faces the Mamu River plain and has a local relief of between 80 and 30 N west of it, is the higher cuesta, formed by the same stones of the Ameke Formation. Its height is above 400 m in the south-east at Igboukwu and Isuofia decreasing northwestward to less than 300 m; at Agbana, and to only 100 m at Aguleri (Egboka 1993).

There are only of moderate height, they provide elevated, well drained and attractive settlement sites, hence, they are closely settled even up to their crests. Agulu, Agbana, Awkuzu, Nteje an Aguleri are some of the settlements on the crest of the higher cuesta, and Ifite Awka, Mgbakwu, Amanuke and Achalla are some of those on the crest of the lower cuesta. The dip slope of the cuesta extends westwards for over 30 km and is heavily settled. The plains lie west and north of the highland; The River Niger plain, south of Onitsha, about 9 km wide, and the Niger Anambra River plain north of Onitsha, which stretches for over 36 km east of the Niger, are really low plains, well below 30 m above mean sea level, and are liable to flood. They are underlain by recent alluvium; and, east of the Anambra River, by the Imo Shale formation (Egboka 1993).

The plains are almost featureless, except for sporadic broad undulations, rising above the flood plain at forming sites for the farming and fishing settlement in the area. Such settlements include Nzam, Nmiata, and Anam in Anambra West Local Government Area, Atani, Odekpe, and Oshita in Ogbaru LGA. East of the Anambra River, a narrow and elongated sandstone ridge, projecting about 30 m above the level at the plain, formed settlement sites for Anaki Igbakwu, Ifute, and Umueje in Ayamelum LGA. The Mamu River plain, east of the cuesta landscape, is a little higher than the other two plains. It lies to between 30 and 70 m above sea level in the area and underlain by the lmo Shale, rising higher southwards. East of the Mamu River are found the Moriu, resistant sandstone ridge, at some 50 m above the level of the plains. The extension of this ridge southward is settled by the people of Ufuma, Ajali Isu Ulo, Ezira, and Umunze (Egboka 1993).

2.27. 5. The Main Drainage System in Anambra State

The Anambra River rises on the Gala Plateau near Ankpa in Kogi State and, for its over 85km course in Anambra State, flows through the northern low plain where it, as well as its right bank tributaries, meander heavily, developing oxbow lakes and abandoned meander channels. Its largest left bank tributary is the Mamu River, which drains the eastern low plain on the Imo Shale Formation (Egboka 1993).

Egboka (1993) asserted that, the higher cuesta forms the watershed separating the numerous east flowing tributaries of the Mamu River from the west flowing rivers, the Idemili, the Nkisi, and the Oyis, which drain the dip slope of the cuesta. All but one of the main rivers in Anambra state, empty into the River Niger which forms the western boundary of the state, and constitutes the local base level for the rivers. The exception is the Ulasi River, which rises near Dikenafai in Imo State, flows northward to Ozubulu in Anambra State and then turns round in a wide loop and heads for the Atlantic Ocean. The dip slope of the higher cuesta between Nsugbe, Onitsha, Ogbunike and Umunya is dissected by the numerous tributary streams of the Mamu Anambra into a rolling landscape (Egboka 1993).

2.27.6 Vegetation and Soils:

Although annual rainfall is high in Anambra State, ranging from 1,400 mm in the north to 2,500 mm in the south, it is concentrated in one season, with about four months of dryness, November to February. Consequently, the natural vegetation in the greater part of Anambra State is tropical dry or deciduous forest, which, in its original form, comprised tall trees with thick under growth and numerous climbers (Nwosu 2003). The typical trees (silk cotton, Iroko and oil bean) are deciduous, shedding their leaves in the dry season. Only in the southern parts of the state, where the annual rain fall is higher and the dry season shorter, is the natural vegetation marginally the tropical rainforest type. Because of the high population density in the state, most of the forests have been cleared for settlement and cultivation. What exists now in many places is secondary re-growth, or a forest savannah mosaic, where the oil palm is predominant, together with selectively preserved economic trees. Relics of the original vegetation may, however, be found in some "juju" shrines or some inaccessible areas (Nwosu 2003).

According to Egboka (2003), three soil types can be recognized in Anambra State. They are:

(i) Alluvial soils,

(ii) Hydromorphic soils, and

(iii) Ferallitic soils.

The alluvial soils are pale brown loamy soils. They are found in the low plain south of Onitsha in Ogbaru and in the Niger Anambra low plain north of Onitsha. They differ from the hydromorphic soils in being relatively immature, having no well developed horizons. He further stated that, they (alluvial soils) however, sustain continuous cropping longer than the other two types. Hydromorphic soils are developed on the Mamu plain east of the cuesta, extending northward into the eastern part of Anambra River floodplain, where the underlying impervious clayey shales cause water logging of the soils during the rainy season. The soils are fine loamy, with lower layers faintly mottled; while the subsoil layers are strongly mottled and spotted, containing stiff grey clay. The soils are good for yam, cassava and maize, and for rice in the more heavily waterlogged areas. The cuestas and other elevated areas under lain by sandstones and shales of the Ameke Formation and the Nanka Sands are regions of ferrallictic soils. The soils are deep, red to reddish brown loamy sands, often referred to as "red earth" or acid sands because of low fertility. They are easily eroded into gullies.

2.27.7. Ecological Hazards:

The main ecological hazards in the state according to Egboka (1993) are accelerated gully erosion and flooding. Extensive forest clearing, often by bush burning, and continuous cropping with little or no replenishment of soil nutrients, resulted in the disruption of the ecological equilibrium of the natural forest ecosystem. Such a situation in a region of loosely consolidated friable soils is prone to erosion, giving rise to extensive gully formation. In the Agulu, Nanka and Oko areas, which are underlain by the Nanka Sands, the gullies have attained spectacular and alarming proportions, turning the area into real "bad lands." Many of the gullies are at the head streams of the rivers that flow down the cuestas. The head streams carve their valleys deep into the deeply weathered red earth, developing dendritic patterns of gullies (Egboka 1993).

Such gullies are also found in Nnobi, Alor and Ideani, along the course of the Idemili River. Besides, the greater part of the state is prone to severe sheet erosion. In the low plains of the Niger and Mamu Rivers, heavy rains often result in excessive flooding, such that the undulations occupied by settlements are marooned for some months. The people resort to the use of canoes for movement and transportation. Orba Ofemili and Ugbenu on the plains of the Mamu River are sometimes, in the rainy season, cut off from others as their roads remain flooded knee-deep for many weeks. The floods also cause serious damage to crops.

2.28. Soil Physical and Chemical Characteristics

2.28.1. Bulk Density

Bulk density estimates add a valuable and missing dimension to understanding soils on the national scale. These estimates are required for calculating stocks of carbon and other nutrients found in soils (Christensen, 1985). Current national estimates of soil organic carbon rely upon bulk density estimates generated from soil properties, such as organic matter, clay content and silt content. Little is known about the accuracy and suitability of applying mathematical estimates of bulk density to soils. Without better knowledge of bulk density and other factors (i.e. the spatial extent of land use classes and soil types) affecting estimates of carbon and nutrient stocks in soils, we can understand nothing of the changes in these stocks over time (Christensen, 1985, Chase *et al.*, 1989). The variation of bulk density for grassland soils is the largest with estimates of 0.37-1.17 g cm^{-3} for the top 10 cm and 0.16-1.48 g cm^{-3} for 40-50 cm depth. Groninger *et al*., 2007 observed that the bulk density of forested sites depends on whether the forest is coniferous or broadleaf. Coniferous forest, often planted on marginal land, have highly organic/peaty soils with low bulk densities, 0.13-1.28 g cm^{-3}. Broadleaf forest, found primarily on mineral soils, have higher bulk densities, 0.58-1.39 g cm^{-3}. Sites with peat soils, such as bog and rough lands, have low bulk densities ranging from 0.07-0.37 g cm^{-3} for the top 10 cm and 0.07-1.18 g cm^{-3} for 40-50cm depth (Torbert and Burger 2000, Brady and Weil 2002). The high bulk density estimates at depth in bog sites are due to the influence of mineral soils. Knowing these variations in soil bulk densities will facilitate more exact estimate of soil carbon, therefore enabling increased precision in carbon accounting and modeling.

Since the late 1970s and the passage of the Surface Mining Control and Reclamation Act (SMCRA), mined lands have commonly been reclaimed using smooth grading followed by the establishment of grasses and legumes (Groninger *et al*., 2007). Using this approach, the surface of reclaimed land is heavily compacted for soil stabilization, erosion control, and to provide a good seed bed for planting pasture and hay plant species. However, in the late 1990s landowners and coal operators began showing an increasing interest in reclaiming mined land to forest (Torbert and Burger, 2000). Even though the post-mining land use was different, the practice of heavily compacting soils has remained and heavy soil compaction has continued to be a primary reason for poor tree performance on reclaimed mine lands (Larson and Vimmerstedt, 1983; Sweigard *et al.*, 2007).

Compacted soils can lead to an increase in soil resistance to root penetration, poor aeration, slow movement of nutrients and water, and the buildup of toxic gases around the roots (Brady and Weil, 2002). One way to avoid negative effects to roots would be to limit compaction of the surface during the reclamation process.

2.28.2. Organic matter

It has been suggested that small particles with a relatively large specific surface are particularly effective in stabilizing soil organic matter (Christensen, 1988; Cheshire *et al*., 1990; Leinweber *et al*., 1993), and hence in the formation of organo-mineral associations. Certainly, such fractions can preserve large amounts of soil organic matter in biologically resistant forms and thus provide a pool of moderately available nutrients (Anderson and Paul, 1984). In arid and semiarid zones, water erosion processes lead to a substantial loss of these fine fractions -20 mm, which are the most fertile and, as a consequence, soil fertility declines (Stocking, 1984).

Likewise, the amounts of C and N that may be associated to clay and silt size fractions are affected by many factors including soil texture (Christensen, 1992; Hassink, 1995), the dominant type of clay mineral (Hassink, 1997) and the use to which the land is put (Hassink, 1994; Parfitt *et al*., 1997). Thus, in arable soils most of the soil organic matter can be found in the clay and silt fractions, whereas in forest and grassland soils the contribution of sand size organic matter to total soil organic matter is greater (Christensen, 1992; Hassink, 1997). On the other hand, soils dominated by clays with a high specific surface area and numerous reaction sites probably adsorb more humic substances than soils dominated by clays with a low specific surface area (Tate and Theng, 1980).

The loss of organic matter from forest soils following disturbance is an important source of CO2 for the atmosphere. Bolin (1977) and Schlesinger (1977, 1983) have estimated the net loss of organic carbon from the world's soil. Bolin (1977) states that if it is assumed that from 25 to 50 per cent of the presently cultivated land has been converted from forest land since the early nineteenth century, the release of organic carbon from the soil to the atmosphere during the last two centuries can be estimated at 10 to 40 X1015g, with an annual loss at 0.1 to 0.5 x 1015 g. Kovda (1974) has estimated the total humus in the earth's soil at 2400 x 1015 g, equivalent to approximately 1400x 1015 g of carbon. Bohn (1976) stated that earlier in this century the organic carbon in the world's soil was estimated at 710 x 1015 g. This estimate was based on the carbon content of nine North American soils. Bohn estimated that there are 3000: 1500 x 1015 g of organic carbon in the world's soil. Although he did not try to estimate the amount of CO2 released to the atmosphere, Bohn (1976), says that the decay of soil organic matter is one of the largest CO2 inputs to the atmosphere'. Both plants and animals provide inputs of organic matter to soils. Once within the soil organic residues can be distinguished on the basis of their chemical structure (e.g., old lignified humic substances that degrade slowly), by their source (plant or animal) or by location.

The standing crop of litter in semi-arid grasslands is usually more than 3 t/ha and in temperate dry steppe may exceed 11 t/ha (Klemmedson 1989). There has been much debate about the relative contents of organic matter in tropical and temperate soils. Within those wet-and-dry climates that have hot summers assisting rapid decomposition, there is no evidence of inherently lower levels of organic matter in the tropics than in comparable temperate regions (Juo and Payne 1993). Kowal and Kassam (1978) and Juo and Payne (1993) review the role of organic matter in tropical soils. Here, it is sufficient simply to state that organic matter has various interrelated effects on soil fertility. In particular it should be noted that both chemical and physical effects are of relatively great importance in the soils of the semi-arid tropics because these generally have low cation exchange capacity.

Schlesinger (1977, 1983) has calculated the mean carbon content in 11 ecosystem types and multiplied the mean by the amount of land included in these ecosystems. He offered a preliminary estimate that the earth's total soil carbon is 1515x 1015 g. The annual release of soil carbon by his estimate is about 0.8 x 1015 g. This figure is based on the assumption that the annual conversion of forest to cultivated land is 15 x 106 ha and that the average carbon content of 131 t/ha in forest soil drops to 78.6 t/ha after conversion to cultivation, a decline of 40 per cent.

Although organic matter is often present in the soil to a depth of 1 or 1.5 m, most is in a surface layer of from 1 to 20 cm. Carbon also exists in the mineral part of soils or in the soil solution, mainly as carbonates and bicarbonates of calcium, magnesium and sodium. Dudal (1978), observed that there is also a slight increase in soil carbon when land is irrigated, when organic manure is added or when cropping is intensified, but annual addition of soil carbon due to these practices is very small in comparison to the net loss.

The organic matter content in soil depends on soil conditions, present and recent vegetation cover, topography, hydrological conditions, and elevation and farm management practices. Soil conditions in turn are most influenced by the soil moisture and temperature regimes, although the biological and mineralogical regimes are also important. For example, soil derived from rocks that are basic (as opposed to felsic) generally contains more organic matter than soil from felsic rocks. Clay content and type also affect organic matter content. Furthermore, the oxidation of organic matter is more rapid in calcareous soil than in non-calcareous soil. Various attempts have been made to correlate the organic matter content of soils in a specific region or country with some of these factors. Young (1976) has provided a summary of processes that affect organic matter content.

Under natural conditions the content of organic matter in soil is constant; the rate of decomposition is equal to the rate of supply of organic matter from plants. The equilibrium is disturbed when forests are cleared and the land is used for agriculture. There is also a decline in organic matter when grassland in the tropics and subtropics is transformed into cropland, or when savannahs are burned. The decline is rapid in the first few years after deforestation and gradually slows over the next 10 to 50 years. Organic matter is also lost through misuse or deterioration of land (soil erosion, salinization, alkalization and soil degradation), and because of the increasing non-agricultural use of land (urbanization and highway construction).

On the other hand, there may be an increase in organic matter when good farm management is practiced and organic manure and compost are used, when arid land is irrigated, or where agricultural land is reforested. The proportion of animal and human manure used on cropland is more variable. Some farmers have developed stable systems which strongly emphasize the use of animal manure on crops. For example, Norman *et al.,* (1982) describe how farmers in northern Nigeria managed to apply 4 t/ha of manure to their heavily-cropped crop land though they had only 3 cows each. Many other farmers do not ensure adequate recycling, either because they are more concerned with livestock management or they do not know the importance of maintaining a 'zero nutrient budget' to replace nutrients removed by the crop.

Norman *et al.*, (1982) also describe farmers with 10 cows each, who applied only 1.9 t manure/ha to their crops.

Within a cropping system, manuring practice varies with location. There is transference towards the centre of the system. On traditional farms, the area near the household or village is highly fertilized with human and animal manure while more distant fields receive little or no organic matter. Fussell (1992) describes such a traditional 'ring' farming system in semi-arid West Africa. Here, if houses are thatched, the village needs rebuilding or moving every 2 to 4 years. Moving takes advantage of the fertility gradient. Where the huts are not moved, the fertility gradient becomes steeper with time. Rather than trying to even out fertility by labour-intensive transport of manure, farmers vary the cropping of the fields. Continuous cropping of millet is sustainable close to the hut or village where there is plenty of human and animal manure but crop rotations are essential at the periphery.

2.28.3 Soil Nitrogen

Plants take up most minerals as inorganic nutrients from the soil solution (except legumes, which may fix dinitrogen gas directly from the soil air). An element is available (to the plant) if it is present as, or can be transformed into, a free ion, and it is within the plant root zone. Most elements move within physical proximity of roots through soil water movement and into the plant through evapotranspiration. Diffusion along concentration gradients is important for less-mobile ions such as phosphorus, particularly where soil solution concentrations are weak and root densities are high (i.e., the transport path is short). Sposito (1984) and others give calculated values for the diffusivity of nutrients. Diffusion times range from 1 day for an ion to move 3 mm (which is comparable with the time it would take to move by convection in the mass flow of water) for nitrate to about 200 days for potassium, magnesium and molybdenum, and to thousands of days for other nutrients.

The concentrations of nutrients in solution fluctuate daily and seasonally. The most dynamic are nitrate and ammonium ions, which are interconverted by bacteria. Fluctuations can be explained by the effects of temperature and soil water on mineralization (breaking down organic matter to release ammonium), immobilization (the reverse) and nitrification (conversion of organic matter to nitrate, which is stable and highly soluble), and by the effects of rainfall leaching nitrate to depth. In seasonally wet-and-dry cropping systems, there is a flush of nitrate following the start of the wet season and nitrate-N may accumulate in the topsoil by capillary rise of water during the dry season. Within the major seasonal patterns driven by soil water, Rochester *et al.* (1991) found that the soil nitrate cycle lagged three months behind changes in temperature.

One of the key soil nutrients is nitrogen (N). Plants can take up N in the ammonium (NH_4^+) or nitrate ($N0_3$-) form. At pH's near neutral (pH 7), the microbial conversion of NH_4^+ to nitrate (nitrification) is rapid, and crops generally take up nitrate. In acid soils (pH < 6), nitrification is slow, and plants with the ability to take up NH_4^+ may have an advantage.

Soil pH also plays an important role in volatization losses. Ammonium in the soil solution exists in equilibrium with ammonia gas (NH_3). The equilibrium is strongly pH dependent. The difference between NH_3 and NH_4^+ is a H^+. For example, if NH_4^+ were applied to a soil at pH 7, the equilibrium condition would be 99% NH_4^+ and 1% NH_3. At pH 8, approximately 10% would exist as NH_3 (Rochester *et al.* (1991).

This means that a fertilizer like urea (46-0-0) is generally subject to higher losses at higher pH. But it does not mean that losses at pH 7 will be 1% or less. The equilibrium is dynamic. As soon as a molecule of NH_3 escapes the soil, a molecule of NH_4^+ converts to NH_3 to maintain the equilibrium.

There are other factors such as soil moisture, temperature, texture and cation exchange capacity that can affect volatilization. So pH is not the whole story.

The important point to remember is that under conditions of low soil moisture or poor incorporation, volatilization loss can be considerable even at pH values as low as 5.5.

Soil pH is also an important factor in the N nutrition of legumes. The survival and activity of Rhizobium: the bacteria responsible for N fixation in association with legumes, declines as soil acidity increases. This is the particular concern when attempting to grow alfalfa on soils with pH below 6 (Anderson and Paul 1984).

2.28.4 Soil Phosphorus

The form and availability of soil phosphorus (P) is also highly pH dependent. Plants take up soluble P from the soil solution, but this pool tends to be extremely low, often less than 1 lb/ac.

The limited solubility of P relates to its tendency to form a wide range of stable minerals in soil. Under alkaline soil conditions, P fertilizers such as mono-ammonium phosphate (11-55-0) generally form more stable (less soluble) minerals through reactions with calcium (Ca).
Contrary to popular belief, the P in these Ca-P minerals will still contribute to crop P requirements. As plants remove P from the soil solution, the more soluble of the Ca-P minerals dissolve, and solution P levels are replenished. Greenhouse and field research has shown that over 90 per cent of the fertilizer P tied up this year in Ca-P minerals will still be available to crops in subsequent years.

The fate of added P in acidic soils is somewhat different as precipitation reactions occur with aluminum (A1) and iron (Fe). The tie-up of P in A1-P and Fe-P minerals under acidic conditions tends to be more permanent than in Ca-P minerals.

2.28.5 Soil Potassium

The fixation of potassium (K) and entrapment at specific sites between clay layers tends to be lower under acid conditions. This situation is thought to be due to the presence of soluble aluminum that occupies the binding sites. One would think that raising the pH through liming would increase fixation and reduce K availability; however, this is not the case, at least in the short term. Liming increases K availability, likely through the displacement of exchangeable K by Ca (Brady and Weil, 2002).

2.28.6 Calcium in soil

Calcium Improves Soil Structure in heavy clay soils; Calcium is used to flocculate the clays in the soil. Flocculation is the process where smaller clay particles are broken up and then held together in fewer but larger particles. These particles allow more air space between them which means more air and water movement down through the root system. Better infiltration and conductivity results in less water on the surface which may help minimize algae problems. **Calcium Helps plants absorb Nutrients better.** In a simplified manner, Calcium is a nutrient carrier in both the soil and the turf grass tissue. In the soil it helps control the water movement and conductivity which means it can deliver more nutrients from the soil solution. In the turf grass, calcium helps regulate water and nutrient uptake by the roots and the movement throughout the plant. Calcium aids cell division and cell wall formation and is critical for respiration during high heat and humidity periods. A large

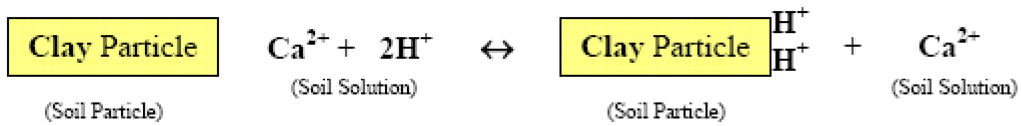
Calcium deficiency within the turf grass could result in poor root development and little response to nitrogen or iron applications. Also, high nitrogen applications in the spring or fall can lead to wilt if the calcium within the turf grass is below its target range.

Calcium helps bind organic matter to Clay. The value of organics is increased when Calcium levels in the soil are correct. Microbial populations favor a correct Ca: Mg ratio (1). Imbalances of Calcium and Magnesium can permit organic residues to decay into alcohol, a sterilant to bacteria, and also into formaldehyde, a preservative of cell tissue. In soil tests, this is exactly what is happening when we see high levels of organics and low levels of available Calcium. A minimal response to organic fertilizer inputs can be seen in these situations. **Calcium can decrease the Sodium content in the soil.** Because Calcium is divalent (double positive charge), and atomic weight of the Calcium molecule being 40 and sodium being 23 with a single charge, sodium can be replaced on the soil colloid by Calcium. The sodium is then ionized in the soil solution, which then can be flushed (Brady and Weil, 2002).

2.28.7. Cation Exchange Capacity (CEC)

In soil science, cation-exchange capacity (CEC) is the maximum quantity of total cations, of any class, that a soil is capable of holding, at a given pH value, available for exchange with the soil solution. CEC is used as a measure of fertility, nutrient retention capacity, and the capacity to protect groundwater from cation contamination. It is expressed as milli-equivalent of hydrogen per 100 g of dry soil (meq+/100g), or the SI unit centi-mol per kg (cmol+/kg). The numeric expression is coincident in both units.

Chase *et al* (1989), stated that Some plant nutrients and metals exist as positively charged ions, or “cations”, in the soil environment. Among the more common cations found in soils are hydrogen (H^+), aluminum (Al^{+3}), calcium (Ca^{+2}), magnesium (Mg^{+2}), and potassium (K^+). Most heavy metals also exist as cations in the soil environment. Clay and organic matter particles are predominantly negatively charged (anions), and have the ability to hold cations from being “leached” or washed away. The adsorbed cations are subject to replacement by other cations in a rapid, reversible process called “cation exchange”.



Cations leaving the exchange sites enter the soil solution, where they can be taken up by plants, react with other soil constituents, or be carried away with drainage water.
The "cation exchange capacity", or "CEC", of a soil is a measurement of the magnitude of the negative charge per unit weight of soil, or the amount of cations a particular sample of soil can hold in an exchangeable form. The greater the clay and organic matter content, the greater the CEC should be, although different types of clay minerals and organic matter can vary in CEC Cation exchange is an important mechanism in soils for retaining and supplying plant nutrients, and for adsorbing contaminants. It plays an important role in wastewater treatment in soils. Sandy soils with a low CEC are generally unsuited for septic systems since they have little adsorptive ability and there is potential for groundwater (Brady and Weil, 2002).
Clay and humus have electrostatic surface charges that attract the solution ions, and hold them. This holding capacity varies for the different clay types and clay-blends present in soil, and is very dependent of the proportion of clay+humus that is present in a particular soil. One way to increase CEC is to favor the formation of humus. **Cation exchange capacity (CEC) is** the total amount of exchangeable cations that a particular material or soil can adsorb at a given pH. Exchangeable cations are held mainly on the surface of colloids of clay and humus, and are measured in milligram equivalents per 100 g of material or soil. In general, the higher the CEC, the higher the soil fertility.

2.28.8. Soil pH

Many soils' CEC is dependent upon the pH of the soil. This is due mostly to the lyotrophic series, which describes the relative strength of various cations' absorption, and is generally as follows:

$$Al^{3+} > H^{+} > Ca^{2+} > Mg^{2+} > K^{+} = NH_4^{+} > Na^{+}$$

As soil acidity increases (pH decreases) more H^+ ions are attached to the colloids and push other cations from the colloids and into the soil solution (CEC decreases). Inversely, when soils become more basic (pH increases), the available cations in solution decreases, because there are fewer H^+ ions to push cations into the soil solution from the colloids (CEC increases).

Soil pH or soil reaction is an indication of the acidity or alkalinity of soil and is measured in pH units. The pH scale goes from 0 to 14 with pH 7 as the neutral point (Brady and Weil 2002). As the amount of hydrogen ions in the soil increases, the soil pH decreases, thus becoming more acidic. From pH 7 to 0, the soil is increasingly more acidic, and from pH 7 to 14, the soil is increasingly more alkaline or basic. Using a strict chemical definition, pH is the negative log of hydrogen (H^+) activity in an aqueous solution. The point to remember from the chemical definition is that pH values are reported on a negative log scale. So, a 1 unit change in the pH value signifies a 10-fold change in the actual activity of H^+, and the activity increases as the pH value decreases (Sposito, 1984). To put this into perspective, a soil pH of 6 has 10 times more hydrogen ions than a soil with a pH of 7, and a soil with a pH of 5 has 100 times more hydrogen ions than a soil with a pH of 7. Activity increases as the pH value decreases.

Chase *et al.,* (1989) discovered that low soil pH affects plant roots directly because of the effects of the hydrogen ion concentration on root membrane integrity and exchange capacity. Acidity also affects roots indirectly in two ways. It alters the availability of ions in the soil solution (possibly making available toxic aluminum species, relatively toxic to plants). It also affects mineralization through the protons competing with cations for dissolved ligands and surface charged groups. Soil pH also affects micro-organisms, and thus the speed of transformations, for example, those between nitrate and ammonium. Poor plant growth on acid soils may thus be caused directly by hydrogen ions, by toxicities of aluminum or manganese, or through deficiencies of calcium, magnesium, potassium, phosphorus, nitrogen or trace elements. Chase *et al.* (1989) describe these relationships for sandy Sahelian soils. Variation in pH across distances of 15 m can be as much as pH 4.5 to 7.5, with associated decreases in aluminum and hydrogen ions, and increases in crop productivity. The critical pH at which crop growth is affected varies with crop, cultivar and soil type. Critical levels may be as high as pH 5 to 5.5 for less tolerant plants in soils with soluble sources of aluminium but otherwise can be as low as pH 3.9 to 4. Agronomists generally use soil pH as measured in a 2:1 water-to-soil mixture as an index of a soil's acidity or alkalinity.

2.29. Soil Minerals

Almost any mineral that exists may be found in some soil, somewhere. The broad and deep subject area of soil mineralogy can barely be touched upon here. Only some of the elementary basics shall be discussed.

The mineral portion of soil is divided into three particle-size classes: sand, silt, and clay. Note: Sand, silt, and clay are collectively referred to as the fine earth fraction of soil. They are <2 mm in diameter. Larger soil particles are referred to as rock fragments and have their own size classes (pebbles, cobbles, and boulders). Rock fragments do not play a significant role in ACE Basin soils. The three particle size classes are defined as follows: Mineralogically, sand, and silt are just small particles of rock and are largely inert. The two important differences among them are their relative capacity to hold water that is available for uptake by plants and their effects on soil drainage.

Clay particles are mineralogically different from sand and silt. Clay minerals form at or near earth's surface, in soil or in water. Most clay belongs to a class of minerals called phyllosilicates, which have formed from the breakdown products of other minerals. Like all phyllosilicates, clay minerals have a sheet-like structure, which is revealed when the crystals are observed through a scanning electron microscope. More familiar phyllosilicate minerals that are often large enough to be seen with the naked eye are the micas such as muscovite and biotite.

Due to isomorphous substitution, in which one ion is substituted for another in the crystal structure of a mineral, many types of clay have a net negative charge. That is, if all the protons and all the electrons that are part of the clay mineral's crystal structure were counted, there would be more electrons than protons. Another source of negative charge on clays is the ionization of hydroxyl groups at the edge of crystal (called broken edge charge). The net negative charge of clay minerals is responsible for a property called cation exchange capacity , or CEC. When placed in a solution, clay minerals attract cations (positively charged particles) to their surfaces. The bonds between the clay mineral surface and the cations are relatively weak, and these cations can be exchanged for other cations that are dissolved in the solution.

The significance of CEC is that cations moving through a soil in solution may be held by the soil. Sometimes these cations (usually metals) are plant nutrients, like potassium, calcium, and magnesium. The loosely held nutrients can then be taken up by plant roots or by other soil organisms. This is one of the ways that soils store nutrients for future biological use. The cation exchange property is also responsible for the soil's ability to filter some environmental contaminants from water (Brady and Weil, 2002).

There are many different phyllosilicate clay minerals. Two that are commonly found in the soils of the ACE Basin study area include kaolinite and members of the smectite group of clay minerals. (Montmorillonite is one of the better known smectites.) Kaolinite does not shrink and swell when dried or wet, which makes it ideal for making bricks and pottery. It also has many other commercial uses. Kaolinite has a very low CEC. Smectites, on the other hand, have a high CEC and a very high shrink-swell capacity. Soils with high smectite content are known to cause problems with the construction of buildings, roads, and other infrastructure. Most soils in the ACE Basin study area have only low to moderate shrink-swell potentials, however. The few soils with high shrink-swell potential also happen to be saltwater wetlands.

2.30. Soil structure

Sweigard *et al.,* 2007, stated that soil structure is of particular importance in the absorption of water and the circulation of air. A desirable structure should have a high proportion of medium-sized aggregates and an appreciable number of large pores through which water and air can move. Structure of both the B horizon and the A horizon is very crucial to proper drainage, infiltration, and productivity. In soils with poor structure, root penetration is limited thus reducing the plants access to water and nutrients. Structure of the A horizon has received a great deal of attention because of its relation to (a) seedbed preparation, (b) erosion potential, (c) aeration, (d) water infiltration, and (e) overall soil health.

There are three very important aspects of soil structure. They are (a) the arrangement into aggregates of a desirable shape and size, (b) the stability of the aggregate, and (c) the configuration of the pores, that is, whether or not they are connected by channels or isolated.

Aggregates that are stable in water permit a greater rate of absorption of water and greater resistance to erosion. Aggregates that are unstable in water tend to slake and disperse. These aggregates, when exposed to raindrops, are particularly subject to dispersion and the resultant crusting of soils. This crusting greatly affects seeding emergence, and increases runoff and erosion (Quiroga *et al.*, 1996, Parfitt *et al*., 1997).

The stability of aggregates is due to the kind of clay, the chemical elements associated with the clay, the nature of the products of decomposition or organic matter, and the nature of the microbial population. The expanding type of clay is more likely to produce unstable aggregates, other things being equal. An excess of sodium associated with clays tends to cause dispersion. A high proportion of hydrogen and/or calcium are associated with aggregation. The mycelial growth of fungi appears to have a binding effect on soils.

Although kind of clay and amount of organic matter affects soil structure, there are other factors that also affect soil structure. The following have long been known to improve structure: freezing and thawing, wetting and drying, action of burrowing insects and animals, and the growth of root systems of plants. All of these have a loosening effect on the soil, but it should be kept in mind that they have no part in aggregate stability. The loosening of the soil is a necessary part of aggregate formation, not aggregate stability (MacLeod 1973).

2.31. Soil Textural Class

The relative combination of sand, silt, and clay in a soil defines its texture (Parfitt *et al*., 1997, Sweigard *et al*., 2007). It is obvious that soil texture is important in determining the nutrient-holding abilities of a soil. Along with soil structure (the arrangement of soil particles in aggregates), the texture of soil is also important to water-holding capacity, water movement, and the amount and movement of soil air in a given soil. All of this is important to the health and type of plants and other organisms that can exist in a particular soil. Once the percent by weight of sand, silt, and clay are known (or, rather, any two of them), the soil texture can be plotted on the triangular graph known as the soil textural triangle. Laker and Dupreez (1982) stated that the region on the graph where the three particle size percentages meet is the soil's texture. Loam has been determined to be the texture best suited to the growth of most agricultural crops, having the optimum combination of heavy and light soil qualities.

2.32 Ordination and Principal component Analysis

Ordination is a collective term for multivariate techniques which adapt a multi-dimensional swarm of data points in such a way that when it is projected onto a two dimensional space any intrinsic pattern the data may possess becomes apparent upon visual inspection (Pielou, 1984). Basically, ordination serves to summarize community data (such as species abundance data) by producing a low-dimensional ordination space in which similar species and samples are plotted close together, and dissimilar species and samples are placed far apart.

Generally, ordination techniques are used to describe relationships between species composition patterns and the underlying environmental gradients which influence these patterns (asking, what factors structure the community?). For example, if you wanted to examine the distribution patterns of tree species in the Sierra Nevada Mt. Range, ordination could be used to determine which species are commonly found associated with one another, and how the species composition of the community changes with increase in elevation. Recently, use of ordination techniques have expanded to include analysis of dietary overlap (Schluter and Grant, 1982), and to explore patterns of within species morphological differences with geographic distance between populations (Alisauskas, 1998).

Principal component analysis

Principal component analysis (PCA), a type of ordination, according to Anderson and Ter Braak (2002) is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. The number of principal components is less than or equal to the number of original variables. This transformation is defined in such a way that the first principal component has the largest possible variance (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it is orthogonal to (i.e., uncorrelated with) the preceding components. The principal components are orthogonal because they are the eigenvectors of the covariance matrix, which is symmetric. PCA is sensitive to the relative scaling of the original variables.-

CHAPTER THREE

3.0 Materials and Methods

3.1 The Study Area

The study was carried out in Anambra State, with a total land area of 4,416 sq. km, Anambra State is situated on a generally low elevation on the eastern side of the River Niger, and shares boundaries with Kogi, Enugu, Imo, Abia, Rivers, Delta and Edo states. It lies within the following geographical locations: 5º 451 N to 6° 451 N and 6° 361 E to 7° 081 E (Egboka 1993). It is bordered in the West by Delta state, on the North by Kogi State, on the east by Enugu State and on the South by Imo state.

According to Anambra State Director of Forestry's report (Ezike 2011), Anambra state is made up of five (5) forest zones which are also based on the five agricultural zones of the state. They include: Awka zone, Nnewi zone, Abagana zone, Otuocha zone, and Onitsha zone. Out of these five zones, three zones were randomly selected for sampling and characterization. Egboka (1993) stated that, Anambra is a state in the south-eastern Nigeria. Its name is an anglicized version of the original 'Oma Mbala', the name of the river now known as Anambra River. The state derives its name from the Anambra River, the largest, most southerly, left bank tributary of the River Niger.

3.2 The Climate Anambra State

The climate of Anambra State is an equatorial tropical rain forest type. It is characterized by two main seasons viz: the rainy (wet) season and the dry season. The rainy season is characterized by heavy thunder storms and occurs between the months of April and October, while the dry season extends from November to March annually (Nwosu, 2003).

The intensity of the rainfall is generally heavy during the rainy season, except in the month of August when there is a noticeable drop in rainfall. This phenomenon is normally referred to as the August break and hence the double maxima of rainfall which is characteristic of this pattern of rainfall. This rainy season is characterized by high temperature (25ºC to 33ºC), and high relative humidity (85%) (Nwosu, 2003). Nwosu (2003) reported that the dry season is characterized by chilly and dry North east Monsoon or hamattan winds. This lowers temperature appreciably especially in the months of December and January. He noted that its main features are: excessive evaporation, low relative humidity, and general dry weather which results in the drying and loss of vegetal cover. He also noted that in most part of Anambra State, temperature is usually high over the year. Thus the average minimum and maximum temperatures are about 25ºC and 32°C, respectively, while the annual rainfall is also very high with a mean of about 2000 mm.

3.3 Experimental design

In accordance with the design, soil samples were collected from the three forest types in the three forest zones at three different points and in three different depths 0-15 cm, 15-30 cm, and 30-45 cm.

Abagana forst zone covered the following five (5) Local GovenmentAreas: Dunokofia, Njikoka, Idemmili North and South and Oyi. The following sites were sampled and characterized: Achala Forest Reserve (Achala), Odengwu community forest (Nteje) and Iyiocha shrine forest (Awkuzu).

Awka forest Zone comprised the following five (5) Local Government areas: Awka North and South, Orumba North and South and Anaocha. The following sites were sampled and characterized: Mamu Forest Reserve (Ozu, Orumba), Unenzu Community forest (Mgbakwu) and Ngene Shrine Forest (Amawbia).

Nnewi forest Zone covered the following five (5) Local Government Areas: Nnewi North and South, Ekwusigo, Ihiala and Ogbaru and the following sites were sampled and chararcterized: Osomari East Forest Reserve (Oseakwa), Ukpor Community Forest (Ukpor), Ogugu-Nza Shrine forest (Ozubulu). Parameters under consideration in soil sampling analysis include: Bulk density, Moisture content, Organic matter, Organic carbon, Cation exchange capacity, pH, and Nitrogen, Phosphorus, Potassium, Calcium and soil Textural classes.

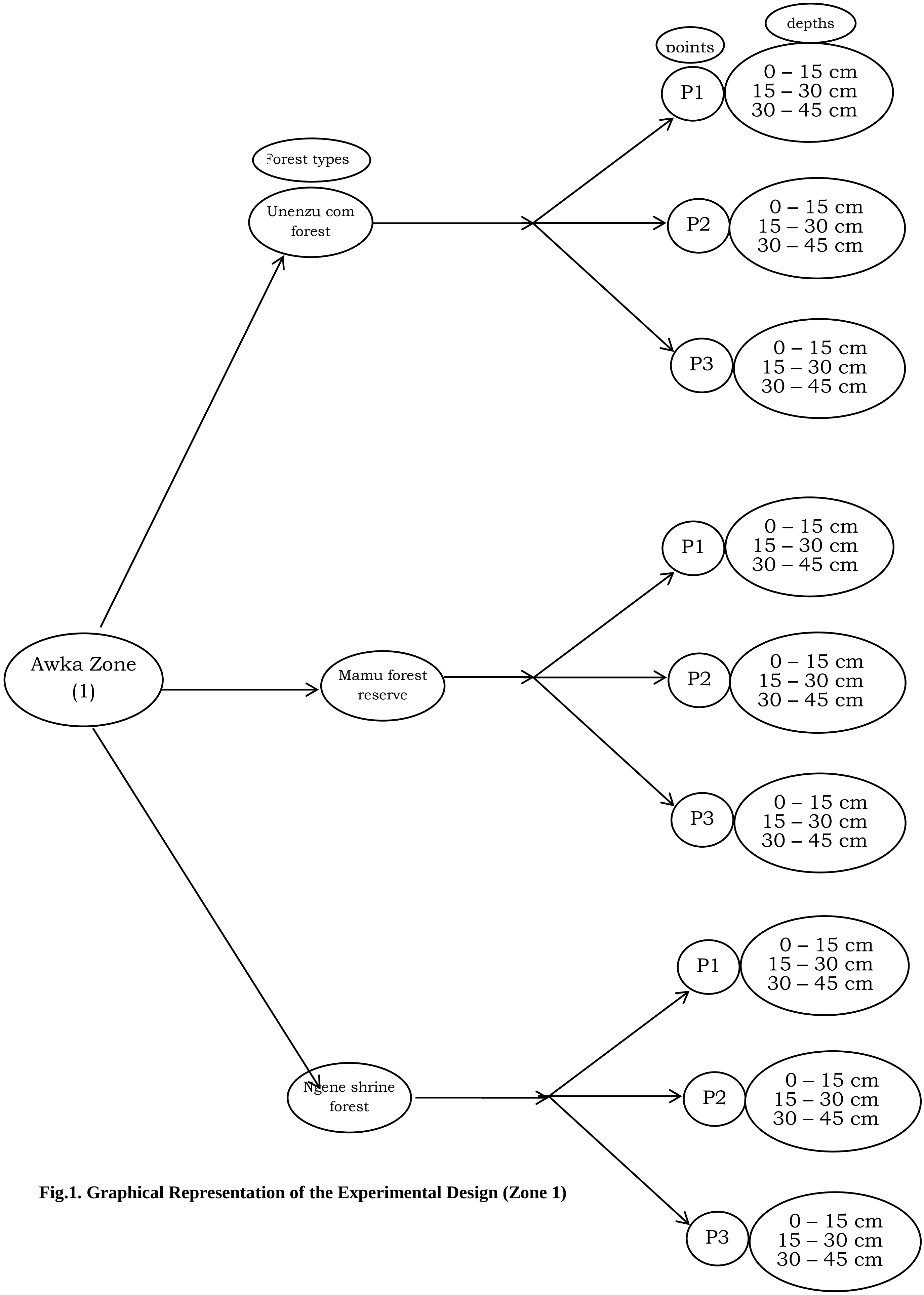


Fig.1. Graphical Representation of the Experimental Design (Zone 1)

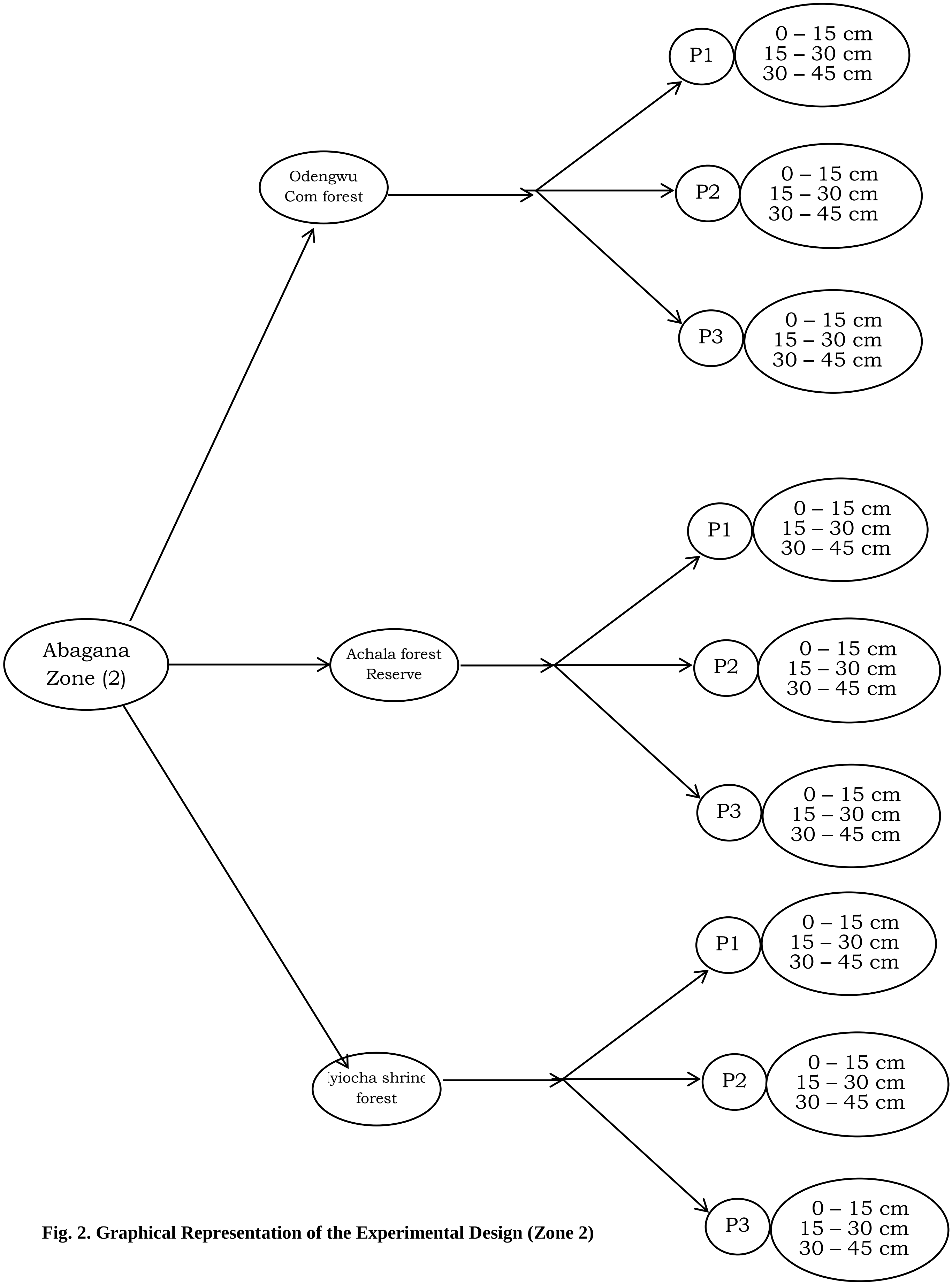
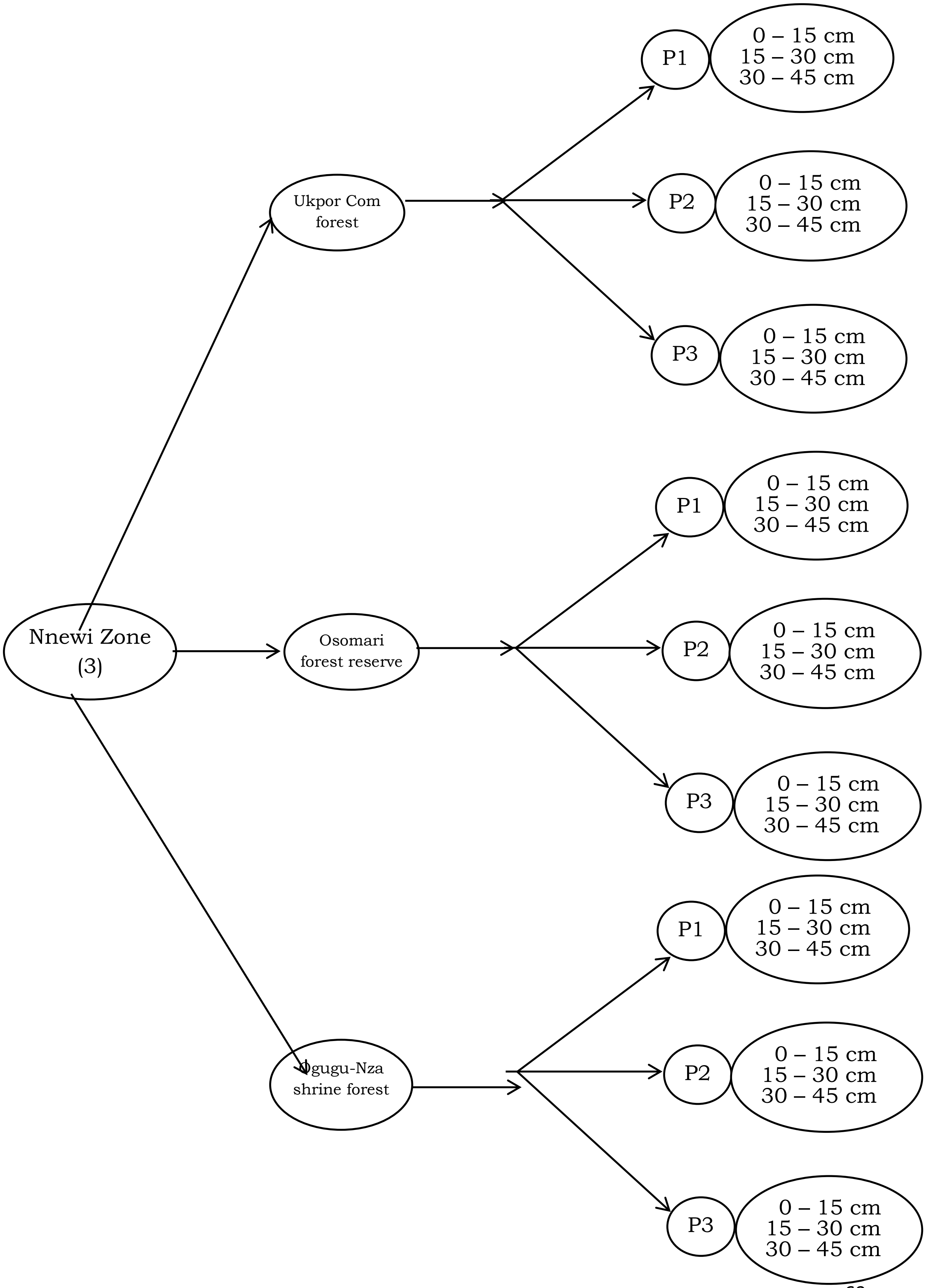


Fig. 2. Graphical Representation of the Experimental Design (Zone 2)


Nnewi Zone
(3)
Ukpor Com
forest
Osomari
forest reserve
Ogugu-Nza
shrine forest
P1
0 – 15 cm
15 – 30 cm
30 – 45 cm
P2
0 – 15 cm
15 – 30 cm
30 – 45 cm
P3
0 – 15 cm
15 – 30 cm
30 – 45 cm

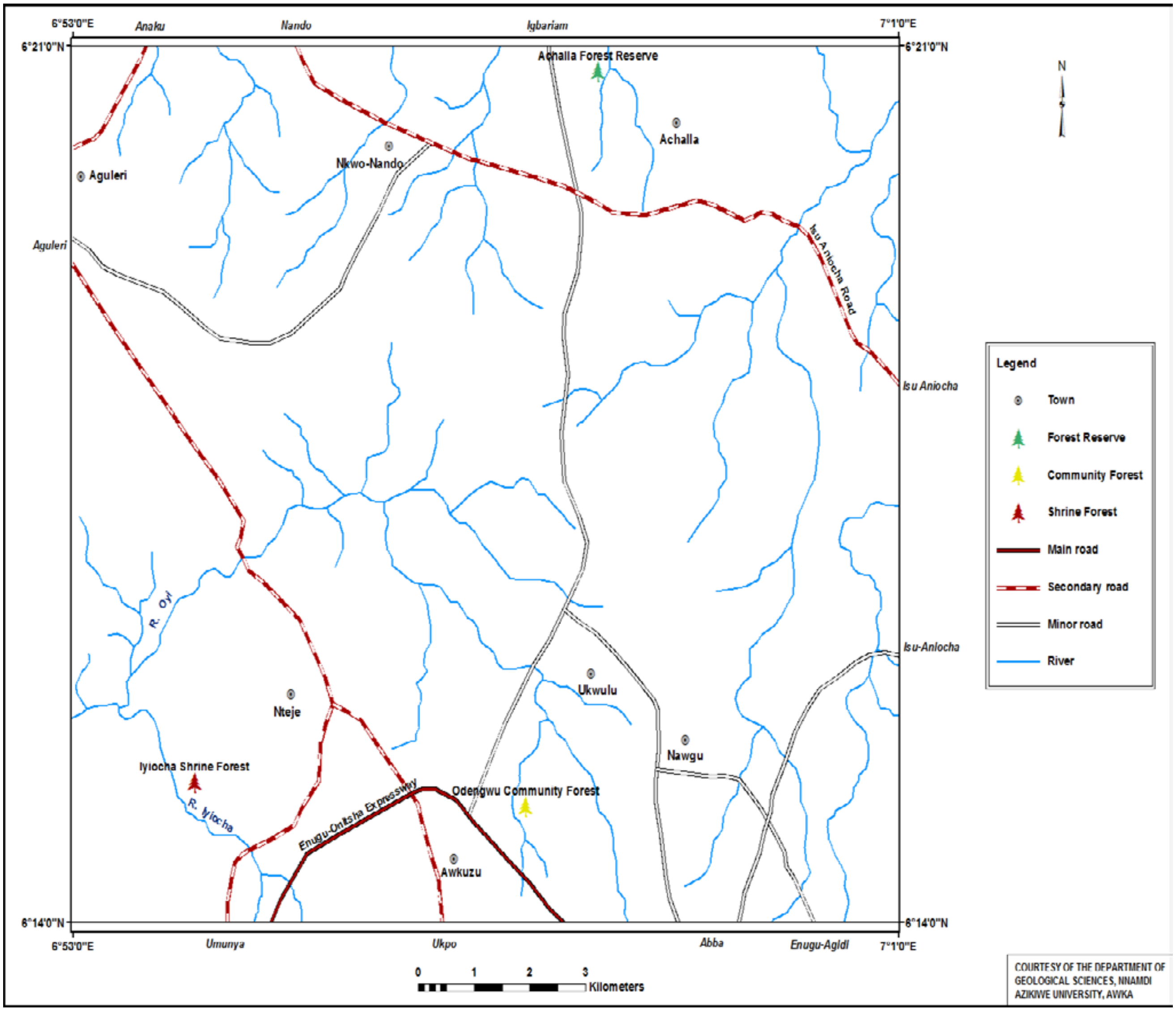


Fig.4. Map of Abagana forest zone, indicating the sampled sites

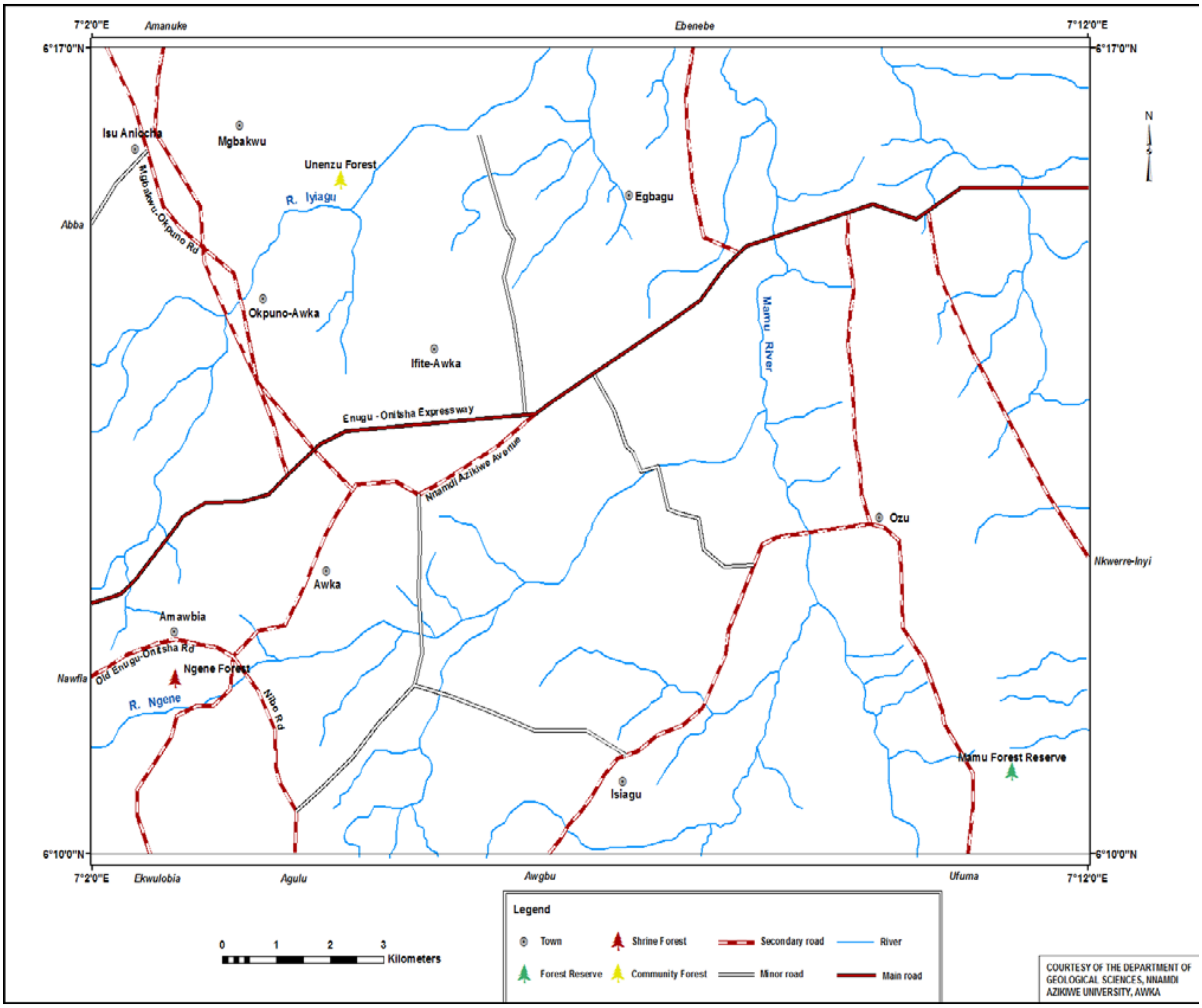


Fig.5. Map of Awka forest zone, indicating the sampled sites

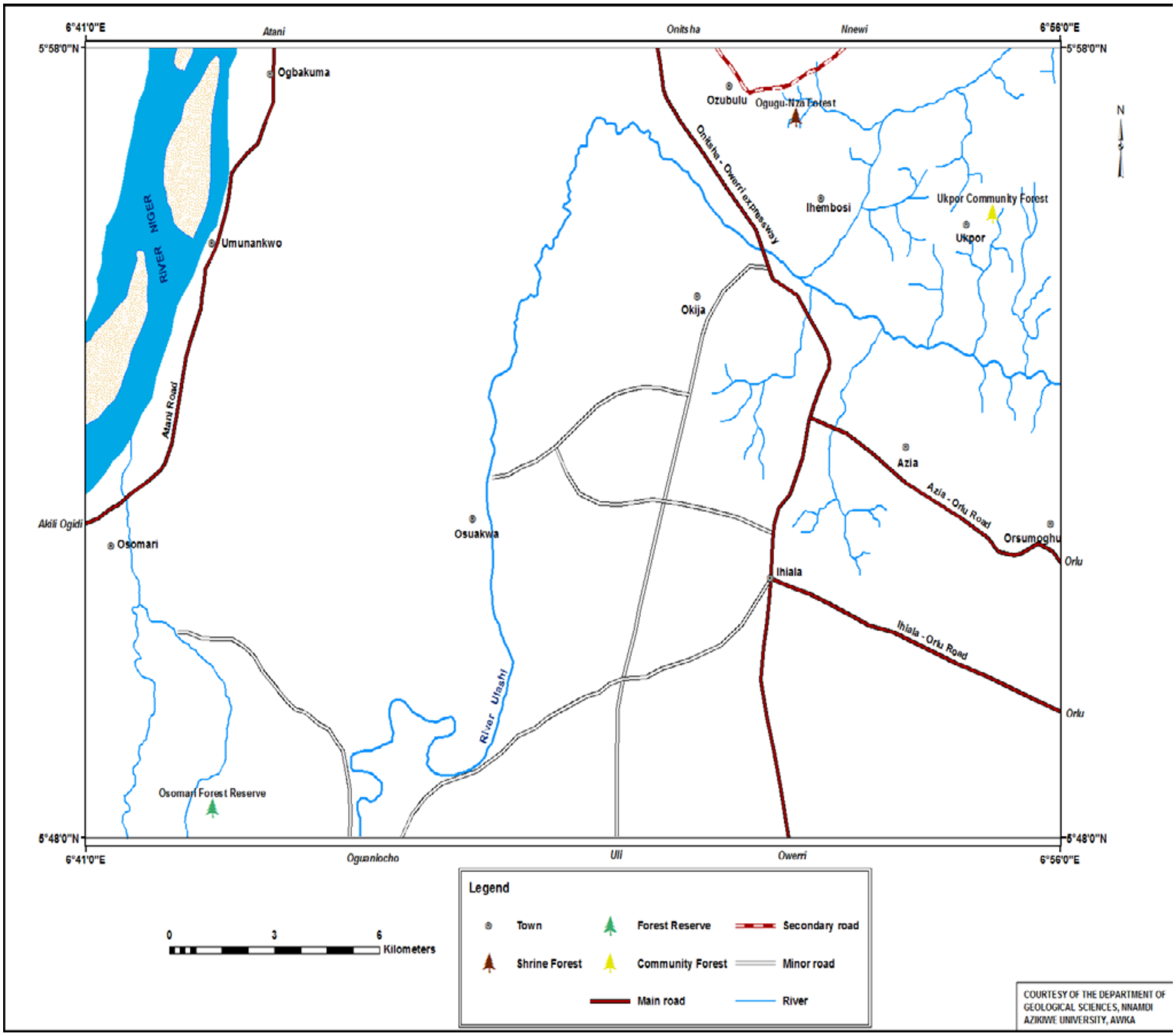


Fig.6. Map of Nnewi forest zone indicating the sampled sites

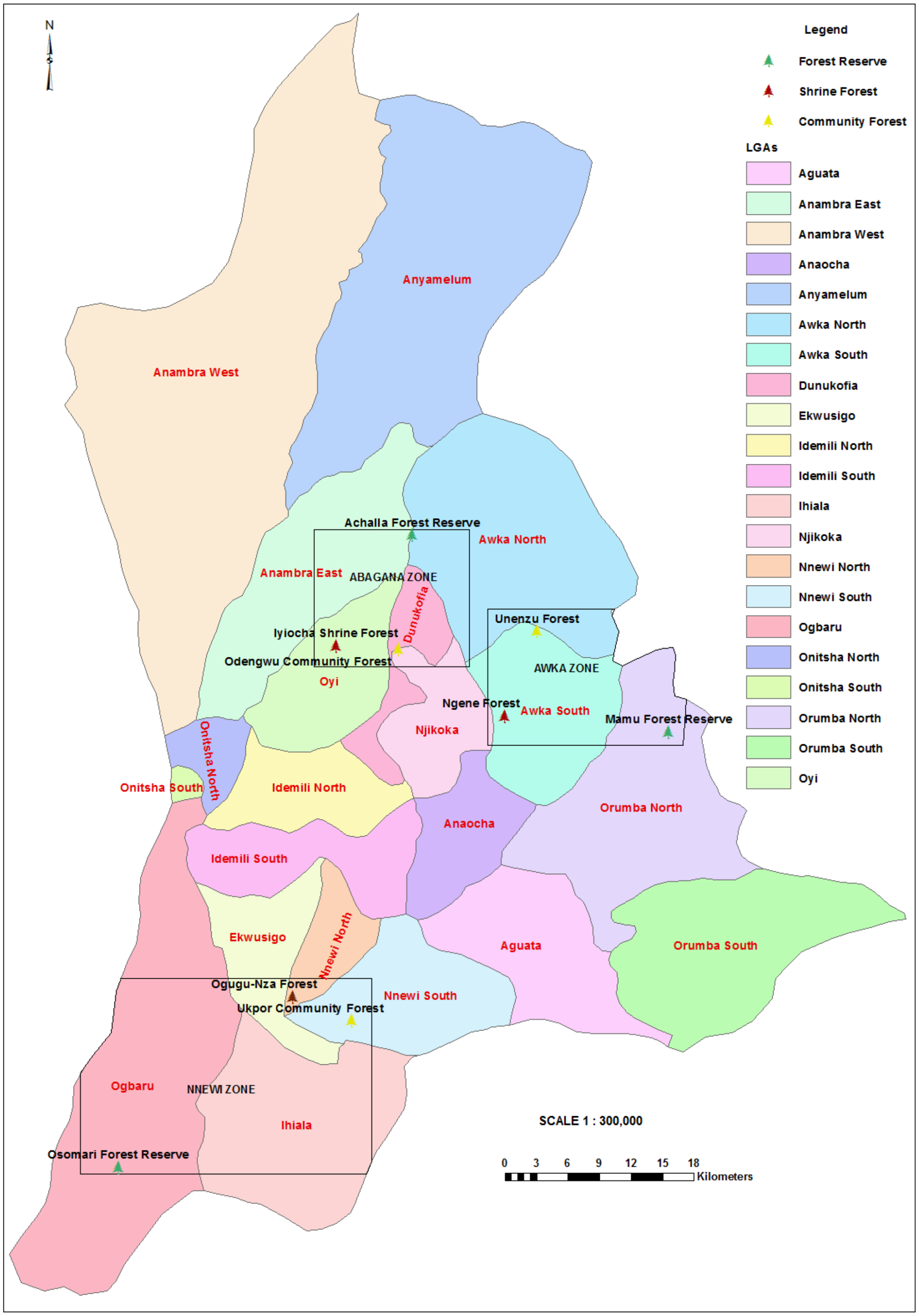


Fig.7. Map of Anambra state, indicating the study areas

3.4 Biodiversity Studies

3.4.1 Measures Based on Floristic

The first step taken to carry out this research was a preliminary/reconnaissance survey of the forests to be sampled. This entailed a careful study of the areas in question to determine the heterogeneity and the technique to be used in sampling the areas. The species composition of each sampled forest was assessed floristically; this was accompanied by the abundance of each species present at a site. It is useful to distinguish between abundance and richness, the latter being the number of species present on a particular area.

However, the forest area was marked out and randomly stratified, and then measurement by girth was made of trees above one metre in height. Species were identified using Flora of West Tropical Africa vol 2 by Hutchinson and Dalziel (1963) and Nigerian Trees by Keay *et al.,* (1989). Also the service of Prof. J. C. Okafor, a renowned plant Taxonomist cum Ecologist from the Department of Applied Biology, Ebonyi State University was employed.

3.5 Stratified Sampling

This involves subdividing the field of study into relatively homogeneous parts and then sampling' each subdivision according to its area, or some other parameter (Moore and Chapman 1986). The use of plotless method was employed to estimate the density of the species. This design could also be used for collecting information about the species composition (inventory), growth and environmental factors. The type of plotless method that was employed is the **Point Center quarter Method**.

3.6 The Point-Center-quarter Method

In the point-center-quarter method, four distances were measured at each sampling point. Four quarters were established at the sampling point through a cross formed by two lines. One line was the compass direction and the second line running perpedincular to the compass direction through the sampling point. The line cross can also be randomly established by spinning a cross over each sampling point. The distance to the mid-point of the nearest tree from the sampling point was measured in each quarter.

The four distances of a number of sampling points were averaged and when squared were found to be equal to the mean area occupied by each tree. Cottam and Curtis (1956) tested the reliability of this method on several random populations by checking the result with the plot method. The estimates of the correct mean area per tree (MA) were found to apply to each of the different sets of mean distance. Therefore no correction factor is needed when the four quarter distances were averaged; $MA = D^2$, where D = the mean distance of four points to the nearest tree distances taken in each of four quarters. The mathematical prove of the workability of this method has been given by Morisita (1954). According to Cottam and Cuttis (1954), the accuracy increases with the number of sampling points and a minimum of 20 points was recommended. Newsome and Dix (1968) noted that one of the limitations of this method for field application is that an individual must be located within each quarter and an individual must not be measured twice.

In point-center-quarter method sampling, two coordinates are chosen as the boundries of the plot. Slips or papers are numbered one to the estimated length of the coordinates which represents the length and breadth of the plot to be sampled or random numbers generated from the random number table. A number is picked from numbered pieces of paper which represents the distance of the sample point on the x-axis, which is then placed along the axis. Then the slip is put back into a bag reshuffled and another number is picked from the bag which represents the next number of the sample point along the y-axis. The investigator then turns 90^{o} and paces the number steps along the y-axis, where the step falls is the sampling point. Two sticks are crossed perpendincular to each other to creat a quadrant. The nearest tree in each quadrant is measured from the point of crossing to the centre of the tree in metres for all the quadrants. The investigator goes to the starting point, repeats the process for the number of times to be taken in the field. The tree species are idenfied to species leve and their girths at breast height measured

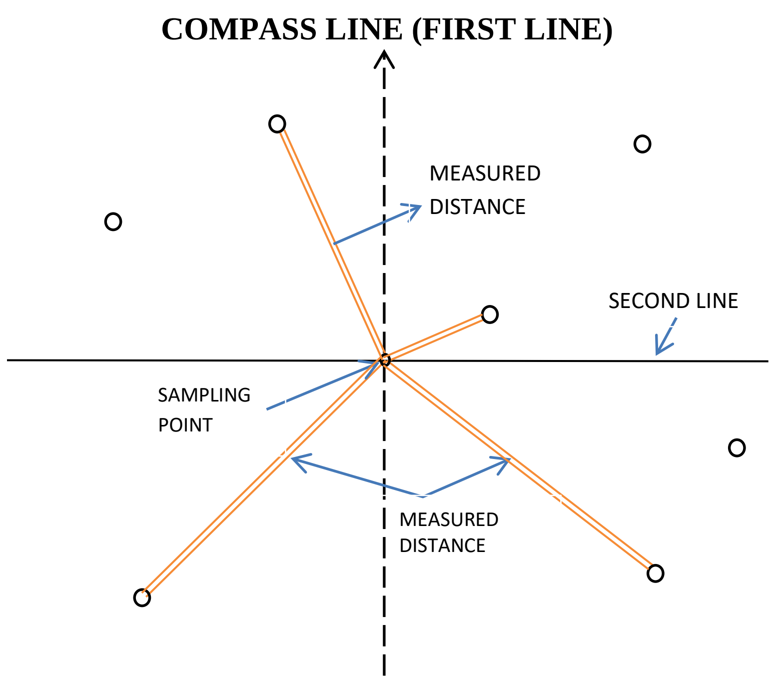


Fig.8. Graphic representation of Points Center Quarter Method

3.7 Shannon Wienner Index of Diversity

After sampling, the species diversity was calculated using the data that accrued from the sampling of the forests. Shannon-Winner Index of Diversity was used to analyze and determine the species diversity of each of the sampled sites, using the formulae**:**

$$H' = -\sum_{i=1}^{s} (Pi) \times (InPi)$$

$$H_{Max} = Ins$$

$$E, \text{Equitability} = \frac{H'}{H_{Max}}$$

Where; Σ = summation
S = number of tree species
i-I = individual species to one
pi = proportion of individual species
Ln pi = natural log of the proportion of the individual species

3.8 Data and statistical analysis

Regression and correlation analyses as well as analyses of variance were also employed to analyze the relationship between the forests and also relate their variations to the soil physical and chemical factors. The correlation coefficient was used to relate the quantitative measures of abundance of one species to quantitative value of another. Principal component analysis, a type of ordination was employed to compare the differences and similarities between the different forests in the vegetation zones of the state in terms of species composition. It was also used to analyse and evaluate the effect of the soil parameters on the productivity of the sampled forests.

3.9 Determination of the soil physicochemical characteristics

3.9.1 Moisture content determination

Before the commencement of sampling, a reconnaissance survey was first carried out in the areas to be sampled. In accordance with the design, a total of 3 plots were randomly mapped out for sampling. A careful observation was made at the study areas to exclude any anthropogenic or natural factors that may militate against the homogeneity of the plots. Random sampling technique was employed in the collection of the soil samples. The plot size of 40m x 60m (2400m^2) was used. After marking out the plots, pegs were used at each end to peg them for proper delineation. Ten (10) pairs of random numbers were generated with papers using two co-ordinates AB and BC. From the pairs of random numbers thus generated, three random points were established using a tape. Pegs were used to fix at the points of intersections from where the soil samples were collected. The same sampling technique was adopted in sampling all the forests. An overall total of eighty one (81) samples were collected, three samples were collected per forest and 27 samples per zone, at the depth of 0-15cm, 15-30cm and 30-45cm in each forest.

After collections from each of the forest, the soil samples were immediately taken to the laboratory for moisture content determination as well as determination of other parameters. A standard oven (Genlab Oven, model MINO/30) was used for oven-drying at the temperature of 104^oC for 24 hours. Meanwhile, before the sample collection, the weight of empty cylinder was determined to be 0.19kg using an electronic weighing scale of 0.60kg maximum point scale. The moisture contents were thus determined using the formular

$$MC = FW – DW$$

Where: MC = Moisture Content

FW = Fresh Weight

DW = Dry Weight

3.9.2 Particle Size Analysis

Particle size analysis is the standard laboratory procedure for the determination of the particle size distribution of a soil. This was determined, using the method of Laker & Dupreez 1982 and Standard Association of Auatralation (1976). Particle size analysis is the standard laboratory procedure for the determination of the particle size distribution of a soil.

Principle

Soil consists of assembly of ultimate soil particles (discrete particles) of various shapes and sizes. The object of a particle size analysis is to group these particles into separate ranges of sizes and so determine the relative proportion by weight of each size range. The method employs sieving and sedimentation of a soil/water/dispersant suspension to separate the particles. The sedimentation technique is based on an application of stokes' law to a soil/water suspension and periodic measurement of the density of the suspension.

Special Apparatus

- Soil (ASTM 152H hydrometer used)
- Uniform set of sedimentation cylinders with internal depth of 340 ± 20mm and capacity of 1 litre.
- 0.20, 2.00 and 4.75mm sieves.
- Internal timer.
- End - over-end shaker, rotating at 15rpm.

Reagents

25% sodium hexametaphosphate (calgon)

250g of sodium hexametaphophate was dissolve in 900mml warm deionised water. When cool, sufficient sodium carbonate was added to bring to pH 8 or 9 and diluted to 11 with deionised water.

Sample Preparation

Sample preparation was carried out according to sample receipt, preparation and storage (SIA/5). The whole sample was weighed and recorded. The sample was passed through the 4.75mm and 2mm sieves making sure that no aggregates were retained on the sieve. Alternatively, the sample may be passed through a mechanical crusher with apertures of 2mm to obtain the material <2mm. weigh and record the amount of particles >475mm and 2.0 to 4.75mm (Laker and Dupreez 1982).

Sample Pretreatment

It is necessary that the following pretreatment be done on the sample prior to dispersion.

Removal of Soluble Salts

On the electrical conductivity of (1.5» 1.0 dS/m) and the clay flocculates in a 1:5 suspension, soluble salts were removed as follows:

1. Weigh 50g of air dry soil («2mm) into a shaking bottle. Half with a hot tap water and was shaken for 10 minutes. The soil was allowed to settle until the supernatant was clear.
2. The clear liquid was siphoned off. Refilled with deionised water and repeated more than four times.

Dispersion and Shaking

1. The soil having been pretreated, add 200ml of deionised water and 20ml of 25% sodium hexametaphosphate.
2. Place the bottle on an end-over-end shaker and shake for 16hours (overnight) at 15rprn.

Hydrometer

The value of effective depth (I) for each hydrometer and the sedimentation cylinder in which it was to be used was calculated as follows: For all readings, the hydrometer was placed in the suspensions 20 seconds before each reading. The volume of the hydrometer bulb (Vb) was measured by the rise in level of water in a 250 ml measuring cylinder, initially filled to the 150ml mark. An effective depth (l) was worked out for each of the major calibration marks from 60 to 5-g/L on each hydrometer. (Standards Association of Australia. AS 1289. C6. 1976),

3.9.3 Soil Sedimentation Determination

1. On completion of shaking, the prepared and dispersed samples were transfer to 1L measuring cylinders. Filled to the 1L mark with deionised water. Note the hydrometer used.
2. It was stirred with a plunger for 20-30 seconds ensuring that all materials at the bottom were brought into suspension. At the end of stirring, the plunger was removed and immediately starts the interval timer.

3. After 4 minutes sedimentation, the hydrometer was immersed to a depth slightly below its floating position and allowed to float freely. Reading was taken at 5 minutes, at the top of the meniscus and recorded to the nearest 0.5g/L.
4. The hydrometer was removed slowly, rinsed clean and placed in a sedimentation cylinder filled with deionised water and 20ml of 25%'sodium hexametaphosphate (blank solution). The water temperature in the blank cylinder was ensured to be the same as that of the soil suspension.
5. The hydrometer was re-inserted in the soil suspension for reading at different periods taken in the same manner as above. At about the same time as each soil suspension hydrometer reading, hydrometer and temperature reading were taken (to the nearest 0.5^0C) of the blank solution.

Sand Measurement

1. The contents of the cylinder was passed through the 0.20mm sieve and thoroughly washed free of all fine particles. Those particles retained on the sieve were the coarse sand fraction.
2. The coarse sand was transferred from the sieve into a pre-weighed, numbered weighing tin. Placed in a drying oven between 105^0C and 110^0C. When dry, was cooled in a dessicator and then weighed.

Calculation

Calculate for each hydrometer reading the summation percentage (P)

$$P (\%) = \frac{(H) \times 100\ W}{W}$$

Where:

H = Hydrometer reading in soil suspension (g/L)

W = weight of the sample

After the sedimentation period, the suspended clay fraction was decanted from the settled silt particles and discarded. The settled silt fraction was then dried in the beaker at 105^0C to constant weight. The soil sand % and silt % were calculated based on their fraction of the original sample mass:

Sand % = $\frac{\text{(oven dry sand mass)}}{\text{Original sample mass}}$ x 100%

Silt % = $\frac{\text{(oven dry silt mass)}}{\text{Original sample mass}}$ x 100%

The clay % was determined by calculating the difference of 100 % minus the sum of the sand % and silt%,

Clay % = 100 - (sand% + silt %).

3.9.4. pH Measurement

i) A 10%w/v suspension of the sample was prepared in distilled water

ii) Mixed thoroughly in a warring micro-blender, then the pH was measured with a good pH meter. (Hanna pH Meter, Model HI 77706P).

3.9.5 Determination of % Nitrogen in White and Red Malt

The micro-kjeldahl method for protein determination was employed for protein determination. This is based on three principles:

Digestion: $R\,NH_2 + 2H_2SO_4 \longrightarrow (NH_4)_2SO_4 + CO_2 + H_2O$

Distillation: $(NH_4)_2\,SO_4 + 2NaOH \longrightarrow (NH_3 + H_2O + Na_2SO_4$

Absorption: $3NH_3 + H_3 + H_3BO_3 \longrightarrow (NH_4)_3\,BO_3$

Titration: $(NH_4)_3\,BO_3 + HCL \longrightarrow H_3BO_3 + 3NH_4CL$

Procedure

The sample (0.5) was weighed into the micro - kjeldahl flask. To this were added 1 kjeldahl catalyst tablet and 10ml of cone. H_2SO_4. These were set in the appropriate hole of the digestion block heaters in a fume cupboard. The digestion was left on for 4 hours after which a clear colourless solution was left in the tube. The digest was carefully transferred into 100ml volumetric flask, thoroughly rinsing the digestion tube with distilled water and the volume of the flask made up to the mark with distilled water. 5ml portion of the digest was then pipette to kjeldahl apparatus and 5ml of 40% ($^W/_V$) NaOH added.

The mixture was then steam-distilled and the liberated ammonia collected into a 50ml conical flask containing 10ml of 2% boric acid plus mixed indicator (bromol cresol green and methyl orange) solution. The green colour solution was then titrated against 0.01 NHCL solutions. At the end point, the green colour turned to wine colour, which indicated that, all the nitrogen trapped as ammonium chloride. The percentage nitrogen was calculated by using the formula: % N = Titre value **x** atomic mass of nitrogen **x** normality of HCL used **x** 4

3.9.6 Soil Phosphorus determination (AOAC, 1990)

Description of digestion step

Since phosphorus exists in several distinct forms in samples and the approved test method measures only the orthophosphate form, pretreatment methods have been developed to convert the various forms of phosphate-phosphorus to the orthophosphate form. Since the only determination to be made is Total Phosphate-Phosphorus, the sample is digested to convert both the polyphosphate and the organic phosphate to the ortho form at the same time

Equipment and reagents

Equipment

1. Hot plate

2. Tongs or gloves

3. 125mL Erlenmeyer flasks (acid washed)

4. 50mL graduated cylinders (acid washed)

Reagents

1. Phenolphthalein indicator
2. Sulfuric acid solution
3. Ammonium persulfate, crystal
4. Sodium hydroxide. 1 N

Digestion of Sample

(i) Weigh out 2g of the dried sample into a digestion flask and add 20ml of the acid mixture (6S0ml cone $HN0_3$; 80ml Perchloric acid; 20ml conc H_2SO_4).

(ii) Heat the flask until a clear digest is obtained

(iii) Dilute the digest with distilled water to the 50ml mark

Laboratory Procedure

1. Measure 50ml or an appropriate amount of sample diluted to 50ml with distilled water
2. Add 1 drop phenolphthalein indicator. At the development of red colour, add sulfuric acid solution until colour just disappears.
3. Add 1ml of sulfuric acid solution and 0.4 g of ammonium persulfate
4. Boil gently for 30 to 40 minutes or until the total volume is 10ml.
5. Cool, add 1 drop of phenolphthalein and neutralize to a faint pink color with 1 N sodium hydroxide
6. Make up to 50 mL with distilled water. The digested sample is then tested for total Phosphorus.

Preparation of Standard

100mg/1standard phosphorus solution was prepared from 1000mg/1 stock solution and treated as sample Digestion reagents.

$$\text{Conc. of sample} = \frac{\text{Abs sample}}{\text{Abs of standard}} \times \text{conc. of standard}$$

1. Surface Acid Digestion Reagent

Carefully add 300ml concentrated Sulfuric acid to approximately 600ml distilled water. Cool and dilute to 1L with distilled water.

2. Sodium Hydroxide 1 N

Dissolve 40g of Sodium hydroxide pellets in distilled water Cool and dilute to 1L.
Ascorbic acid procedure:

1. Sulfuric Acid Solution 5N. Dilute 70ml of concentrated Sulfuric acid to 500ml with distilled water (add acid to water, carefully).
2. Potassium Antimonyl Titrate Solution. Dissolve 1.3715gm of Potassium antimonyl tartrate in 400ml of distilled water in a 500 mL volumetric flask and dilute to 500ml. Store in a glass stoppered bottle.
3. Ammonium Molybdate Solution. Dissolve 20 g of Ammonium molybdate in 500ml of distilled water store in a glass stopper bottle.

4. Ascorbic Acid Solution 0.1M. Dissolve 1.76g of Ascorbic acid in 100ml of distilled water. Store at 4°C and discard after 1 week

5. Combined Reagent. To prepare 100ml of combined reagent, the following reagents were combined and mixed thoroughly after each addition. P [poi] 50ml 5 N Sulfuric acid 5ml Potassium antimonyl titrate solution 15ml Ammonium molybdate solution 30ml Ascorbic acid solution

Reagents were added in the order listed. All reagents were at room temperature before mixing. At the occurrence of turbidity, the reagents were shaken and allowed to stand until turbidity clears. The combined reagent was stable for only 4 hours.

6. Stock Phosphate Solution. Dissolve 2195mg of anhydrous Potassium dihydrogen phosphate in distilled water and dilute to 1L. This Yields a concentration of 50 mg/L

7. Standard Phosphate Solution. Dilute 10 ml of the stock solution to 100 ml with distilled water. This yields a concentration of 50 mg/L.

$$\text{Density} = \frac{\text{Weight of sample}}{\text{Volume of sample}}$$

3.9.7 Cation Exchange Capacity

CEC and base saturation with neutral NH_4OAc

Equipment and Apparatus

1. 250 ml beaker
2. Balance to weigh to the nearest 0.01 gm
3. 7.0cm Buchner funnel
4. Filter paper (7cm Whatman #1 or #42)
5. 250ml suction flask connected to vacuum pump
6. 250ml volumetric flasks
7. Balance, stir plate, stirr bars and container for reagents
8. Apparatus and instrumentation for NH_4^+ analysis. Apparatus and instrumentation for Ca^{2+}, Mg^{2+}, K^+, and Na^+ analyses

Reagents

I. 1M NH_4OAc at pH 7.00

Following are directions for making 10L of this reagent. Multiply quantities by appropriate values for making larger or smaller volumes.

The solution was made in a fume hood to avoid breathing vapors of ammonia and acetic acid. 580ml of glacial acetic acid (99.5%) was added to approximately 5L of water. Add 680ml of concentrated ammonium hydroxide (58% NH_40H). Add water to yield a volume of approximately 1900ml. Adjust pH to 7.00 with drop wise additions of either ammonium hydroxide or acetic acid. Dilute to 10L.

2. Ethyl alcohol (95%).

3. 1M KCL

Exchangeable Cations and Cation Exchange Capacity

1.0 M potassium chloride. Dissolve 74.56g KCl in distilled water. Transfer to a 1000mL flask and make to volume with distilled water.

0.01 M sodium hydroxide. Dissolve 0.4g NaOH in distilled water. Transfer to a 1000ml flask and make to volume with distilled water. Prepare in a fume cupboard.

Strontium nitrate/hydrochloric acid solution. Dissolve 10g strontium nitrate in distilled water. Transfer 10 a 100ml volumetric flask and dilute to volume with distilled water. Pipette 8.9ml conc. hydrochloric acid into a 100ml flask half full of distilled water. Cool and dilute to volume. Mix the two solutions in a reagent bottle. Prepare in a fume cupboard. Phenolphthalein indicator Dissolve 1g of phenolphthalein in 100ml ethanol then mix with 100ml distilled water stirring constantly. Filter if a precipitate forms and transfer to a reagent bottle.

0.5 add 1mmol$_c$ L^{-1} Mg standards Pipette 0.6 and 1.2ml stock Mg standard solution into 100ml flask. Pipette 4ml strontium nitrate hydrochloric acid mixture into each flask and make to volume with KCl solution. I and 2 mmol$_c$ L^{-1} Ca standards Pipette 2 and 4ml stock Ca standard solution into 100ml volumetric flasks. Pipette 4ml strontium nitrate/hydrochloric acid mixture into each flask and make to volume with KCI solution.

Exchangeable cations are displaced by leaching soil with a solution of potassium chloride. In the leachate, exchangeable calcium and magnesium are determined by atomic absorption spectrometry and exchangeable acidity by titration against standard sodium hydroxide solution. The generally small contributions from exchangeable Na and K were ignored and calculated the effective CEC as the sum of changeable Ca. Mg and acidity.

i. Weigh 5g (-0.01g) of dry soil into a clean 50 ml beaker. Add 25 ml potassium chloride (KCI) solution and stir thoroughly.

ii. Place a filter paper in a funnel over a 100ml collecting bottle. Pour the soil suspension through the filter. When the liquid has drained, leach the soil with 3 further 25ml portions of KCl, allowing each to drain before adding the next (total of 100ml leaching solution). Retain the leachate for analysis of Ca. Mg and acidity once drainage stopped.

iii. Determination of Exchange Ca and Mg.

- Using a measuring cylinder, transfer 25ml of the leachate to a clean beaker and add 1ml strontium nitrate solution.
- Determine the concentrations (as $mmol_c\ L^{-1}$) of Ca and Mg in the leachate by atomic absorption spectrophotometry (AAS).
- Calculate exchangeable Ca and Mg in the soil sample (as $mmol_c\ L^{-1}$, kg^{-1}) by multiplying the concentrated of each ion by 20.

iv. Determination of exchangeable acidity

- Using a measuring cylinder, transfer 25 ml of the leachate to a 50ml flask. Add 5 drops phenolphthalein indicator.
- Place the flask on a magnetic stirrer and titrate against 0.01m sodium hydroxide (NaOH) solution. Add the NaOH slowly from a burette until the first appearance of a faint pink colour. Record the burette until reading (4ml).
- Calculate exchangeable acidity (as $mmol_c\ kg^{-l}$) by multiplying 4 by 8.

v. Determination of Cation Exchange Capacity (CEC) and Base Saturation (BS)

- The formula below was used to calculate CEC ($mmol_c\ kg^{-1}$) and BS (%):

  CEC = Ca + K + H

Soil survey standard test method

3.9.8 Soil Organic Carbon

Scope

Estimates of total organic carbon (OC expressed as C) were used to assess the amount of organic matter in the soils. According to Allison, In Black, *et al* (1994), the method measures the amount of carbon in plant and animal remains. Including soil humus but not charcoal or coal Levels are commonly highest in surface soils but wide variations from almost zero to above 15% C are possible. The presence of Cl will produce a positive interference in saline soils (>0 5% Cl). The bias resulting from the presence of CI can be corrected if required.

Principle

The determination of soil organic carbon is based on the Walkley-Black chromic acid wet oxidation method (McLeod, 1973). Oxidisable matter in the soil is oxidised by 1 N $K_2Cr_20_7$ solution. The reaction is assisted by the heat generated when two volumes of H_2S0_4 are mixed with one volume of the dichromate. The remaining dichromate is titrated with ferrous sulphate. The titre is inversely related to the amount of C present in the soil sample.

Apparatus

- Hot plate with simmerstat control or electric nest as used in macro-nitrogen determinations or Bunsen burner with tripod and gauze.
- Heat-resistant sheet on which to cool flasks
- Fume cupboard.
- 10 mL automatic zero pipette or syringe pipette.

Caution: If using an ordinary pipette, use a rubber pipette filter to suck up the potassium dichromate solution which is poisonous.

- 20ml measuring cylinder or syringe pipette for dispensing concentrated sulphuric acid.
- 250ml dry Erlenmeyer (conical) flasks 250ml tall form beakers can be used as an alternative to Erlenmeyer flasks for Potentiometric titration.
- 200°C thermometer
- 50ml burette or automatic titration unit
- 1000ml volumetric flask

- 100ml volumetric flask

Reagents

I N Potassium Dichromate

Dissolve 49 040g $K_2Cr_20_7$ AR (dried at 105°C) in deionised water, transfer to a 1 L volumetric flask and make to volume with deionised water.

Sulphuric Acid 98% w/w

This should be used fresh from the bottle and not left standing in a burette or beaker, as it rapidly picks up moisture from the air. It is satisfactory until the strength falls to <96%.

0.4 N Ferrous Sulphate

Dissolve 112g FeS04.7H20 in 800ml deionised water containing 15ml concentrated H2S04 Dilute to 1 L with deionised water and store in a dark bottle.

"Ferroin"

Dissolve 1.485 g O-phenanthroline monohydrate and 0695g ferrous sulphate in approximately 80 mL deionised water, then dilute to 100 mL Store in a dark bottle away from light.

Procedure

1. Determine the moisture content of the air-dry soil which has been ground to pass a 0.42 mm sieve.
2. Weigh accurately enough soil to contain between 10 mg and 20 mg of carbon into a dry tarred 250 mL conical flask (between 0.5g and 1g for topsoil and 2g and 4g for subsoil)
3. Accurately add 10ml 1 N $K_2Cr_20_7$ and swirl the flask gently to disperse the soil in the solution. Add 20ml concentrated H2S04, directing the stream into the suspension. Immediately swirl the flask until the soil and the reagent are mixed. Insert a 200^{o}C thermometer and heat while swirling the flask and the contents on a hot plate or over a gas burner and gauze until the temperature reaches 135°C (approximately ½ minute)

4. Set aside to cool slowly on an asbestos sheet in a fume cupboard. Two blanks (without soil) must be run in the same way to standardise the $FeS0_4$ solution.
5. When cool (20-30 minutes), dilute to 200ml with deionised water and proceed with the $FeS0_4$ titration using either the "ferroin" Indicator or potentiometrically with an expanding scale pH/mV meter or auto-titrator.

"Ferroin" Titration

Add 3 or 4 drops of Ferroin indicator and titrate with 0.4 N $FeS0_4$. As the end point is approached, the solution takes on a greenish colour and then changes to a dark green. At this point, add the ferrous sulphate drop-by-drop until the colour changes sharply from blue-green to reddish-grey. If the end point is overshot, add 0.5 or 1.0ml of 1 N K_2Cr_2O and reapproach the end point drop-by-drop Correct for the extra volume added. If over 8ml of the 10ml dichromate have been consumed, the determination must be repeated with a smaller soil sample.

Manual Potentiometric Titration

1. Set an expanded scale pH/mV meter with a platinum electrode and calomel reference electrode to read E (mV). Insert the electrodes and temperature compensator in the solution and stir with a magnetic stirrer. Tall form beakers are used as an alternative to conical flasks giving more room for the electrodes, temperature compensator and burette.
2. Using one of the unknowns, plot a titration curve by recording values of measured E (mV) and mL titrant (04 N FeS04) added from a burette. The end point is then found on the point of inflexion on the curve (approximately 750 mV). Subsequent titrations are simply discontinued when this point is reached, and the corresponding titrant consumption is then measured. If over 8ml of the 10ml has been consumed, the determination must be repeated with a smaller soil sample.

Automatic Potentiometric Titration

Use an auto-titrator with a platinum electrode to the mV terminal and calomel reference electrode to the glass electrode terminal. Use a 25 mL auto-burette for the 0.4 N $FeS0_4$ titrant. The titration is carried out by first plotting a titration curve as described above and then automatically titrating to the end point (approximately 750 mV) thus determined.

Titrator settings are as follows proportional band 2, delay 5 seconds, direction of titration downscale burette speed 1.

Calculations

From the equation

$$2Cr_2O_7^{2-} + 3C + 16H^+ \longrightarrow 4Cr^{3+} + 8H_2O + 3CO_2\uparrow$$

1mL of 1 N Dichromate solution is equivalent to 3mg of carbon.

Where the quality and normality of the acid/dichromate mixture used are as stated in the method, the percentage carbon is determined from the following

$$\text{Organic Carbon (\%)} = \frac{0.003g \times N \times 10ml \times (1 - T/S) \times 100}{ODW}$$

$$= \frac{3(1 - T/S)}{W}$$

Where:

N = Normality of $K_2Cr_2O_7$ solution

T = Volume of $FeSO_4$ used in sample titration (mL)

S = Volume of $FeSO_4$ used in blank titration (mL)

ODW = Oven-dry sample weight (g)

3.9.9 Procedure for Analysis of Heavy Metals

Materials and Method

Apparatus

FS 240 Varian Atomic absorption spectrophotometer

Nitrous oxide oxidant gas

Acetylene gas

Air oxidant gas

Distilled water

Conical f1ask

Reagents

1000ppm Ca standard solutions

1000ppm K standard solution

Preparation of Working Solutions

Ca Working Solution

100ppm or Ca working solution was first prepared in 100ml of distilled water.

Calculation

Cl V1 = C2V2

C1 = concentration of the working solution = 100ppm

V1 = volume of distilled water used to prepare the working solution = 100ml

C2 = concentration of zinc stock solution = 1000ppm

V2 = vol or stock that was used

$$\frac{100ppm \times 100ml}{1000ppm} = V2$$

V2 = 10ml of stock solution + 90ml or distilled water

10ppm were prepared from 100ppm working solution by collecting 10ml of· working solution and adding 90ml of distilled water.

K working solution

100ppm of K working solution was first prepared in 100ml of distilled water.

Calculation

$C1V1 = C2V2$

C1 = concentration of the working solution = 100ppm

V1 = volume of distilled water used to prepare the working solution = 100ml

C2 = concentration of zinc stock solution = 1000ppm

V2 = vol of stock that will be used

$$\frac{100ppm \times 100ml}{1000ppm} = v2$$

V2 = 10ml of stock solution + 90ml of distilled water

10ppm was prepared from 100ppm working solution by collecting 10ml of working solution and adding 90ml of distilled water.

Principle of AAS

Working principle: according to American Public Health Association (1998), Atomic absorption spectrometer's working principle is based on the sample being aspirated into the flame and atomized when the AAS's light beam is directed through the flame into the monochromator, and onto the detector that measures the amount of light absorbed by the atomized element in the flame. Since metals have their own characteristic absorption wavelength, a source lamp composed of that element is used, making the method relatively free from spectral or radiational interferences. The amount of energy of the characteristic wavelength absorbed in the flame is proportional to the concentration or the element in the sample.

Procedure:

The sample is thoroughly mixed by shaking, and 100ml or it is transferred into a glass beaker of 250ml volume. The sample is aspirated into the oxidizing air-acetylene flame or nitrous oxide acetylene flame. When the aqueous sample is aspirated, the sensitivity for 1% absorption is observed. (Makino and Takahara 1999).

3.9.10 Determination of Organic Matter

- The mass of an empty was determined and recorded, clean, and dry porcelain dish (mp).
- A part of or the entire oven dried test specimen from the moisture content experiment was placed in the porcelain dish, and the mass of the dish and soil sample Mpps was determined and recorded.
- The dish was placed in a muffle furnace. Gradually increase the temperature in the furnance to 44^0C leave the specimen in the furnace overnight.
- The porcelain dish was removed carefully using the tongs (the dish is very hot) and allow it to cool to room temperature. The mass of the dish containing the ash (burned soil) (Mp_A) was determined and recorded.

Calculation

Determine the mass of the dry soil

$MD = MP_{DS} - Mp$

Determine the mass of the ash in the soil.

$MA = Mp_A - Mp$

Determine the mass of organic matter

$M_0 - M_D - M_A$

Determine the organic matter (content)

$$OM = \frac{M_A}{M_D} \times \frac{100}{1}$$

Where:

MD = Mass of Soil

MPDS = Mass of Crucible + Soil

M_P = Mass of Crucible

M_A = Mass of Ash

MPA = Mass of Crucible + Ash

MP = Mass of Crucible

M_A = Mass of Ash

MD = Mass of Soil

CHAPTER FOUR

4.0 RESULTS

4.1 Ecological Survey of Plant Species in the forest sites

Floristics, species important value indices and structural characters of the forest zones

A total of 12 species of plants belonging to 8 families were recorded in Achala forest reserve. *Tectona grandis* recorded the highest importance value index (62.53), succeeded by *Gmelina aborea* (42.14) while *Milletia zechiana* recorded the least important value index (6.38). *Tectona grandis* therefore becomes the most abundant species of Achala forest reserve (Table 1).

Table 1: Species Abundance of Achala Forest Reserve

All Species	Freq	R. Freq%	Dens	R. Dens%	Domin	R. Domin%	IVI
Tectona grandis	90	25.35	1.28	30	239.53	7.18	62.53
Gmelina arborea	60	16.9	0.8	18.75	216.48	6.49	42.14
Melicia excelsa	25	7.04	0.27	6.25	686.09	20.56	33.85
Tetrapleura tetraptera	25	7.04	0.27	6.25	588.09	17.62	30.91
Adansonia digitata	20	5.63	0.21	5	471.66	14.13	24.76
Irvingia gabonensis	30	8.45	0.32	7.5	252.13	7.55	23.5
Ceiba pentandra	20	5.63	0.21	5	339.52	10.17	20.81
Vitex doniana	25	7.04	0.27	6.25	170.16	5.1	18.39
Daniella oliveri	25	7.04	0.27	6.25	138.3	4.14	17.44
Draecena arborea	15	4.23	0.16	3.75	71.39	2.14	10.11
Milletia thonningii	10	2.82	0.11	2.5	128.87	3.86	9.18
Milletia zechiana	10	2.82	0.11	2.5	35.55	1.07	6.38
Total	**355**	**99.99**	**4.27**	**100**	**3337.76**	**100.01**	**300**

A total 23 species of plants belonging to 16 families were recorded in Iyiocha shrine forest. *Newbouldia laevis* recorded the highest importance value index (45.99), followed by *Pterocarpus* sp (33.26) while *Dialum guineense* recorded the least importance value index (2.77). *Newbouldia laevis* therefore is the most abundant species in IyiOcha Shrine Forest (Table 2).

Table 2: Species Abundance of IyiOcha Shrine Forest

Species	**Freq**	**R. Freq%**	**Dens**	**R. Dens%**	**Domin**	**R. Domin%**	**IVI**
Newbouldia laevis	65	16.67	0.5	17.5	373.59	11.83	45.99
Pterocarpus sp	35	8.97	0.29	10	451.31	14.29	33.26
Pointiana regia	35	8.97	0.25	8.75	190.25	6.02	23.75
Dacroydes edulis	25	6.41	0.18	6.25	290.38	9.19	21.85
Melicia excelsa	15	3.85	0.11	3.75	393.38	12.45	20.05
Sarcocephalus latifolius	25	6.41	0.18	6.25	132.55	4.2	16.86
Irvingia gabonensis	20	5.13	0.14	5	173.58	5.49	15.62
Ficus exasperata	20	5.13	0.14	5	64.17	2.03	12.16
Syzigium guineense	15	3.85	0.11	3.75	118.93	3.76	11.36
Gambeya albida	10	2.56	0.07	2.5	184.15	5.83	10.89
Parkia biglobosa	15	3.85	0.11	3.75	94.77	3	10.6
Spondias mombin	15	3.85	0.11	3.75	70.49	2.23	9.83
Borassus aetheopicum	15	3.85	0.11	3.75	68.26	2.16	9.76
Aubrrevillea kerstingii	15	3.85	0.11	3.75	59.67	1.89	9.49
Hildegardia barteri	10	2.56	0.07	2.5	98.21	3.11	8.17
Piptadeniastrium africanum	10	2.56	0.07	2.5	84.99	2.69	7.75
Anthocleista djalonensis	10	2.56	0.07	2.5	63.41	2.01	7.07
Adansonia digitata	5	1.28	0.04	1.25	129.47	4.1	6.63
Ficus carpensis	10	2.56	0.07	2.5	36.8	1.16	6.23
Monodora myrtstica	5	1.28	0.04	1.25	38.86	1.23	3.76
Enantia chlorantha	5	1.28	0.04	1.25	18.84	0.6	3.13
Bukholtzia coriaceae	5	1.28	0.04	1.25	15.51	0.49	3.02
Dialum guineense	5	1.28	0.04	1.25	7.37	0.23	2.77
Total	**390**	**99.99**	**2.86**	**100**	**3158.95**	**99.99**	**300**

A total of 30 species of plant belonging to 17 families were recorded in Ogugu-Nza shrine forest. *Newbouldia laevis* and *Pterocarpus* sp have the highest importance value index (28.80) (21.82) respectively, while *Datarium microcarpium* has the least importance value index (2.77). It is obvious that *Newbouldia laevis* is the most abundant species in Ogugu-Nza Shrine Forest (Table 3).

Table 3: Species Abundance of Ogugu-Nza Shrine Forest

Species	**Freq**	**R. Freq%**	**Dens**	**R. Dens%**	**Domin**	**R. Domin%**	**IVI**
Newbouldia laevis	45	11.25	0.17	11.25	191.12	6.3	28.8
Pterocarpus sp	25	6.25	0.09	6.25	282.82	9.32	21.82
Afzelia africana	20	5	0.07	5	296.49	9.77	19.77
Gambeya albida	20	5	0.07	5	282.07	9.29	19.29
Melicia excelsa	15	3.75	0.06	3.75	261.49	8.62	16.12
Dacroydes edulis	20	5	0.07	5	107.68	3.55	13.55
Irvingia gabonensis	20	5	0.07	5	97.16	3.2	13.2
Prosopis africana	20	5	0.07	5	89.35	2.94	12.94
Ficus carpensis	20	5	0.07	5	84.38	2.78	12.78
Parkia biglobosa	15	3.75	0.06	3.75	137.98	4.55	12.05
Syzigium guineense	15	3.75	0.06	3.75	124.04	4.09	11.59
Myrianthus arborea	15	3.75	0.06	3.75	113.15	3.73	11.23
Hildegardia barteri	15	3.75	0.06	3.75	104.84	3.45	10.95
Enantia chlorantha	15	3.75	0.06	3.75	90.74	2.99	10.49
Anthocleista djalonensis	15	3.75	0.06	3.75	84.44	2.78	10.28
Pentaclethra macrophylla	10	2.5	0.04	2.5	151.91	5	10
Adonsonia digitata	10	2.5	0.04	2.5	122.23	4.03	9.03
Draecena arborea	10	2.5	0.04	2.5	49.96	1.65	6.65
Ceiba pantandra	10	2.5	0.04	2.5	45.59	1.5	6.5
Pointiana regia	10	2.5	0.04	2.5	37.32	1.23	6.23
Spondias mombin	10	2.5	0.04	2.5	32.86	1.08	6.08
Tetrapleura tetraptera	5	1.25	0.02	1.25	62	2.04	4.54
Buchholzia coriaceae	5	1.25	0.02	1.25	41.72	1.37	3.87
Daniella oliveri	5	1.25	0.02	1.25	30.69	1.01	3.51
Dialium guineense	5	1.25	0.02	1.25	30.15	0.99	3.49
Sarcocephalus latifolius	5	1.25	0.02	1.25	21.24	0.7	3.2
Sensepalum dulcificum	5	1.25	0.02	1.25	17.41	0.57	3.07
Aubrevillea kerstingii	5	1.25	0.02	1.25	16.52	0.54	3.04
Elaeis guineensis	5	1.25	0.02	1.25	16.42	0.54	3.04
Datarium microcarpium	5	1.25	0.02	1.25	11.47	0.38	2.88
Total	400	100	1.49	100	3035.22	99.99	299.99

A total of 23 species of plant belonging to 12 familiea were recorded in Osomari forest reserve. *Gmelina arborea* and *Tectona grandis* have the highest importance value index (69.99) (43.64) respectively, while *Borassus aethiopicum* has the least importance value index (2.75). *Gmelina arborea* therefore becomes the most abundant species of Osomari Forest Reserve (Table 4).

Table 4: Species Abundance of Osomari-East Forest Reserve.

Species	Freq	Freq%	Dens	R. Dens%	Domin	R. Domin%	IVI
Gmelina arborea	95	26.76	0.14	30	68.79	12.9	69.66
Tectona grandis	50	14.08	0.08	17.5	64.29	12.06	43.64
Adansonia digitata	20	5.63	0.02	5	63.09	11.83	22.46
Beistsclemeidia manii	20	5.63	0.02	5	49.82	9.34	19.98
Daniella oliveri	25	7.04	0.03	6.25	27.53	5.16	18.45
Datarium macrophylla	15	4.23	0.02	3.75	37.14	6.96	14.94
Parkia biglobosa	15	4.23	0.02	3.75	23.09	4.33	12.3
Melicia excels	10	2.82	0.01	2.5	34.3	6.43	11.75
Vitex doniana	15	4.23	0.02	3.75	11.97	2.24	10.22
Draecena arborea	15	4.23	0.02	3.75	7.87	1.48	9.45
Pentaeclethra nacrophylla	5	1.41	0.01	1.25	31.25	5.86	8.52
Hildegardia barteri	10	2.82	0.01	2.5	14.35	2.69	8.01
Enantia chlorantha	10	2.82	0.01	2.5	13.65	2.56	7.88
Afzelia Africana	5	1.41	0.01	1.25	21.53	4.04	6.7
Milletia thorningii	5	1.41	0.01	1.25	13.71	2.57	5.23
Aubrevillea kerstingii	5	1.41	0.01	1.25	13.51	2.53	5.19
Pointiana regia	5	1.41	0.01	1.25	8.79	1.65	4.31
Irvingia gabonensis	5	1.41	0.01	1.25	8.79	1.65	4.31
Piptadeniastrum ıfricanam	5	1.41	0.01	1.25	6.93	1.3	3.96
Sarcocephalus latifolius	5	1.41	0.01	1.25	5.08	0.95	3.61
Anthocleista djalonensis	5	1.41	0.01	1.25	3.79	0.71	3.37
Pterocarpus sp	5	1.41	0.01	1.25	3.54	0.66	3.32
Borassus aethiopicum	5	1.41	0.01	1.25	0.5	0.09	2.75
Total	355	100.03	0.45	100	533.29	99.99	300.01

A total of 25 species of plants belonging to 14 families were recorded in Ngene shrine forest. *Melicia excelsa* has the highest importance value index (31.08) while *Ficus exasperata* has the least importance value index (2.77). *Melicia excelsa* therefore becomes the abundant species of Nwangene Shrine Forest (Table 5).

Table 5: Species Abundance of Ngene Shrine Forest

Species	Freq	R. Freq%	Dens	R. Dens%	Domin	R. Domin%	IVI
Melicia excels	30	7.69	0.05	7.5	139.4	15.89	31.08
Newbouldia laevis	40	10.26	0.07	11.25	46.58	5.31	26.81
Ceiba pantandra	25	6.41	0.04	6.25	84.34	9.61	22.27
Spondias mombin	30	7.69	0.05	7.5	26.03	2.97	18.16
Adansonia digitata	15	3.85	0.02	3.75	84.26	9.6	17.2
Irvingia gabonensis	25	6.41	0.04	6.25	38.69	4.41	17.07
Pterocarpus sp	20	5.13	0.03	5	56.87	6.48	16.61
Dacroydes edulis	20	5.13	0.04	6.25	34.5	3.93	15.31
Afzelia africana	15	3.85	0.02	3.75	60.72	6.92	14.52
Gambeya albida	15	3.85	0.02	3.75	56.34	6.42	14.02
Delonix regia	15	3.85	0.02	3.75	32.24	3.67	11.27
Enanthia chlorantha	15	3.85	0.02	3.75	30.16	3.44	11.03
Parkia biglobosa	15	3.85	0.02	3.75	25.53	2.91	10.51
Elaeis guineensis	15	3.85	0.02	3.75	15.54	1.77	9.37
Datarium microcarpium	10	2.56	0.02	2.5	22.37	2.55	7.61
Monodora myristica	10	2.56	0.02	2.5	14.96	1.71	6.77
Buchholzia coriaceae	10	2.56	0.02	2.5	13.86	1.58	6.64
Dalium guineense	10	2.56	0.02	2.5	8.58	0.98	6.04
Hildegardia barteri	5	1.28	0.01	1.25	18.15	2.07	4.6
Myrianthus arboreus	5	1.28	0.01	1.25	12.25	1.4	3.93
Prosopis africana	5	1.28	0.01	1.25	11.6	1.32	3.85
Rauvolfia vomitoria	5	1.28	0.01	1.25	9.41	1.07	3.6
Sansepalum dulcificum	5	1.28	0.01	1.25	9.32	1.06	3.59
Ficus capensis	5	1.28	0.01	1.25	7.29	0.83	3.36
Ficus exasperata	5	1.28	0.01	1.25	2.06	0.23	2.77
Total	**390**	**100**	**0.63**	**100**	**877.51**	**100.01**	**299.99**

A total of 31 species of plants belonging to 14 families were recorded in Unenzu community forest. *Pterocarpus* sp had the highest importance value index (25.36), followed by *Newbouldia laevis* (20.35), while *Buchholzia coriaceae* had the least importance value index (2.75). *Pterocarpus sp* therefore becomes the most abundant species of Unenzu Community Forest (Table 6).

Table 6: Species Abundance of Unenzu Community Forest

Species	Freq	R. Freq%	Dens	R. Dens%	Domin	R. Domin%	IVI
Pterocarpus sp	30	7.59	0.08	8.75	110.08	9.01	25.36
Newbouldia laevis	30	7.59	0.07	7.5	64.15	5.25	20.35
Afzelia africana	15	3.8	0.03	3.75	148.95	12.19	19.74
Dacroydes edulis	30	7.59	0.07	7.5	54.63	4.47	19.57
Irvingia gabonensis	25	6.33	0.05	6.25	67.59	5.53	18.11
Anacardium occidentalis	25	6.33	0.05	6.25	37.8	3.09	15.67
Spondias mombin	20	5.06	0.04	5	41.07	3.36	13.43
Daniella oliveri	15	3.8	0.03	3.75	69.83	5.72	13.26
Vitex doniana	15	3.8	0.03	3.75	49.16	4.02	11.57
Prosopis africana	15	3.8	0.03	3.75	44.4	3.64	11.18
Sarcocephalus latifolius	10	2.53	0.02	2.5	55.74	4.56	9.6
Ficus exasperata	15	3.8	0.03	3.75	18.92	1.55	9.1
Ceiba pentandra	10	2.53	0.02	2.5	48.96	4.01	9.04
Anthocleista djalonensis	10	2.53	0.02	2.5	46.15	3.78	8.81
Pointiana regia	10	2.53	0.02	2.5	44.37	3.63	8.66
Gambeya albida	10	2.53	0.02	2.5	37.91	3.1	8.13
Ficus carpensis	10	2.53	0.02	2.5	24.77	2.03	7.06
Dialium guineense	10	2.53	0.02	2.5	24.34	1.99	7.02
Dracena arborea	10	2.53	0.02	2.5	24.17	1.98	7.01
Borassus aethiopicum	10	2.53	0.02	2.5	16.13	1.32	6.35
Datariun microcarpium	10	2.53	0.02	2.5	14.01	1.15	6.18
Monodora myristica	10	2.53	0.02	2.5	10.48	0.86	5.89
Elaeis guineensis	10	2.53	0.02	2.5	8.98	0.73	5.77
Melicia excelsa	5	1.27	0.01	1.25	38.8	3.18	5.69
Pentaclethra macrophylla	5	1.27	0.01	1.25	27.04	2.21	4.73
Rauvolfia vomitoria	5	1.27	0.01	1.25	26.37	2.16	4.67
Tetrapleura tetraptera	5	1.27	0.01	1.25	26.27	2.15	4.67
Hildegardia barteri	5	1.27	0.01	1.25	14.87	1.22	3.73
Parkia biglobosa	5	1.27	0.01	1.25	12.6	1.03	3.55
Milletia zechiana	5	1.27	0.01	1.25	10.11	0.83	3.34
Buchholzia coriaceae	5	1.27	0.01	1.25	2.91	0.24	2.75
Total	**395**	**100**	**0.88**	**100**	**1221.54**	**100**	**299.99**

A total of 35 spp belonging to 19 families were recorded in Odengwu community forest. *Ceiba pentandra* and *Afzelia africana* have the highest importance value index (25.86) (25.53) respectively, while *Rauvolfia vomitoria* had the least importance value index (2.54). *Ceiba pentandra* and *Afzelia africana* are therefore the most abundant species in Odengwu Community Forest (Table 7).

Table 7: Species Abundance of Odengwu Community Forest

Species	Freq	R. Freq%	Dens	R. Dens%	Domin	R. Domin%	IVI
Ceiba pentandra	25	6.25	0.05	6.25	147.17	13.36	25.86
Afzelia Africana	20	5	0.04	5	171.03	15.53	25.53
Tetrapleura tetraptera	20	5	0.04	5	112.88	10.25	20.25
Parkia biglobosa	30	7.5	0.05	7.5	44.92	4.08	19.08
Pterocapus sp	30	7.5	0.05	7.5	38.6	3.5	18.5
Newbonldia laevis	30	7.5	0.05	7.5	34.61	3.14	18.14
Irvingia gabonensis	25	6.25	0.05	6.25	37.93	3.44	15.94
Adansonia digitata	10	2.5	0.02	2.5	66.78	6.06	11.06
Vitex doniana	15	3.75	0.03	3.75	32.38	2.94	10.44
Dacroydes edulis	15	3.75	0.03	3.75	30.06	2.73	10.23
Daniella oliveri	15	3.75	0.03	3.75	29.88	2.71	10.21
Hildegardia barteri	10	2.5	0.02	2.5	54.27	4.93	9.93
Gambeya albida	10	2.5	0.02	2.5	44.26	4.02	9.02
Elaeis guineense	15	3.75	0.03	3.75	13.85	1.26	8.76
Datarim microcarpium	10	2.5	0.02	2.5	25.85	2.35	7.35
Poitiana regia	10	2.5	0.02	2.5	15.69	1.42	6.42
Prosopis Africana	10	2.5	0.02	2.5	12.15	1.1	6.1
Pentaclethera macrophylla	5	1.25	0.01	1.25	32.42	2.94	5.44
Myrianthus arboreus	10	2.5	0.02	2.5	4.48	0.41	5.41
Melicia excels	5	1.25	0.01	1.25	31.56	2.87	5.37
Ceiba pentandra	5	1.25	0.01	1.25	29.87	2.71	5.21
Borassus aethiopicum	5	1.25	0.01	1.25	16.56	1.5	4
Enantia chlorantha	5	1.25	0.01	1.25	14.24	1.29	3.79
Milletia zachiana	5	1.25	0.01	1.25	10.72	0.97	3.47
Buchholzia coriaceace	5	1.25	0.01	1.25	7.99	0.72	3.22
Ficus exesperata	5	1.25	0.01	1.25	7.99	0.72	3.22
Ficus capensis	5	1.25	0.01	1.25	5.73	0.52	3.02
Spondias mombin	5	1.25	0.01	1.25	5.73	0.52	3.02
Dialium gunncense	5	1.25	0.01	1.25	4.95	0.45	2.95
Piptadeniastrum africanum	5	1.25	0.01	1.25	4.58	0.42	2.92
Syzigium guineense	5	1.25	0.01	1.25	3.82	0.35	2.85
Sarcocephalus latifolius	5	1.25	0.01	1.25	2.4	0.22	2.72
Anthocleista djalonensis	5	1.25	0.01	1.25	2.34	0.21	2.71
Sensepalum dulcificum	5	1.25	0.01	1.25	0.93	0.08	2.58
Rauvolfia vomitoria	5	1.25	0.01	1.25	0.47	0.04	2.54
Total	**400**	**100**	**0.73**	**100**	**1101.46**	**100**	**300**

A total of 29 spp belonging to 14 families were recorded in Mamu forest reserve. *Tectona grandis* had the highest importance value index (60.31), followed by *Gmelina arborea* (44.08) while *Rauvolfia vomitoria* (3.11) had the least importance value index (2.94). *Tectona grandis* therefore becomes the most abundant species in Mamu Forest Reserve (Table 8).

Table 8: Species Abundance of Mamu Forest Reserve.

Species	Freq	R. Freq%	Dens	R. Dens%	Domin	R. Domin%	IVI
Tectona grandis	75	21.13	0.2	27.5	99.98	11.68	60.31
Gmelina. Aborea	60	16.9	0.13	17.5	82.81	9.68	44.08
Melicia excelsa	15	4.23	0.03	3.75	109.93	12.85	20.82
Pterocarpus sp	20	5.63	0.04	5	70.23	8.21	18.84
Adansonia digitata	10	2.82	0.02	2.5	47.01	5.49	10.81
Dialium guineense	10	2.82	0.02	2.5	36.21	4.23	9.55
Irvingia gabonensis	10	2.82	0.02	2.5	31.61	3.69	9.01
Daniella oliveri	10	2.82	0.02	2.5	31.34	3.66	8.98
Vitex doniana	10	2.82	0.02	2.5	31.04	3.63	8.94
Dacroydes edulis	10	2.82	0.02	2.5	30.03	3.51	8.83
Sensepalmum dulcificum	10	2.82	0.02	2.5	24.28	2.84	8.15
Enantia chhlorantha	10	2.82	0.02	2.5	21.32	2.49	7.81
Ceiba pentrandra	10	2.82	0.02	2.5	19.75	2.31	7.62
Pentaclethra macrophylla	5	1.41	0.01	1.25	39.61	4.63	7.29
Newbouldia laevis	10	2.82	0.02	2.5	12.75	1.49	6.81
Afzelia africana	5	1.41	0.01	1.25	33.02	3.86	6.52
Elaeis guineensis	10	2.82	0.02	2.5	8.07	0.94	6.26
Gambeya albida	5	1.41	0.01	1.25	24.14	2.82	5.48
Datariun macrocarpium	5	1.41	0.01	1.25	14.66	1.71	4.37
Hildegardia barteri	5	1.41	0.01	1.25	14.21	1.66	4.32
Milletia thonningii	5	1.41	0.01	1.25	14.21	1.66	4.32
Myrianthus arboreus	5	1.41	0.01	1.25	9.07	1.06	3.72
Prosopis africana	5	1.41	0.01	1.25	8.23	0.96	3.62
Anthocleista djalonensis	5	1.41	0.01	1.25	7.94	0.93	3.59
Ficus capensis	5	1.41	0.01	1.25	7.99	0.93	3.59
Parkia biglobosa	5	1.41	0.01	1.25	7.9	0.92	3.58
Ficus exasperata	5	1.41	0.01	1.25	6.41	0.75	3.41
Borassus aethiopicum	5	1.41	0.01	1.25	5.67	0.66	3.32
Rauvolfia vomitoria	5	1.41	0.01	1.25	3.88	0.45	3.11
Total	**355**	**100.06**	**0.72**	**100**	**855.72**	**99.98**	**300**

A total of 35 spp belonging to 18 families were recorded in Ukpor community forest. *Ceiba pentandra* and *Gambeya albida* have the highest importance value index (8.87) (18.38) respectively while *Rauvolfia vomitoria* reported the lowest important value index (2.58). *Ceiba pentandra* and *Gambeya albida* are therefore the most abundant species of Ukpor community forest (Table 9).

Table 9: Species Abundance of Ukpor Community Forest

All Species	**Freq**	**R. Freq%**	**Dens**	**R. Dens%**	**Domin**	**R. Domin%**	**IVI**
Ceiba pentandra	5	5.06	0.07	5	202.61	8.87	18.93
Gambeya albida	3.75	3.8	0.05	3.75	247.4	10.83	18.38
Pentaclethra macrophylla	5	5.06	0.07	5	172.75	7.56	17.62
Adansonia digitata	3.75	3.8	0.05	3.75	167.21	7.32	14.87
Sarcocephalus latifolius	5	5.06	0.07	5	77.54	3.39	13.46
Irvingia gabonensis	3.75	3.8	0.05	3.75	102.31	4.48	12.03
Pterocarpus sp	3.75	3.8	0.05	3.75	97.89	4.28	11.83
Datarium microcarpium	3.75	3.8	0.05	3.75	82.02	3.59	11.14
Hildegardia barteri	3.75	3.8	0.05	3.75	66.14	2.89	10.44
Buchholzia coriaceae	3.75	3.8	0.05	3.75	64.43	2.82	10.37
Myranthus arboreus	3.75	3.8	0.05	3.75	61.99	2.71	10.26
Pointiana regia	3.75	3.8	0.05	3.75	54.8	2.4	9.95
Vitex doniana	3.75	3.8	0.05	3.75	46.97	2.06	9.6
Afzelia Africana	2.5	2.53	0.03	2.5	94.72	4.15	9.18
Tetrapleura tetraptera	2.5	2.53	0.03	2.5	88.2	3.86	8.89
Ficus exasperate	3.75	3.8	0.05	3.75	23.69	1.04	8.58
Prosopis Africana	2.5	2.53	0.05	3.75	37.04	1.62	7.9
Sensepalum dulcificum	2.5	2.53	0.03	2.5	50.78	2.22	7.25
Piptadeniastrum africanum	2.5	2.53	0.03	2.5	48.74	2.13	7.17
Draecena arborea	2.5	2.53	0.03	2.5	44.87	1.96	7
Anthocleista djalonensis	2.5	2.53	0.03	2.5	44.36	1.94	6.97
Milletia thoningii	2.5	2.53	0.03	2.5	33.89	1.48	6.52
Enantia chlorantha	2.5	2.53	0.03	2.5	28.09	1.23	6.26
Newboudia laevis	2.5	2.53	0.03	2.5	28.06	1.23	6.26
Dacroydes edulis	2.5	2.53	0.03	2.5	27.76	1.22	6.25
Syzigium guineense	2.5	2.53	0.03	2.5	25.93	1.14	6.17
Parkia biglobosa	2.5	2.53	0.03	2.5	20.88	0.91	5.95
Melicia excels	1.25	1.27	0.02	1.25	69.72	3.05	5.57
Aubrevillea kerstingii	1.25	1.27	0.02	1.25	48.63	2.13	4.64
Beitschlemeidia manii	1.25	1.27	0.02	1.25	40.01	1.75	4.27
Dialium guineense	1.25	1.27	0.02	1.25	38.16	1.67	4.19
Daniella oliveri	1.25	1.27	0.02	1.25	30.57	1.34	3.85
Spondias mombin	1.25	1.27	0.02	1.25	10.59	0.46	2.98
Borassus aethiopicum	1.25	1.27	0.02	1.25	4.33	0.19	2.71
Rauvolfia vomitoria	1.25	1.27	0.02	1.25	1.51	0.07	2.58
Total	**98.75**	**100**	**1.32**	**100**	**2284.6**	**100**	**300**

The number of species was observed to be highest in all the community forests, Ukpor, Odengwu and Unenzu (35, 35 and 31) respectively. The number of families was also observed to be highest in community forests (Odengwu and Unenzu 16, Ukpor 15). In terms of spp density, Achala forest reserve had highest (4.27). Total frequency was seen to be highest in Odengwu and Ogugu-Nza forest (400%) each. Total dominance was found to be highest in Achala forest reerve (3337.8). Species diversity was highest in Ukpor community forest (3.555) and lowest in Achala forest reserve (2.485). Evenness index was highest in Mamu Ukpor forests (0.976) each. (Table 10)

Table 10: summary of the floristic and structural characteristics of the forest sites in Anambra State

Parameters	Achala	Iyiocha	Og-nza	Osomari	Ngene	Unenzu	Odengwu	Mamu	Ukpor
No of species	12	23	30	23	25	31	35	29	35
No of families	5	13	14	9	12	16	16	11	15
Total Density	4.27	2.86	1.49	0.45	0.63	0.88	0.73	0.72	1.32
Total Frequency	355	390	400	355	390	395	400	355	98.75
Total dominance	3337.8	3158.98	3035.22	533.29	877.51	1221.54	1101.46	855.72	2284.6
Species diversity	2.485	2.892	3.229	2.511	3.258	3.258	3.353	3.472	3.555
Evenness index	0.873	0.910	0.949	0.800	0.942	0.949	0.936	0.976	0.976

The species diversity of the sampled sites as well as the dominant species in each of the sample sites was summarized in table 19 below. From the table, the ranking of the species diversity indicated that Ukpor Community Forest and Mamu Forest Reserve ranked highest (3.555) and 3.472 respectively, with 35 numbers of species recorded in each of the forests. In Ukpor community forest, the dominant species is *Ceiba pentandra,* while in Mamu forest reserve, it was discovered that *Tectona grandis* dominated the species.

Achala forest reserve ranked the least in species diversity (2.485) with 12 species and*Tectona grandis* as the dominant species in the forest. (Table 11).

Table 11: Summary of Species Indices of the forest sites

Forest	**Number of Species**	**Shannon Weaver Species Diversity Index**	**Ranking by Species Diversity**	**Dominant Species**
Odengwu	36	3.353	*3th*	*Ceiba pentandra*
Ukpor	35	3.555	*1st*	*Ceiba pentandra*
Mamu	35	3.472	*2nd*	*Tectona grandis*
Unenzu	31	3.258	*4th*	*Pterocarpus sp*
Ogugu- Nza	30	3.229	*5th*	*Newbouldia laevis*
Ngene	26	3.258	*4th*	*Melicia excels*
Iyi-Ocha	24	2.892	*6th*	*Newbouldia laevis*
Osomari	23	2.511	*7th*	*Gmelina aborea*
Achala	12	2.485	*8th*	*Tectona grandis*

Abagana forest zone recorded a total of 17 families, with Odengwu Community forest having the highest number of families. Among all the families recorded, Fabacea dominated the sampled sites (Table 12)

Table 12: Summary of Families of trees found in Abagana forest zone

S/No	Name of forest	Families	No of species
1	Achala forest Reserve	Verbenaceae	3
		Bombacaceae	2
		Irvingaceae	1
		Agvaceae	1
		Fabaceae	5
2	Iyiocha shrine forest	Bignoniaceae	1
		Fabaceae	9
		Bursaraceae	1
		Rubiaceae	1
		Irvingaceae	1
		Myrtaceae	1
		Sapotaceae	1
		Anacardiaceae	1
		Sterculiaceae	1
		Loganiaceae	1
		Annonaceae	2
		Capparidaceae	1
		Arecaceae	1
3	Odengwu community forest	Bombacaceae	3
		Fabaceae	12
		Bignoniaceae	1
		Irvingaceae	1
		Verbenaceae	1
		Bursaraceae	1
		Sterculiaceae	1
		Sapotaceae	2
		Arecaceae	2
		Capparidaceae	1
		Anacardiaceae	1
		Myrtaceae	1
		Rubiaceae	1
		Loganiaceae	1
		Apocynaceae	1
		Annonaceae	1

Nnewi forest zone recorded a total of 15 families, with Ukpor Community forest having the highest number of families. In all the families recorded, Fabaceae dominated the sampled sites (Table 13)

Table 13: Summary of Families of trees found in Nnewi forest zone

S/No	Name of forest	Families of trees	No of species
1	Osomari forest Reserve	Verbenaceae	4
		Bombacaceae	1
		Agavaceae	1
		Sterculaceae	1
		Fabacaea	12
		Irvingaceae	1
		Rubiaceae	1
		Loganiaceae	1
		Arecaceae	1
2	Ogugu-Nza Shrine forest	Bignoniaceae	1
		Fabaceae	15
		Sapotaceae	2
		Bursaraceae	1
		Irvingaceae	1
		Myrtaceae	1
		Sterculiaceae	1
		Loganiaceae	1
		Bombacaceae	2
		Agavaceae	1
		Anacardiaceae	1
		Capparidaceae	1
		Rubiaceae	1
		Arecaceae	1
3	Ukpor Community forest	Bombacaceae	2
		Sapotaceae	3
		Rubiaceae	1
		Irvingaceae	1
		Fabaceae	16
		Sterculiaceae	1
		Capparidaceae	1
		Verbenaceae	1
		Agavaceae	1
		Loganiaceae	1
		Bignoniaceae	1
		Bursaraceae	1
		Anacardiaceae	1
		Arecaceae	1
		Apocynaceae	1

A total of 18 families were found in Awka forest zone, with Unenzu Community forest having the highest number of families. Among all the families recorded, Verbanaceae and Fabaceae dominated the sampled sites (Table 14)

Table 14: Summary of the Families of trees found in Awka forest zone

S/No	Name of forest	Families of trees	No of species
1	Mamu forest Reserve	Verbenaceae	5
		Fabaceae	13
		Bombacaceae	2
		Irvingaceae	1
		Bursaraceae	1
		Bignoniaceae	1
		Arecaceae	2
		Sapotaceae	2
		Sterculiaceae	1
		Loganiaceae	1
		Apocy naceae	1
2	Ngene Shrine Forest	Fabaceae	10
		Bignoniaceae	1
		Bombacaceae	2
		Anacardiaceae	1
		Irvingaceae	1
		Bursaraceae	1
		Sapotaceae	2
		Arecaceae	1
		Annonaceae	2
		Capparidaceae	1
		Sterculiaceae	1
		Apocynaceae	1
3	Unenzu Community forest	Fabaceae	14
		Bignoniaceae	1
		Bursaraceae	1
		Irvingaceae	1
		Anacardiaceae	2
		Verbenaceae	1
		Rubiaceae	1
		Bombacaceae	1
		Loganiaceae	1
		Sapotaceae	1
		Agavaceae	1
		Arecaceae	2
		Annonaceae	1
		Apocynaceae	1
		Sterculiaceae	1
		Capparidaceae	1

4.2: Relationship between number of species and species diversity in the forest zones.

The t-value of the coefficient of the number of species is significant ($P<0.05$) indicating a significant relationship between number of species and species diversity. The coefficient of 0.005 implies that a unit increase in the number of species increases species diversity by 0.005. The number of species actually explains about 48.0% of species diversity. The p-value of the F-statistics is significant ($P<0.05$) indicating that the model is a good fit (table 15).

Table 15: Summary of Regression and Correlation Analysis

Species Diversity=0.782+0.005Number of Species

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.782	0.057459	13.60918	0.0000
Number of Species	0.005	0.001986	2.543793	0.0385

R-squared	0.480361	Mean dependent var	0.923444
Adjusted R-squared	0.406127	S.D. dependent var	0.056232
S.E. of regression	0.043334	Akaike info criterion	-3.246624
Sum squared resid	0.013145	Schwarz criterion	-3.202796
Log likelihood	16.60981	Hannan-Quinn criter.	-3.341204
F-statistic	6.470885	Durbin-Watson stat	2.558927
Prob(F-statistic)	0.038450		

4.3 Results of the forest sites using vegetation and soil attributes.

The lists of the vegetation and soil attributes used for the ordination f the forest site are presented in Tables 16-20. The aim was to ascertain the relationship that exists between the soil physicochemical parameters and the vegetation attributes, and also how they influence one another. The data matrix used in this ordination included the values of density of the abundant plants species, the quantitative values of all the soil attributes and those of the vegetation attributes.

Table 16: List of 20 most abundant species in forest sites (and their codes) used in the ordination by Principal Component analysis

S/No	Codes	Species
1	A	*Tectona grandis*
2	B	*Gmelina arborea*
3	C	*Newbouldia laevis*
4	D	*Delonix regia*
5	E	*Pterocarpus spp*
6	F	*Irvingia garbonensis*
7	G	*Vitex doniana*
8	H	*Ceiba pentandra*
9	I	*Melicia excels*
10	J	*Tetrapleura tetraptera*
11	K	*Dacroydes edulis*
12	L	*Parkia biglobosa*
13	M	*Adansonia digitata*
14	N	*Nauclea latifolia*
15	O	*Ficus exasperata*
16	P	*Anacardium occidentalis*
17	Q	*Ficus carpensis*
18	R	*Pentaclethra machrophylla*
19	S	*Spondias mombin*
20	T	*Afzelia Africana*

Table 17: List of soil and vegetation attributes and their codes used in the ordination by principal component analysis of the forest sites.

Codes	Site attributes
I	Total number of species
Ii	Total number of individual species
Iii	Relative % contribution of six most abundant species
Iv	Relative % contribution of most abundance species
V	Species diversity
Vi	Bulk density
Vii	Cation exchange capacity
Viii	% organic matter
Ix	Soil pH
X	Soil Phosphorus
Xi	Soil Organic carbon
Xii	Soil Total nitrogen
Xiii	Soil Calcium
Xiv	Soil Potassium
Xv	Soil Moisture content
Xvi	Soil %sand
Xvii	Soil %silt
Xviii	Soil % clay

Table 18: List the soil attributes used in the Ordination with species diversity by principal component analysis

Codes	Attributes
A	Species diversity
B	Bulk density
C	Cation exchange capacity
D	% organic matter
E	Soil pH
F	Phosphorus
G	Organic carbon
H	Total nitrogen
I	Calcium
J	Potassium
K	Moisture content
L	% sand
M	% silt
N	% clay

Table 19: List of the soil attributes (only), ordinated with the nine sampled sites by principal component analysis

S/No	Soil attributes
1	Bulk density
2	Cation exchange capacity
3	% organic matter
4	Soil pH
5	Phosphorus
6	Organic carbon
7	Total nitrogen
8	Calcium
9	Potassium
10	Moisture content
11	`% sand
12	% silt
13	% clay

Table 20: List of the six most weighted soil variables used in the ordination by principal component analysis.

S/NO	Soil parameters
1	Bulk density
2	Cation exchange capacity
3	Phosphorus
4	Total nitrogen
5	Organic matter
6	Moisture content

In the ordination of the 20 most abundance species by principal component analysis, three possible groups of associations were observed.

1. The first group of association was between species (o, p, q, r, s, and t).
2. The second group of association was between species l and m. These were found present in all the sampled sites.
3. The third group of association was between (c, d, e f, g, h i, j and k). This association linked all the sampled sites in the sense that all the species were encountered in each of the sampled sites.

Generally, it was observed that these species came from the shrine and community forest. The other species (a, b and n) that has no correlation with other species came from the forest reserves where these trees dominated others (Fig.9).

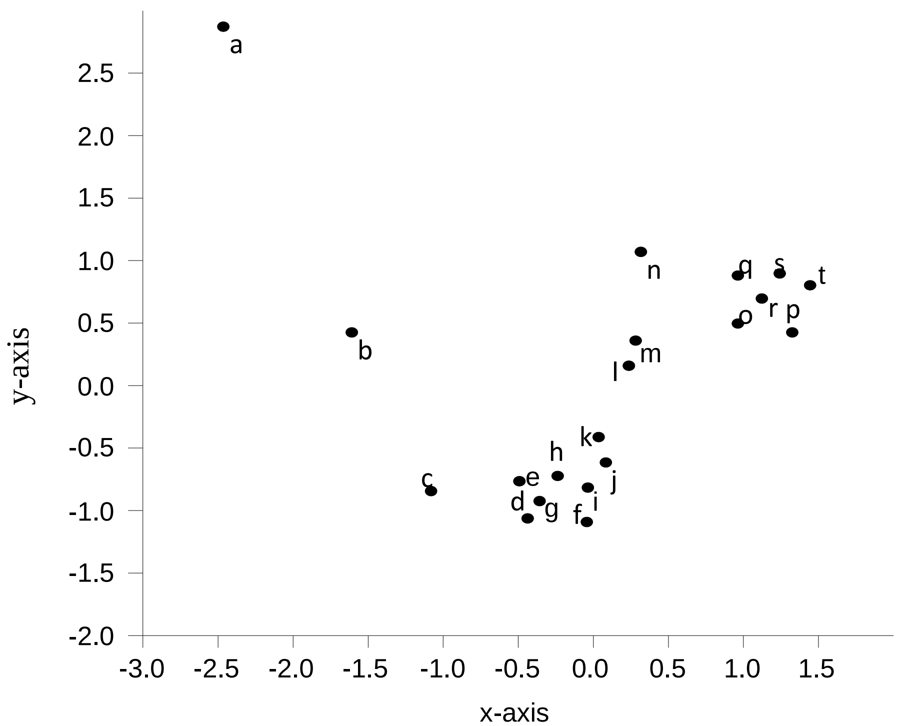


Fig.9. Ordination by Principal Component Analysis of 20 most abundant species

Using the codes and site attributes shown in table 42, five groups of association were observed as seen in Fig.10

1. The first group of association (xviii, xvi and xvii) implies that the soil separates are positively correlated to one another.
2. The second group of association was observed to exist between (xv, xiv and xiii), this indicates that soil calcium, soil potassium and moisture content are positively correlated.
3. The third group of association was observed to exist between (xii, xi, x, ix, viii and vii), implying that the properties that clustered together are similar to each other.
4. The fourth group of association was seen to exist between (v and vi). This indicates that species diversity of the sampled sites depend on the relative percentage contribution of the most abundance species
5. The fifth group of association was observed between (ii and iv) which implies that relative percentage contribution of most abundant species greatly influenced the relative % contribution of most abundant species in the forest sites.

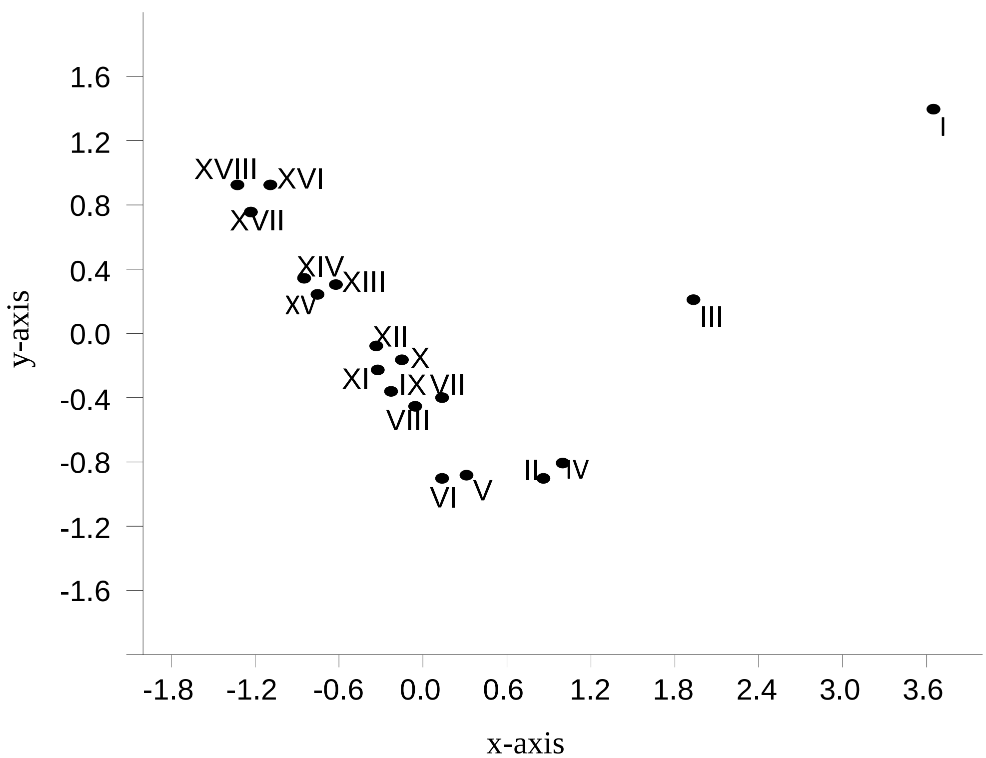


Fig.10. Site attributes ordination by Principal Component Analysis

In the ordination of the species diversity with the soil parameters by principal component analysis, three groups of association were observed (Fig. 11).

1. The first group of association was between cation exchange capacity and % organic matter. These two parameters has the closest affinity to species diversity, hence were presumed to have had the greatest influence on the sites species diversity.
2. The second group of association was found to occur between soil pH and phosphorus. Theis implies that the availability of P is determined by pH of the soil.
3. The third group of association was observed to exist between organic matter and total nitrogen. It could be deduced that these two parameters also have roles to play in the enhancement of the species diversity of the sampled sites, though not in the same magnitude like the first two groups of associations.
4. Other parameters were found scattered farther apart, which implies that they have little or no influence on the species diversity and productivity of the sampled sites (Fig 11).

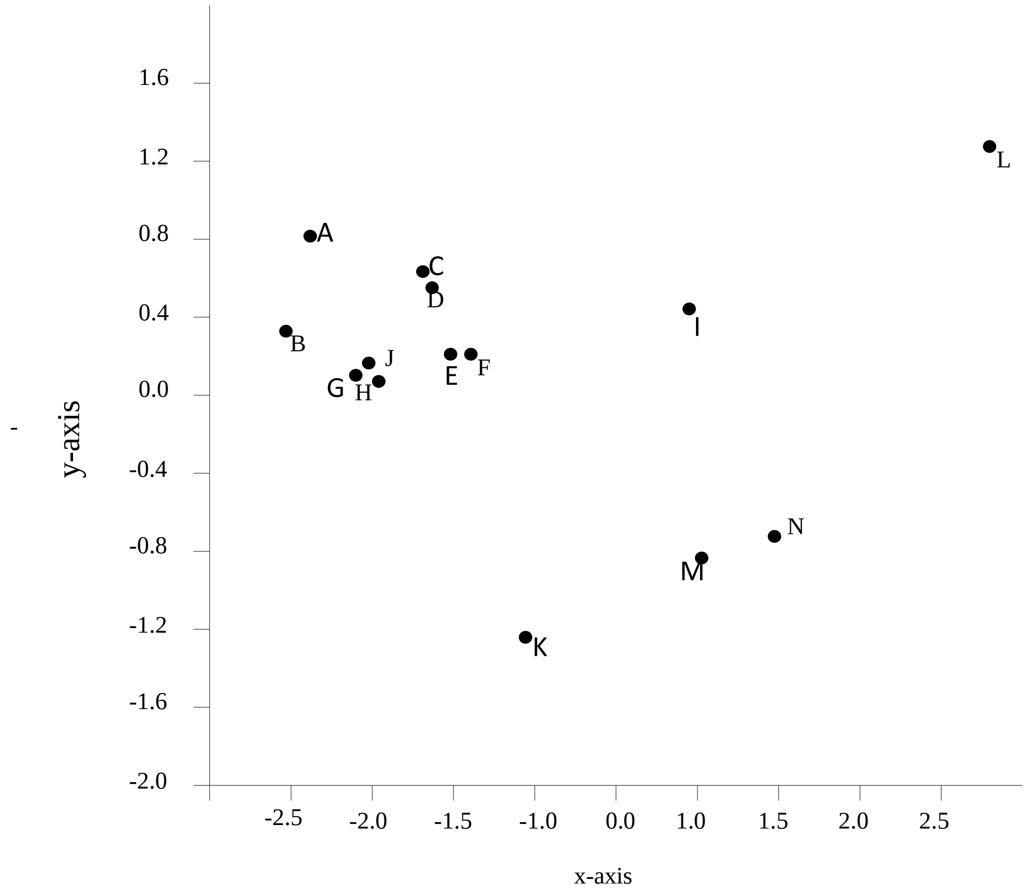


Fig.11 Ordination of the species diversity with the soil attribute by Principle Component Analysis

In the ordination of the soil attributes and the sampled sites by principal component analysis, the following deductions were made (Fig 12).

1. There was an association between four soil parameters (CEC, OM, Sand and OC), and two sites (Ukpor and Iyiocha). This implies that these two sites are similar in soil characteristics.
2. Another association was between (Ca, Bd, K) and (Ngene, Odengwu, Mamu and Ogugu-Nza) forests. The implication is that these sites that clustered together are classified as having similar soil characteristics.
3. In the third group of association, three soil parameters (Silt, P and TN) were observed to have a strong correlation with Unenzu forest.
4. The fourth group of association was observed to exist between (Clay and Moisture content) and Achala and Osomari forest reserves. These sites have similar soil characteristics. Also these two important soil parameters accounted for the overall influence on the species diversity of these sites (Fig 12).

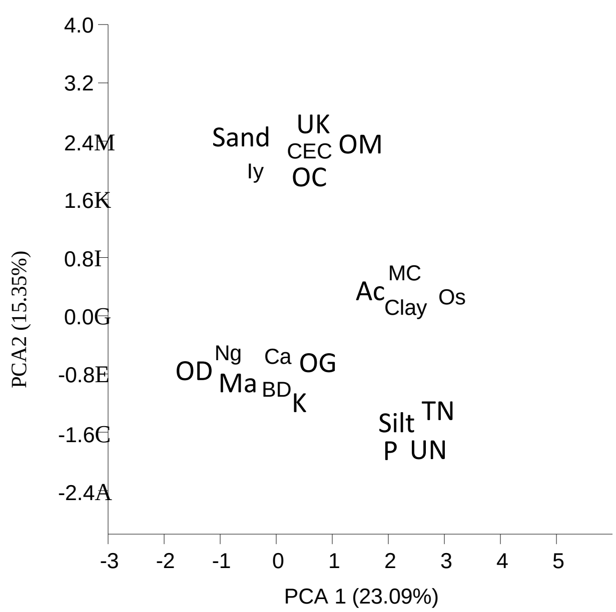


Fig. 12 Ordination of the soil attributes and the nine sampled sites

Based on the ordination of the six most weighted soil variables, the result of the principal component analysis showed the following associations (Fig 13).

1. Three sites were strongly correlated with bulk density. They include (odengwu, Ngene and Achala). This revealed that these sites have similar soil characteristics; it also showed that bulk density plays a major role in boosting the species diversity of these sites.
2. The second group of association was observed to exist between (Ukpor, and Iyiocha forests) and organic matter and cation exchange capacity. By virtue of this association, these sites are presumed to possess similar characteristics and were also influenced by these parameters in terms of species diversity.
3. The last group of association in this ordination was seen to exist between (Ogugu-nza, Unenzu, Osomari and Mamu) and (total nitrogen, moisture content and potassium). It is glaring that these sites have same soil characteristics. This soil attributes also immense influence in the species diversity of these sites (Fig 13).

However, it is important to note that the eigenvalues of the first six principal components are greater than one, implying that the thirteen soil variables of the forest sites can be represented by six soil variables. So based on rotated component matrix, the most weighted soil variables were those listed in table 20 above. Using these six extracted soil variables, the experimental sites were characterized based on canonical discriminant function.

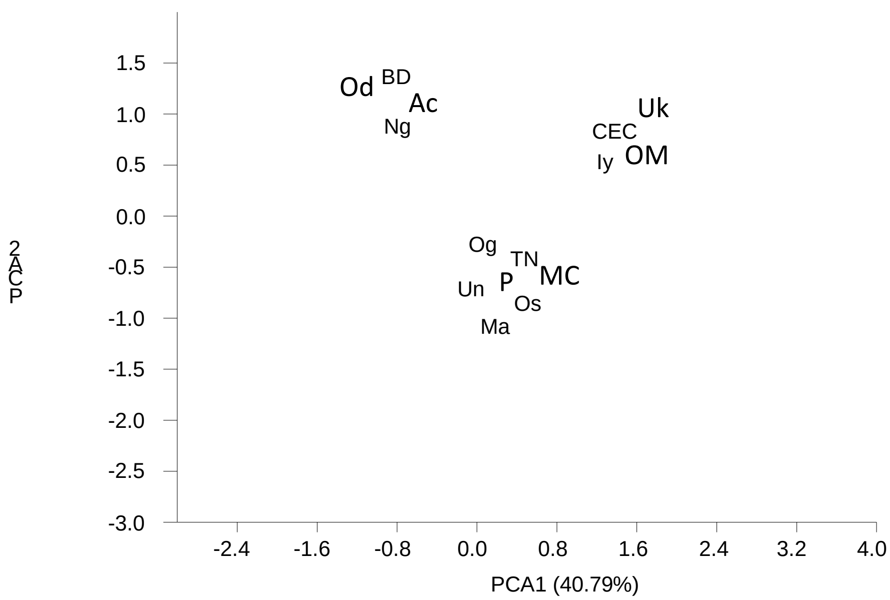


Fig 13 PCA of the six most weighted soil variables

Community Ordination of sampled sites by Species Abundance

Using principal component analysis, the nine sampled sites were characterized by species abundance. The community matrix data conprised plant species (columns) and their important value index by sampled sites (rows). The column component plot showed that the abundance of *Tectonia grandis, Adansonia digitata, Pterocarpus* sp*, Dalium guineense, Elaeis guineense, Myranthus arboreus* and *Ficus capensis* of the sampled sites were similar and have been grouped together (Fig. 14). Another group comprised of *Gmelina aborea, Anthocleista djalonensis, Rauvolfia vomitoria, Milletia thoningii, Melicia excelsa, Daniella oliveri, Pentaclethera macrophylla, Dracena arborea, Sansepalum dulcificum, Hildegardia barteri* and *Vitex doniana* and so on are also similar in characteristics (Figure 14). The row component plot showed that the species abundance of Osomari forest reserve, Achala forest reserve and Mamu forest reserve were similar and so have been grouped together. Ogugu-Nza, Odengwu, Ukpor and IyiOcha were also similar and so have been grouped together. Ngene and Unenzu forests clustered a little farther from Ogugu-Nza, Odengwu, Ukpor and IyiOcha (Figure 15).

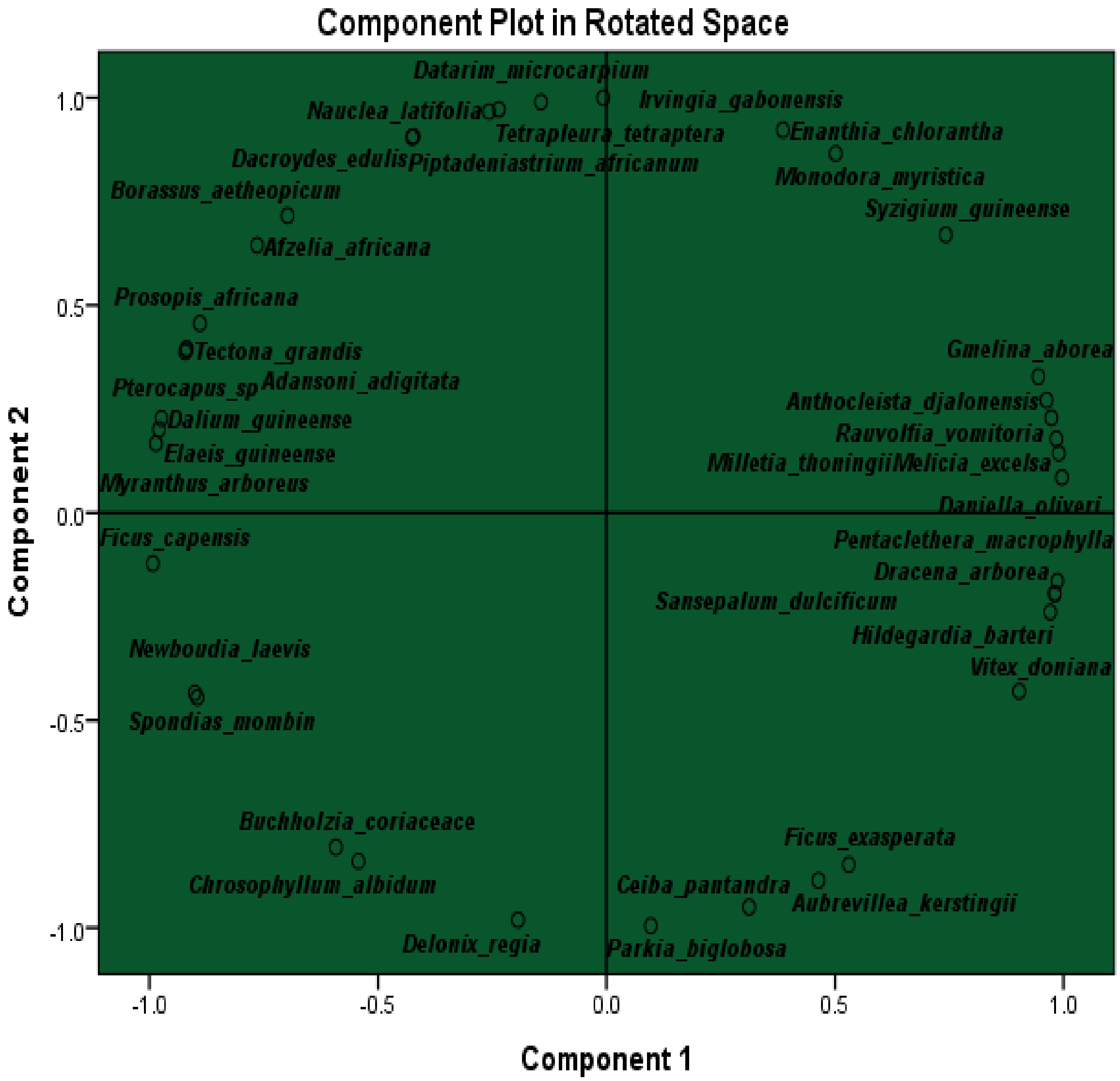


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Figure 14: Component of plot of Species of the Experimental forest

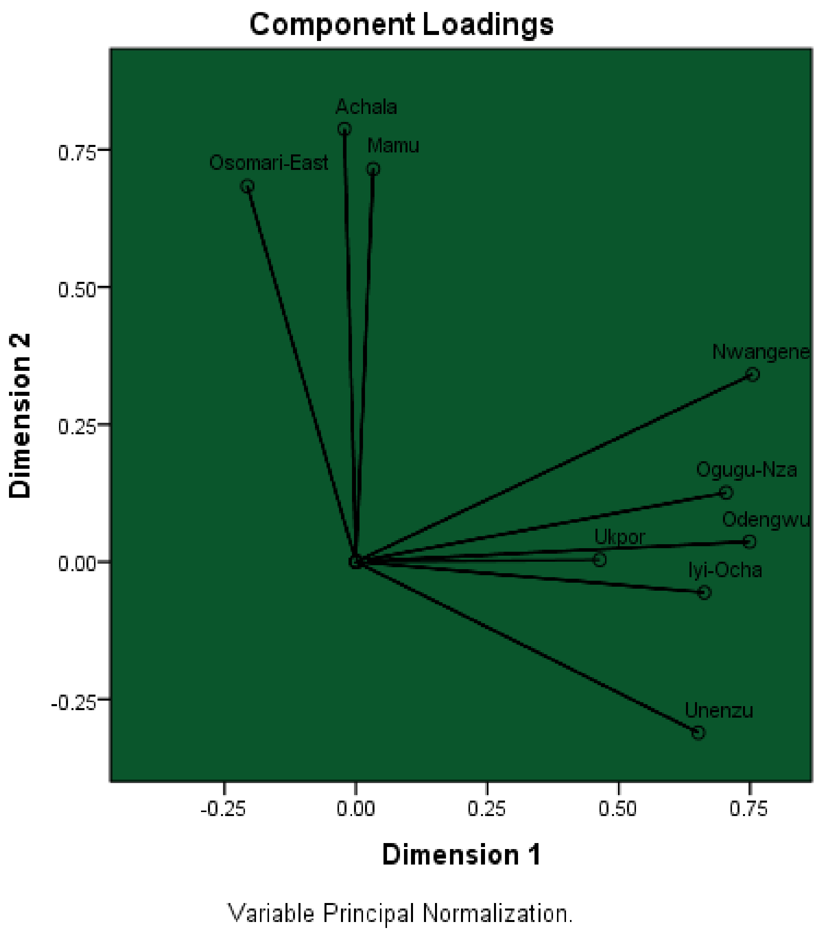

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Figure 15: Component of plot the experimental forest base on species abundance

The principal component matrix correlation between forests based on soil parameters. The table revealed that Ngene forest is most similar to Iyiocha (0.944), Unenzu forest is most similar to Iyiocha (0.894), Mamu is most correlated with Ngene forest (0.771), Achalla is most similar to Iyiocha (0.977), Odengwu is most similar to Ogu-Nza (0.817), Iyiocha forest is most similar to Achalla forest (0.997), Osomari is most similar to Ogu-Nza (0.714), Ukpor is most similar to Iyi-ocha (0.563) while Ogu-Nza is most similar to Iyiocha (0.922) in terms of soil properties. There was a significant correlation in the soil properties between some of the forest sites (Table 21).

Table 21: **Principal Component Matrix between Forests, Based on Soil Parameters**

Forests		Ngene	Unenzu	Mamu	Achala	Odengwu	Iyiocha	Osomari	Ukpor	OguNza
Correlation	Ngene	1.000	.844	.771	.918	.656	**.944**	.496	.460	.848
	Unenzu	.844	1.000	.613	.869	.756	**.894**	.698	.411	.867
	Mamu	**.771**	.613	1.000	.719	.411	.752	.586	.390	.666
	Achala	.918	.869	.719	1.000	.721	**.977**	.625	.505	.921
	Odengwu	.656	.756	.411	.721	1.000	.730	.632	.319	**.817**
	Iyiocha	.944	.894	.752	**.977**	.730	1.000	.596	.563	.922
	Osomari	.496	.698	.586	.625	.632	.596	1.000	.221	**.714**
	Ukpor	.460	.411	.390	.505	.319	**.563**	.221	1.000	.451
	OguNza	.848	.867	.666	.921	.817	**.922**	.714	.451	1.000
Sig. (1-tailed)	Ngene		.000	.000	.000	.000	.000	.000	.000	.000
	Unenzu	.000		.000	.000	.000	.000	.000	.001	.000
	Mamu	.000	.000		.000	.001	.000	.000	.002	.000
	Achala	.000	.000	.000		.000	.000	.000	.000	.000
	Odengwu	.000	.000	.001	.000		.000	.000	.011	.000
	Iyiocha	.000	.000	.000	.000	.000		.000	.000	.000
	Osomari	.000	.000	.000	.000	.000	.000		.058	.000
	Ukpor	.000	.001	.002	.000	.011	.000	.058		.000
	OguguNza	.000	.000	.000	.000	.000	.000	.000	.000	

4.4 Soil Physical and Chemical Properties of the forest sites

Result of the avialbale soil moisture of the sampled sites indicated that Osomari forest Reserve showed the highest soil moisture availability (0.1389) while Ngene shrine forest showed the least soil moisture content (0.0633). There was a significant difference in the moisture content between the forest sites ($P<0.05$) (Table 22)

Table 22: Available Moisture Content (%) in the sampled sites

Forest Forest	Mean ± Std*
Osomari Forest Reserve	0.1389±0.03100^{c}
Ukpor Community Forest	0.1189±0.03621^{bc}
Unenzu Community Forest	0.1156±0.02128^{bc}
Ogugu-N Shrine Forest	0.1133±0.04031^{bc}
Odengwu Community Forest	0.1111±0.02892^{bc}
Achala Forest Reserve	0.1067±0.02345^{b}
IyiOcha Shrine Forest	0.1000±0.01803^{b}
Mamu Forest Reserve	0.0967±0.01658^{b}
Ngene Shrine Forest	0.0633±0.01803^{a}
F-ratio	**5.093
P-value	0.00

*__LSD (Rows sharing a common alphabet are not significantly different)__

Result of the bulk density of the sampled sites indicated that at depth soil depth of 0-15 cm Odengwu forest recorded highest bulk density (1.46 g/cm^3) while Osomari forest recorded lowest bulk density (0.89 g/cm^3). At the soil depth of 15-30cm, Odengwu forest recorded highest bulk density (1.40 g/cm^3) while Osomari and Ogugu-Nza forests showed lowest bulk density (1.09±0.069 g/cm^3) and (1.09±0.020 g/cm^3) respectively. At soil depth of 30-45cm, Mamu forest recorded highest bulk density (4.98±6.264 g/cm^3) while Osomari, Odengwu and Ngene forests showed lowest bulk density (1.13±0.060 g/cm^3), (1.33±0.046 g/cm^3) and (1.33±0.095 g/cm^3) respectively. There was a significant difference in the bulk density between the forests at all soil depths (p<0.05) (Table 23)

Table 23: Bulk Density (g/cm^3) of the forest sites

	Soil Depth (cm)		
Forest sites	**0-15**	**15-30**	**30-45**
Osomari Forest Reserve	0.89±0.023*	1.09±0.069	1.13±0.060
Ukpor community Forest	1.14±0.009	1.17±0.011	1.15±.0200
Unenzu Community Forest	1.16±0.185	1.23±0.089	1.14±0.097
Ogugu-Nza shrine Forest	1.13±0.014	1.09±0.020	1.17±0.292
Odengwu community Forest	1.46±0.071	1.40±0.026	1.33±0.046
Achala Forest Reserve	1.42±0.008	1.38±0.019	1.37±0.014
IyiOcha Shrine Forest	1.15±0.047	1.11±0.080	1.07±0.031
Mamu Forest Reserve	1.11±0.024	1.28±0.236	4.98±6.264
Ngene Shrine Forest	1.19±0.012	1.13±0.032	1.33±0.095
F-ratio	18.056	5.108	53.639
P-value	**	**	**
	Forest	Soil Depth	Forest * Soil Depth
LSD	1.978	1.978	3.956

**Mean ± Std, **Significant (P<0.05), ns: Not Significant*

In the soil depth of 0-15 cm, Ukpor forest recorded highest CEC value (9.431 cmol/kg), while Ngene forest recorded lowest CEC value (1.477 cmol/kg). In the soil depth of 15-30 cm, Ogugu-nza shrine forest recorded highest (9.970 cmol/kg) CEC value while Ngene forest recorded lower CEC value (1.160 cmol/kg). In the soil depth of 30-45 cm, Ogugu-Nza Forest however recorded highest CEC value (16.105 cmol/kg) while Ngene forest recorded lowest CEC value (1.133 cmol/kg). The analysis of variance indicated a significant difference in the CEC between the forest (P<0.05) and between soil depths (P<0.05). There is also interaction between soil depth and forest (P<0.05) (Table 24).

Table 24: Soil CEC (cmol/kg) in the forest sites

	Soil Depth (cm)		
Forest sites	0-15	15-30	30-45
Osomari Forest	3.748±0.6956*	4.696±0.0806	9.208±7.679
Ukpor Forest	9.431±0.2158	5.340±0.4670	10.763±1.2215
Unenzu Community Forest	3.004±0.2085	1.701±0.3509	4.013±1.5447
Ogugu-Nza Forest	4.483±0.2567	9.970±3.9657	16.105±2.1088
Odengwu Forest	7.681±2.1220	8.008±2.3565	10.172±1.4175
Achala Forest Reserve	4.644±1.0175	7.594±2.0271	11.443±0.6108
IyiOcha Shrine Forest	8.413±3.3407	7.984±1.1035	7.328±0.5777
Mamu Forest	1.987±0.4632	7.243±5.5900	9.149±1.6688
Ngene Forest	1.477±1.1313	1.160±0.5075	1.133±0.5187
F-ratio	7.771	9.361	18.262
P-value	**	**	**
	Forest	Soil Depth	Forest * Soil Depth
LSD	7.892	7.892	15.784

**Mean ± Std, **Significant (P<0.05), ns: Not Significant*

In the soil depth of 0-15 cm, Ukpor forest recorded highest organic matter (32.500 g/kg), while Mamu forest recorded lowest organic matter (4.167 g/kg). In the soil depth of 15-30 cm, Ukpor forest also recorded highest organic matter (22.667 g/kg) while Mamu forest reserve recorded lowest organic matter (3.167 g/kg). In the soil depth of 30-45 cm, Iyiocha forest however recorded higher organic matter (15.667 g/kg) while Mamu forest recorded lower organic matter (1.667 g/kg). The analysis of variance indicated a significant difference in the organic matter between the forest (P<0.05) but no significant difference between soil depths (P>0.05). There is interaction however between soil depth and forest (P<0.05) (Table 25).

Table 25: Soil Organic Matter (g/kg) of the forest sites

	Soil Depth (cm)		
Forest sites	**0-15**	**15-30**	**30-45**
Osomari Forest Reserve	11.667±2.6376*	10.000±5.0000	6.667±7.6376
Ukpor community Forest	32.500±2.6458	22.667±2.6356	12.500±2.5000
Unenzu Community Forest	12.000±4.7697	7.000±6.0622	4.667±8.0052
Ogugu-Nza shrine Forest	11.667±2.8868	10.000±5.0000	7.333±10.4083
Odengwu community Forest	10.000±3.0000	8.667±2.8868	5.333±5.7735
Achala Forest Reserve	13.333±2.8868	10.333±3.6376	8.333±2.8868
IyiOcha Shrine Forest	21.667±7.6376	20.000±5.0000	15.667±4.4338
Mamu Forest Reserve	4.167±0.1932	3.167±0.7638	1.667±4.1633
Ngene shrine Forest	11.667±1.6376	9.333±2.6188	6.667±4.5093
F-ratio	24.556	23.672	14.665
P-value	**	**	**
	Forest	Soil Depth	Forest * Soil Depth
LSD	14.278	14.278	28.556

**Mean ± Std, **Significant (P<0.05), ns: Not Significant*

In the soil depth of 0-15 cm, Iyiocha Shrine forest recorded highest organic carbon (3.517 g/kg), while Mamu forest forest reserve recorded lowest organic carbon (0.073 g/kg). In the soil depth of 15-30 cm, IyiOcha Shrine forest recorded highest organic carbon (0.178 g/kg) while Osomari forest reserve and Ukpor Community forest recorded the lowest available organic matter (0.048 g/kg) each. In the soil depth of 30-45 cm, Osomari forest reserve however recorded highest organic matter content (0.099 g/kg) while Ukpor Community forest recorded the lowest available organic matter (0.018 g/kg). The analysis of variance indicated no significant difference in the organic carbon between the forest and between soil depths (P>0.05). There is no interaction however between soil depth and forest (P<0.05) (Table 26)

Table 26: Soil Organic Carbon (g/kg) of the forest sites

	Soil Depth (cm)		
Forest sites	**0-15**	**15-30**	**30-45**
Osomari Forest Reserve	0.121±0.0473*	0.048±0.0194	0.099±0.0153
Ukpor Community Forest	0.130±0.0823	0.048±0.0115	0.018±0.0065
Unenzu Community Forest	0.097±0.0088	0.059±0.0944	0.034±0.0257
Ogugu-Nza shrine Forest	0.075±0.0745	0.071±0.0317	0.072±0.0447
Odengwu community Forest	1.155±0.0347	0.088±0.0142	0.059±1.9215
Achala Forest Reserve	0.075±0.0125	0.132±0.0095	0.033±0.0113
IyiOcha Shrine Forest	3.517±0.0482	0.178±5.9609	0.067±0.2360
Mamu Forest Reserve	0.073±0.0050	0.066±0.0431	0.020±0.0075
Ngene shrine Forest	0.093±0.0063	0.062±0.2714	0.086±0.0058
F-ratio	1.221	37.645	1.943
P-value	Ns	**	Ns
	Forest	Soil Depth	Forest * Soil Depth
LSD	1.977	1.977	3.954

**Mean ± Std, **Significant (P<0.05), ns: Not Significant*

In the soil depth of 0-15 cm, Achala forest recorded highest percentage sand (81.800 %), while Osomari forest recorded lowest percentage sand (36.867 %). In the soil depth of 15-30 cm, Achala forest reserve recorded highest percentage sand (75.600 %) while Osomari forest recorded lowest percentage sand (43.600 %). In the soil depth of 30-45 cm, Achala forest reserve also recorded highest percentage sand (71.200 %) while Osomari forest recorded lowest percentage sand (17.933 %). The analysis of variance indicated a significant difference in the percentage sand between the forest (P<0.05) but no significant difference between soil depths (P>0.05). There is interaction however between soil depth and forest (P<0.05) (Table 27)

Table 27: Percentage Sand Content of the forest sites

		Soil Depth (cm)	
Forest sites	**0-15**	**15-30**	**30-45**
Osomari Forest Reserve	36.867±2.7592*	43.600±1.8000	17.933±3.3247
Ukpor community Forest	72.733±1.3317	69.200±0.9165	62.667±1.2055
Unenzu Community Forest	51.533±5.8731	49.267±2.3007	43.000±9.2065
Ogugu-Nza shrine Forest	65.133±2.7154	62.733±6.4010	60.733±6.4010
Odengwu community Forest	76.800±8.1413	69.667±9.3602	67.467±4.9893
Achala Forest Reserve	81.800±0.6000	75.600±0.5292	63.267±0.9452
IyiOcha Shrine Forest	76.867±5.9878	71.600±9.8853	66.667±3.4429
Mamu Forest Reserve	74.000±2.2271	73.200±2.9052	60.067±5.8731
Ngene shrine Forest	74.267±0.5033	72.000±1.8330	71.200±1.2490
F-ratio	29.564		
P-value	0.00		
	Forest	Soil Depth	Forest * Soil Depth
LSD	7.585	7.585	15.17
P-value	**	ns	**

**Mean ± Std, **Significant (P<0.05), ns: Not Significant*

In the soil depth of 0-15 cm, Unenzu community forest recorded highest percentage silt (28.833 **%**), while Achala forest reserve recorded the lowest percentage silt (2.667 **%**). In the soil depth of 15-30 cm, Ogugu-Nza forest recorded highest percentage silt (47.933 **%**) while Achala forest reserve recorded lowest percentage silt (6.067 **%**). In the soil depth of 30-45 cm, Osomari forest recorded highest percentage silt (46.000 **%**) while Achala forest reserve recorded lowest percentage silt (11.333 **%**). The analysis of variance indicated a significant difference in the percentage silt between the forest (P<0.05) but no significant difference between soil depths (P>0.05). There is no interaction between soil depth and forest (P>0.05) (Table 28)

Table 28: Percentage Silt Content of the Forest sites

	Soil Depth (cm)		
Forest sites	**0-15**	**15-30**	**30-45**
Osomari Forest Reserve	19.067±1.4189*	31.133±4.9572	46.000±5.6427
Ukpor community Forest	15.533±0.5033	13.133±0.6110	14.933±0.9019
Unenzu Community Forest	28.833±9.5105	29.453±2.2019	27.107±1.8314
Ogugu-Nza shrine Forest	16.333±2.7737	47.933±55.4856	15.600±1.9287
Odengwu community Forest	10.800±8.5510	10.933±2.7301	15.533±1.5275
Achala Forest Reserve	2.667±0.3055	6.067±0.3055	11.333±0.8327
IyiOcha Shrine Forest	17.133±7.9406	14.000±1.9698	17.200±2.6000
Mamu Forest Reserve	14.733±0.8083	14.400±0.6000	31.467±2.2301
Ngene shrine Forest	7.400±0.6000	15.333±0.8327	17.467±0.7572
F-ratio	2.811		
P-value	0.00		
	Forest	Soil Depth	Forest * Soil Depth
LSD	18.407	18.407	36.814
P-value	**	Ns	Ns

**Mean ± Std, **Significant (P<0.05), ns: Not Significant*

In the soil depth of 0-15 cm, Osomari forest recorded highest percentage clay (25.267 %), while Iyiocha forest recorded lowest percentage clay (5.933 %). In the soil depth of 15-30 cm, Osomari forest also recorded highest percentage clay (36.067 %) while Mamu and Iyiocha shrine forest recorded lowest percentage clay (12.267 %). In the soil depth of 30-45 cm, Osomari forest also recorded highest percentage clay (46.467 %) while Mamu shrine forest recorded lowest percentage clay (12.400 %). The analysis of variance indicated a significant difference in the percentage clay between the forest and between soil depths (P<0.05). There was also interaction between soil depth and forest (P<0.05) (Table 29).

Table 29: Percentage Clay Content of the Forest sites

	Soil Depth (cm)		
Forest sites	**0-15**	**15-30**	**30-45**
Osomari Forest	25.267±4.6188	36.067±4.9166	46.467±7.1002*
Ukpor Forest	12.333±0.4619	15.267±1.1373	24.200±1.6371
Unenzu Community Forest	21.680±10.7560	23.893±3.6838	24.333±3.6896
Ogugu-Nza Forest	19.467±2.7154	19.267±2.8937	21.467±2.1939
Odengwu Forest	11.267±6.5310	18.067±6.6040	19.400±6.7557
Achala Forest Reserve	18.333±0.8083	20.200±22.5486	34.067±1.2220
IyiOcha Shrine Forest	5.933±7.3358	14.400±8.5346	16.200±5.8275
Mamu Forest	10.200±4.5033	11.267±2.1939	12.400±2.3065
Ngene Forest	18.333±0.6110	11.333±1.1719	12.667±2.6633
F-ratio	2.811		
P-value	0.00		
	Forest	Soil Depth	Forest * Soil Depth
LSD	10.477	10.477	20.954
P-value	**	**	**

**Mean ± Std, **Significant (P<0.05), ns: Not Significant*

In the soil depth of 0-15 cm, Achala forest reserve recorded highest soil ^{pH} (6.253), while Ogugu-Nza forest recorded lowest soil pH (4.075). In the soil depth of 15-30 cm, Achala forest reserve also recorded highest soil pH (6.403) while Osomari and Ukpor forests recorded lowest soil pH (4.048). In the soil depth of 30-45 cm, Odengwu forest however recorded highest soil P^H (7.950) while Ukpor forest recorded lower soil P^H (4.018). The analysis of variance indicated a significant difference in the soil P^H between the forest (P<0.05) but no significant difference between soil depths (P>0.05). There is no interaction between soil depth and forest (P>0.05) (Table 30).

Table 30: Soil p^H (H2O) of the sampled sites

	Soil Depth (cm)		
Sampled Forest	**0-15**	**15-30**	**30-45**
Osomari Forest	4.121±0.0473*	4.048±0.0194	4.099±0.0153
Ukpor Forest	4.130±0.0823	4.048±0.0115	4.018±0.0065
Unenzu Community Forest	5.223±0.5687	5.303±0.2765	5.133±0.6463
Ngene Forest	4.393±0.3182	5.563±0.3646	6.170±0.1540
Odengwu Forest	5.700±0.2524	5.993±0.0569	7.950±3.5215
Achala Forest Reserve	6.253±0.2715	6.403±0.4253	6.213±0.5105
IyiOcha Shrine Forest	6.063±0.6127	5.480±0.1769	5.860±0.1637
Mamu Forest	5.370±0.0608	4.597±0.4545	4.657±0.4141
Ogugu-Nza Forest	4.075±0.0745	4.071±0.0317	4.071±0.044
F-ratio	12.894	15.612	7.805
P-value	**	**	**
	Forest	Soil Depth	Forest * Soil Depth
LSD	1.216	1.216	2.432

**Mean ± Std, **Significant (P<0.05), ns: Not Significant*

In the soil depth of 0-15 cm, Mamu forest reserve recorded highest phosphorus (60.214 mg/kg), while Osomari forest recorded the lowest phosphorus (2.557 mg/kg). In the soil depth of 15-30 cm, Mamu forest also recorded highest phosphorus (58.523mg/kg) while Ogugu-Nza forest recorded the lowest phosphorus (1.464 mg/kg). In the soil depth of 30-45 cm, Mamu forest also recorded highest phosphorus (48.197 mg/kg) while Osomari forest recorded lowest phosphorus (1.905 mg/kg). The analysis of variance indicated a significant difference in the phosphorus between the forest (P<0.05) but no significant difference between soil depths (P>0.05). There is no interaction between soil depth and forest (P>0.05) (Table 31).

Table 31: Soil Phosphorus (mg/kg) of the forest sites

	Soil Depth (cm)		
Forest sites	**0-15**	**15-30**	**30-45**
Osomari Forest Reserve	2.557±0.2874*	2.177±0.3141	1.905±0.0791
Ukpor community Forest	2.581±0.5045	2.725±0.3933	2.147±0.2332
Unenzu Community Forest	34.258±25.3148	19.875±25.7097	17.524±29.4190
Ogugu-Nza shrine Forest	2.819±0.08554	1.464±0.24410	0.184±0.31179
Odengwu community Forest	4.373±0.8003	3.026±0.5522	2.599±0.2760
Achala Forest Reserve	23.450±31.3801	4.081±0.3265	3.645±0.2489
IyiOcha Shrine Forest	6.347±1.9353	5.477±1.0285	3.005±1.2323
Mamu Forest Reserve	60.214±7.4725	58.523±10.2371	48.197±15.5945
Ngene shrine Forest	14.111±17.9396	6.728±0.2997	5.241±0.3498
F-ratio	6.317		
P-value	0.000		
	Forest	Soil Depth	Forest * Soil Depth
LSD	19.639	19.639	39.278
P-value	**	Ns	Ns

**Mean ± Std, **Significant (P<0.05), ns: Not Significant*

In the soil depth of 0-15 cm, Unenzu forest recorded highest potassium (44.416 cmol/Mg), while Osomari forest recorded the lowest potassium (2.819 cmol/Mg). In the soil depth of 15-30 cm, Odengwu forest recorded highest potassium (37.260 cmol/Mg) while Mamu forest recorded lowest potassium (8.631 cmol/Mg). In the soil depth of 30-45 cm, Odengwu community Forest also recorded highest Potassium (17.316 cmol/Mg) while Ngene shrine forest recorded lowest potassium (8.611 cmol/Mg). The analysis of variance indicated no significant difference in the potassium content between the forests and between soil depths (P>0.05). There was however interaction between soil depth and forest (P<0.05) (Table 32).

Table 32: Soil Potassium Content (cmol/Mg) of the forest sites

	Soil Depth (cm)		
Forest sites	**0-15**	**15-30**	**30-45**
Osomari Forest Reserve	2.819±2.3216*	33.248±3.2604	11.256±0.6836
Ukpo community Forest	7.988±1.2098	10.688±0.3875	17.137±0.7152
Mamu Forest Reserve	8.650±0.7801	8.631±2.1188	15.677±0.7158
Ogugu-Nza shrine Forest	12.610±14.8733	21.606±11.7777	12.610±3.5968
Odengwu community Forest	13.234±2.7719	37.260±43.5323	17.316±12.7699
Achala Forest Reserve	12.350±3.5582	11.715±4.3126	10.296±0.1351
IyiOcha Shrine Forest	11.362±3.5371	10.426±0.5957	12.005±0.7552
Ngene shrine Forest	36.602±2.8216	10.891±0.3265	8.611±0.7318
Unenzu Community Forest	44.416±28.9301	12.609±1.0025	16.734±11.0440
F-ratio	2.392		
P-value	0.003		
	Forest	Soil Depth	Forest * Soil Depth
LSD	18.574	18.574	37.148
P-value	Ns	Ns	**

**Mean ± Std, **Significant (P<0.05), ns: Not Significant*

In the soil depth of 0-15 cm, Ogugu-Nza forest recorded highest Nitrogen (2.819 g/kg), while IyiOcha Shrine forest recorded lowest nitrogen (1.811 g/kg). In the soil depth of 15-30 cm, Mamu forest recorded highest nitrogen (2.800 g/kg) while Unenzu Community forest recorded lowest nitrogen (1.457 g/kg). In the soil depth of 30-45 cm, Iyiocha shrine forest however recorded highest nitrogen (2.651 g/kg) while Odengwu forest recorded lowest nitrogen (1.116 g/kg). The analysis of variance indicated no significant difference in the Nitrogen content between the forest and between soil depths (P>0.05). There is also no interaction between soil depth and forest (P>0.05) (Table 33).

Table 33: Available Nitrogen (g/kg) Content of the sampled sites

	Soil Depth (cm)		
Sampled Forest	**0-15**	**15-30**	**30-45**
Osomari Forest Reserve	2.557±0.2874*	2.177±0.3141	1.905±0.0791
Ukpor community Forest	2.581±0.5045	2.725±0.3933	2.147±0.2332
Unenzu Community Forest	1.885±0.4562	1.457±0.4250	1.790±16.9600
Ogugu-Nza shrine Forest	2.819±0.0855	2.464±0.2441	2.184±0.3118
Odengwu community Forest	2.651±0.2819	2.408±0.2019	1.116±0.7056
Achala Forest Reserve	2.109±0.1166	1.624±0.1120	1.344±0.0560
IyiOcha Shrine Forest	1.811±0.5935	2.221±0.4203	2.651±0.1711
Mamu Forest Reserve	2.669±0.4277	2.800±0.1680	2.632±0.5133
Ngene shrine Forest	2.025±0.5048	2.044±0.5621	2.251±0.8145
F-ratio	1.003		
P-value	0.481		
	Forest	Soil Depth	Forest * Soil Depth
LSD	5.381	5.381	10.765
P-value	Ns	Ns	Ns

**Mean ± Std, **Significant (P<0.05), ns: Not Significant*

In the soil depth of 0-15 cm, Odengwu forest recorded highest calcium (77.509 g/kg), while Ukpor forest recorded lowest calcium (16.957 g/kg). In the soil depth of 15-30cm, Odengwu forest also recorded highest calcium (52.124 g/kg) while Ukpor forest recorded lower calcium (10.688 g/kg). In the soil depth of 30-45 cm, Odengwu forest also recorded highest calcium (41.985 g/kg) while Osomari forest recorded lowest calcium (3. 153 g/kg). The analysis of variance indicated a significant difference in the calcium content between the forest and between soil depths (P<.05). There is interaction between soil depth and forest (P<0.05), (Table 34)

Table 34: Soil Calcium (g/kg) Content of the sampled sites

	Soil Depth (cm)		
Sampled Forests	**0-15**	**15-30**	**30-45**
Osomari Forest Reserve	33.248±3.2604	11.256±0.6836	3.153±2.8979*
Ukpor community Forest	16.957±0.4224	10.688±0.3875	7.988±1.2098
Unenzu Community Forest	50.803±2.7768	32.146±5.1029	16.947±16.5007
Ogugu-Nza shrine Forest	21.606±11.7777	12.610±14.8733	10.610±3.5968
Odengwu community Forest	77.509±52.0386	52.124±11.0318	41.985±5.3501
Achala Forest Reserve	44.972±3.4488	38.703±0.2046	37.851±0.2121
IyiOcha Shrine Forest	41.644±3.1312	39.951±4.2423	37.070±5.2131
Mamu Forest Reserve	43.840±1.0618	24.785±3.6854	12.750±4.1828
Ngene shrine Forest	50.106±2.2232	49.220±0.7296	39.022±11.6245
F-ratio	6.728		
P-value	0.000		
	Forest	Soil Depth	Forest * Soil Depth
LSD	19.416	19.416	38.832
P-value	**	**	**

**Mean ± Std, **Significant (P<0.05), ns: Not Significant*

Table 35: Correlational matrix between Soil Properties of the forest sites

		Bulk Density	CEC	Organic Matter	% sand	% silt	Clay	C	pH	P	K	N	Ca
Bulk Density	Pearson Correlation	1	-.024	-.089	-.019	.061	-.080	-.022	.105	.207	-.051	.018	.034
	Sig. (2-tailed)		.834	.428	.868	.586	.476	.845	.350	.063	.648	.876	.760
CEC	Pearson Correlation	-.024	1	.483**	.077	-.058	-.045	-.028	-.388**	-.172	-.155	-.026	-.336**
	Sig. (2-tailed)	.834		.000	.492	.605	.689	.805	.000	.124	.167	.821	.002
Organic Matter	Pearson Correlation	-.089	.483**	1	-.162	.073	.106	.017	-.320**	-.303**	-.162	-.068	-.244*
	Sig. (2-tailed)	.428	.000		.148	.519	.347	.883	.004	.006	.148	.549	.028
% sand	Pearson Correlation	-.019	.077	-.162	1	-.545**	-.679**	.188	.447**	.075	.127	.010	.337**
	Sig. (2-tailed)	.868	.492	.148		.000	.000	.093	.000	.506	.260	.929	.002
% silt	Pearson Correlation	.061	-.058	.073	-.545**	1	.135	-.062	-.294**	.081	-.101	.117	-.256*
	Sig. (2-tailed)	.586	.605	.519	.000		.230	.585	.008	.474	.368	.298	.021
Clay	Pearson Correlation	-.080	-.045	.106	-.679**	.135	1	-.181	-.338**	-.231*	-.119	-.139	-.224*
	Sig. (2-tailed)	.476	.689	.347	.000	.230		.106	.002	.038	.292	.215	.044
Organic Carbon	Pearson Correlation	-.022	-.028	.017	.188	-.062	-.181	1	.176	-.061	-.066	-.023	.051
	Sig. (2-tailed)	.845	.805	.883	.093	.585	.106		.116	.589	.558	.835	.651

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

		Bulk Density	CEC	Organic Matter	% sand	% silt	Clay	C	PH	P	K	N	Ca
Soil PH	Pearson Correlation	.105	-.388**	-.320**	.447**	-.294**	-.338**	.176	1	.262*	.036	-.018	.632**
	Sig. (2-tailed)	.350	.000	.004	.000	.008	.002	.116		.018	.752	.871	.000
Phosphorus	Pearson Correlation	.207	-.172	-.303**	.075	.081	-.231*	-.061	.262*	1	-.019	.260*	.010
	Sig. (2-tailed)	.063	.124	.006	.506	.474	.038	.589	.018		.866	.019	.930
Potassium	Pearson Correlation	-.051	-.155	-.162	.127	-.101	-.119	-.066	.036	-.019	1	-.060	.569**
	Sig. (2-tailed)	.648	.167	.148	.260	.368	.292	.558	.752	.866		.593	.000
Nitrogen	Pearson Correlation	.018	-.026	-.068	.010	.117	-.139	-.023	-.018	.260*	-.060	1	-.048
	Sig. (2-tailed)	.876	.821	.549	.929	.298	.215	.835	.871	.019	.593		.673
Calcium	Pearson Correlation	.034	-.336**	-.244*	.337**	-.256*	-.224*	.051	.632**	.010	.569**	-.048	1
	Sig. (2-tailed)	.760	.002	.028	.002	.021	.044	.651	.000	.930	.000	.673	

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

The correlation between the soil properties of the forest sites indicates a significant positive relationship between CEC and Organic Matter (0.483), between percentage sand and soil PH (0.447), between percentage sand and Calcium (0.337), between soil pH and Calcium (0.632), between Phosphorus and soil pH (0.262), between Phosphorus and Nitrogen (0.260) and between Potassium and Calcium (0.569). There is however a significant negative relationship between soil pH and CEC (-0.388), between soil pH and Calcium (-0.336) between Organic matter and soil pH (-0.320), between organic matter and Phosphorus (-0.303), between organic matter and Calcium (-0.244), between percentage sand and silt (-5.455), between sand and clay (-0.679) between silt and soil pH (-0.294), between silt and Calcium (-0.256), between clay and soil pH (-0.338) and between clay and Calcium (-0.224) (Table 35)

CHAPTER FIVE

5.1 Discussion

Anambra state as a rainforest region is a biodiversity conservation unit typified by its richness, endemism in flora and fauna with a high potential for agricultural development as a result of the stretches of fertile land on the plains of its various communities (Nwosu, 2003). These areas support healthy crops and vegetables of different varieties. The richness in biodiversity makes it a gene bank for most species.

The flora of the forest resources of Anambra state is characterized by a variety of tree species as well as families. The Fabaceae family was observed to be the most prevalent family in all forest sites. This may be due to their fast germination ability, associated with symbiotic properties which have enabled species to easily establish within habitat types. This finding was in line with the works of Deka *et al*, (2012) on vegetative assessment of tree species in Tarkamand Rainforest, Tanzania.

Aside Fabaceae, Verbanaceae was also found to dominate other families, probably because of their ability to produce numerous seeds which was eventually established at suitable sites. This observation was confirmed by Khan *et al*. (1986) while working on regeneration and survival of tree seedlings in tropical forests. The dominance of these families also could be as a result of habitat adaptation and favourable environmental conditions which encourage root penetration and absorption of mineral nutrients from the subsurface and eventual establishment of species, ie the presence of adapted root architecture to absorb nutrients for growth. Similar situations were reported by Pausas and Austin (2001) on species richness in relation to environment. Austin *et al*. (1996) found that edaphic parameters (soil nutrients) played a major role in species richness and establishment in an ecosystem. The reasons for the low number of species observed in some families in some of the forest sites could be attributed to diseases and over exploitation which resulted in the paucity of the available stocks. Perhaps species needs sustainable exploitation to avoid a total extermination or being placed on the list of endangered species. Similar results were reported by Egbe *et al.,* (2012) on Forest disturbance and natural regeneration in African rainforest at Korup National Park, Cameroon. The low number of species could also be attributed to anthropogenic activities which affected species growth and production. Similar findings have been reported by Sumina (1994) on plant communities on anthropogenically disturbed sites in Chukotka Peninsula.

The ranking of the species diversity indicated that Ukpor Community Forest and Mamu Forest Reserve ranked highest (3.555) each with 35 numbers of species recorded in each of the forest. In Ukpor Community Forest, the dominant tree was *Ceiba pentandra,* while in Mamu Forest Reserve, it was discovered that *Tectona grandis* dominated other species. Meanwhile, Odengwu Community Forest recorded the highest number of species but ranked 3rd in the assessment of the species diversity (3.353), with *Ceiba pentandra* as the dominant species. Achala Forest Reserve ranked the least in species diversity (2.485) with 12 species and *Tectona grandis* as the dominant species in the forest. The regression analysis proved that the t-value of the coefficient of the number of species is significant ($p<0.05$) indicating a significant relationship between number of species and species diversity. The coefficient of 0.005 implies that a percentage point increase in the number of species increase species diversity by 0.005. The number actually explains about 48.0% of species diversity. The p-value of the f-statistics is significant ($p<0.05$) indicating that the model is a good fit.

Jost (2007), Hill (1973), Tuomisto (2010) and Krebs (1999) all agreed that the observed species diversity is affected by not only the number of individual but also by the heterogeneity of the sample. They were also of the opinion that increasing the area samples increases observed species diversity both because more individuals get included in the sample and because large areas were environmentally more heterogenous than small areas. Their observation tallies with the present research work because virtually all the sampled forests were relatively diverse, even the Achala Forest Reserve that was the least in the rank of diversity could also be considered relatively diverse (2.485). Over exploitation of the species could actually be a factor to account for this low diversity in relation to other sampled forests. Plates 16, 15 and 20 detailed this as recorded in the appendix.

Connell (1978) in one of his researches noted that rich plant life forms cover Organ Pipe National Monument in Southern Arizona. He observed that growth of *Ocofillo* species consisting of several slender branches 2 to 3m tall springing from a common base, there was also Palo Verde trees with green bark and tiny leaves. According to Connell (1978), the most abundant was the *Saguaro*, a massive cactus that towers over all the other plants species. This agrees with this present research.

Different plants species were observed with high bifurcation of branches and some were more in abundance and more frequent than others.

Whicker and Defling (1988) has been able to explain much of the variation in woody plant diversity and dominance by some tree species across Sonoran forest landscapes by differences in soil age, frequency of land disturbance caused by soil erosion and soil depth. The key point here is that communities generally consist of many species that potentially interact in all the ways with one another.

Bush *et al.* (1989), Richlefs and Schluter (1993) all concurred that species diversity increases with environmental complexity or heterogeneity. They however noted that an aspect of environmental structure important to one group of organisms may not have a positive influence on another group. Consequently, one must be acquainted with the ecological requirements of species to predict environmental structure that affects the diversity.

Generally, species diversity is one of the most important indices used to evaluate an ecosystem. A rich ecosystem with high species diversity has a large value (H') while an ecosystem with low value (H') will have a low species diversity (Sobuj and Rahman, 2011; Decker *et al*., 2012). The present study sites had relatively high species diversity for tree species. Probably, the high species diversity could be attributed to low or minimal exploitation of the species in these forest sites, the specie ability to cope with adverse environmental factorsprevalent in these locations, also most of these forest sites are attached with many tributaries and streams that empty rich organic content and mineral resources that are utilized by the species for growth and production. Giliba *et al*. (2011) reported similar findings on woodland of Bereku Forest Reserve in Tanzania.

In assessing the species abundance of the sampled sites, Wright (1991) observed that abundance is contrasted with, but typically correlate to incidence, which is the frequency with which the species occur at all in a sample. In his work to determine the abundance of species in the Nature Reserve Wisconsin, he noted that oak tree; Gopherwood and *Virgilia* dominated the forest more than other species, though their quantitative measurements were not given. Damgaard (2009) and Barfet *et al.* (2001) have also worked extensively on species abundance on different forest resources and agreed that some species are actually more in abundance than others. They noted that one of the factors that could account for this was probably because majority of the species could not withstand extreme environmental conditions as well as sustainable exploitation of the species. This is in agreement with the finding of this research work in the sense that some of the dominant species have been sustainably exploited especially in the government regulated areas like the Forest Reserves. Colwell and Coddington (1994) also in their work on species abundance observed that the vast areas of flat or gently slopping land of North American forests were dominated by a single species of shrub-like tree, *Larrea tridentata*, while grasses and forbs grow in the spaces between these trees. Their work contrasted heavily with these findings because despite that a particular tree or two were more in abundance, yet most other trees could be seen juxtaposed within the forests. The observed difference could stem from the fact that their research was conducted in a totally different climatic and environmental condition than the present studies.

5.2 Ordination by PCA

Meanwhile, in the ordination of the 20 most abundance species by principal component analysis, three possible groups of associations were observed.

The first group of association was between species (o, p, q, r, s, and t) (*Ficus exaspearata, Anacardium occidentalis. Ficus carpensis, Pentaclethre machrophylla, Spondias mombin and Afzelia africana*). This implies that these species have similar vegetative characteristics. The second group of association was between species (l and m) (*Parkia biglobosa and Adansonia digitata*). These were also common to and found present in all the sampled sites. They are also presumed to possess similar characteristics. The third group of association was between (c, d, e f, g, h i, j and k) (*Newbouldia laevis, Delonix regia, Pterocarpus sp, Irvingia garbonensis, Vitex doniana, Ceiba pentandra, Melicia excelasa Tetrapleura tetraptera and Dacroydis edulis*). This association linked all the sampled sites in the sense that all these species were (common) encountered in each of the sampled sites.

Generally, it was observed that most of these species came from the shrine and community forest, where the vegetations are relatively in their natural state. The other species (a, b and n) (*Tectona grandis, Gmelina arborea and Nauclea latifolia*) that has no correlation with other species came from the forest reserves where these trees dominated others (Fig.9)

However, using the codes and site attributes shown on table 42, five groups of association were observed as seen in Fig.10

The first group of association (xviii, xvi and xvii) (% clay, % silt and % sand) implies that the soil textural classes are positively correlated to one another. The second group of association was observed to exist between (xv, xiv and xiii) (soil moisture, soil Potassium and Calcium), this indicates that Calcium, Potassium and moisture content are positively correlated. This is because adequate soil moisture availability is critical for determining the growth and development of trees and forests. Soil moisture content affects the availability of K in soil. Tilman *et al.*, (1996) observed a positive relation between the number of days without rain in the growing season and K response of some tree species. Krebs (1999), Huston (1994), Grimme (1973) and He and Legendre (2002), found greater efficiency of K fertilizer with increasing soil moisture. This can be explained by the mechanisms which govern K transport from the soil to plant roots. According to Grimme (1973), a nutrient transport depends on both mass flow and diffusion. The tortuosity or impedance factor also depends on the water content of the soil, because the tortuosity of the diffusion path around soil particles decreases with increasing volume of water present. Another influence of water on K diffusion can arise from buffer power. Since the buffer power will vary if the total proportion of K participating in diffusion does not change as the K concentration of the soil solution varies with the water content of the soil. The third group of association was observed to exist between (xii, xi, x, ix, viii and vii) (soil Nitrogen, soil organic carbon, Phosphorus, soil pH, soil organic matter and CEC), implying that they all largely depended on one another in boosting the productivity of the sampled sites. The fourth group of association was seen to exist between (v and vi) (species diversity and bulk density). This indicates that species diversity of the sampled sites depends to a great extent on the ability of the soil to avoid water logging (low bulk density). Waide *et al*, (1999) and Connell (1978), reviewed literature on the relationship between plant diversity and species richness in boreal forest, tropical forest, and wetland ecosystems. They concluded that trends are variable and that relationship between plant biodiversity and productivity may vary according to different habitats and can also be influenced by other abiotic and biotic factors. In a more specific study, Janssens *et al*., (1999), Langren and Sullivan 2001, looked at the relationship between plant biodiversity and different soil chemical factors in numerous sites located in tropical forest ecosystems. They found a positive relationship between plant biodiversity (richness and diversity) and the concentration of extractable P and K in soil. Their findings tallied with this present research because bulk density and other soil attributes influenced the diversity and the species richness of the forest sites. The fifth group of association implies that, relative percentage contribution of most abundant species greatly influenced the total number of species in the sampled sites.

In the ordination of the species diversity with the soil parameters by principal component analysis, three groups of association were observed (Fig. 11). The first group of association was between cation exchange capacity and % organic matter. These two parameters have the closest affinity to species diversity, hence were presumed to have had the greatest influence on the sites species diversity and hence their richness. The second group of association was found to occur between soil pH and phosphorus. These apart from bulk density are next to influence the species diversity of the sampled sites. The third group of association was observed to exist between organic matter and total nitrogen. It could be deduced that these two parameters also have roles to play in the enhancement of the species diversity of the sampled sites, though not in the same magnitude like the first two groups of associations. This is simply a positive relationship. Other parameters were found scattered farther apart, which implies that they have little or no influence on the species diversity and richness of the forest sites (Fig 11).

However, in a tropical forest, (Huston 1994, landgren and Sullivan 2001) found a decrease in tree species richness with increasing CEC, soil fertility index, and concentration levels of K, P, and Ca in soil. The authors suggested that lower fertility soil generally favoured higher tree species richness (Huston 1994, landgren and Sullivan 2001). In lower fertility soil, a naturally strong tree species competitor may lack resources (nutrients) in order to out-compete the other, thereby causing low tree species richness (Mittelbach *et al.* 2001). This is in agreement with the present research since there is no positive correlation between the soil parameter on the species richness and diversity.

In the ordination of the soil attributes and the forest sites by principal component analysis, the following deductions were made. There was an association between four soil parameters (CEC, OM, Sand and OC), and two sites (Ukpor and Iyiocha). This implies that these two sites are similar in soil characteristics; also the soil parameters played a very vital role in influencing the species diversity of the forest sites. Another association was between (Ca, Bd, K) and (Ngene, Odengwu, Mamu and Ogugu-Nza) forests. The implication is that the relative percentages or quantities of these soil parameters in one way or another influenced the species richness of these sites in which they tilted towards. These sites are also classified as having similar soil characteristics. In the third group of association, four soil parameters (silt, P, K and TN) were observed to have a strong correlation with Unenzu forest. These findings implies that these forest sites are similar in soil properties, while Unenzu forest is unique in soil silt, P, K and N which make it different from other forest sites. The fourth group of association was observed to exist between (clay and moisture content) and Achala and Osomari forest reserves. These sites have similar soil characteristics. (Fig 12).

Based on the ordination of the six most weighted soil variables, the result of the principal component analysis showed the following associations.

Three sites were strongly correlated with bulk density. They include (odengwu, Ngene and Achala). This revealed that these sites have similar soil characteristics. The second group of association was observed to exist between (Ukpor, and Iyiocha forests) and organic matter and cation exchange capacity. By virtue of this association, these sites are presumed to possess similar characteristics and were also influenced by these parameters in terms of species richness. The last group of association in this ordination was seen to exist between (Ogugu-nza, Unenzu Osomari and Mamu) and (total nitrogen, moisture content and potassium). It is glaring that these sites have same soil characteristics (Fig 13).

However, it is important to note that the eigenvalues of the first six principal components are greater than one, implying that the thirteen soil variables (BD, CEC, P, N, K OM, OC, MC, Ca, pH, silt, clay, sand) of the forest sites can be represented by six soil variables. So based on rotated component matrix, the most weighted soil variables were those listed in table 37 above. Using these six extracted soil variables, the forest sites were characterized based on canonical discriminant function.

Using principal component analysis, the nine forest sites were characterized by species abundance. The community matrix data consisted of plant species (columns) and their important value index by forest sites (rows). The column component plot showed that the abundance of *Tectona grandis, Adansonia digitata, Pterocarpus* sp*, Dalium guineense, Elaeis guineense, Myranthus arboreus* and *Ficus capensis* of the forest sites were similar and have been group together. Another group comprised of *Gmelina arborea, Anthocleista djalonensis, Rauvolfia vomitoria, Milletia thoningii, Melicia excelsa, Daniella oliveri, Pentaclethera macrophylla,* *Draecena arborea, Sansepalum dulcificum, Hildegardia barteri* and *Vitex doniana* and so on were also similar in characteristics. It was also observed that the row component plot showed that the species abundance of Osomari forest reserve, Achala forest reserve and Mamu forest reserve were similar and so has been grouped together. Ogugu-Nza, Odengwu, Ukpor and IyiOcha were also similar and so have been grouped together. Ngene and Unenzu forests cluster a little farther from Ogugu-Nza, Odengwu, Ukpor and IyiOcha.

The species evenness of the trees showed some similarities and dissimilarities in all the studied forest sites, this was observed from the principal component analysis of the sites. This study showed to an extent some variation in the distribution pattern of species in the study sites. Similar remarks were made by Sunderland *et al*., (2003) and Nwadinigwe (2013).

The clumped pattern of distribution of species depicts natural vegetation especially in the shrine and community forests (Venna *et al*., 1999). The abundance frequency of the trees was evident on the shrine and community forests which showed that these areas are natural vegetations, in which most seedlings were adapted to grow close to the mother plant. These observations were also reported by Deka *et al*., (2012), Giliba *et al*., (2011), Sobuj and Rahman (2011), Al-Amin *et al*., (2004) and Sugar *et al*., (2004) who mentioned different vegetation types.

5.3 Soil physical and chemical parameters

It was discovered that Osomari Forest Reserve recorded the highest value of moisture content (0.139); and the least was recorded in Ngene Shrine Forest (0.063). The analysis of variance indicated a significant difference in the moisture content of the sampled forests ($p<0.05$). There was a significant difference in the moisture content of the forest sites. However, Doran *et al.* (1991), Orchard and Cook (1983) clearly stated that low water contents can inhibit CO_2 production in soils. In laboratory incubations of mixed soil samples, where the effects of temperature and spatial heterogeneity are controlled, CO_2 production declines as water content falls below field capacity. In a field study in Central Washington State, Wildung *et al.* (1975) found that a temperature-water interaction term explained seasonal variation in CO_2 efflux; they attributed it to the temperature effect being manifest only when there was sufficient soil moisture to permit significant root and microbial CO_2 production. Also, Oberbaner *et al.* (1992), Lain and Doran (1984), Reich and Nadelhoffer (1989) all stated that diffusion of soluble substrates in soil water films is a function of the cube of the volumetric water content, and this functions have been applied to studies of Nitrifreation. Davidson *et al*. (1998) agreed that laboratory studies have demonstrated clearly the importance of water in turn enhances soil production.

The assessment of the bulk density proved that in the depth of 0-15 cm, Odengwu Community Forest recorded highest (1.46 g/cm^3) followed by Achala Forest Reserve (1.42 g/cm^3) while Osomari Forest Reserve has the lowest bulk density (0.89 g/cm^3). In the soil depth of 15-30cm, Odengwu Community Forest also recorded the highest bulk density (1.40 g/cm^3), succeeded by Achala and Ogugu-Nza Shrine Forest recorded lowest bulk density (1.09 g/cm^3) respectively. In the soil depth of 30-45 cm, Mamu Forest Reserve recorded the highest bulk density (4.98 g/cm^3) followed by Achala Forest Reserve (1.37 g/cm^3), while Osomari, Odengwu and Ngene Shrine Forest recorded equal bulk density (1.33 g/cm^3) respectively. The least in this depth was recorded by Iyiocha Shrine Forest (1.07 g/cm^3). The analysis of variance however indicated no significant different in the bulk density between the forests ($p>0.05$) and between soil depths ($p>0.05$). There is also no interaction between soil depth and forests ($p>0.05$).

However, Brady and Weil (2002) stated that soil bulk density is the mass of a unit volume of dry soil in which both solids and pore space are included in the volume measurement. Michels *et al.*, (2007) found bulk densities of 1.60 to 1.72 mgm^{-3} in sandstone mine soils in Eastern Kentucky at the depth of 0-15cm using a radiation method. When compared with this research, there was a slight difference from what was discovered in the forest that has the highest bulk density of (1.46 g/cm^3) at the same depth. Bulk density of 1.61 to 1.65 mgm^{-3} were measured in mine soils of Southern West Virginia using the soil clod method by Skousen *et al.*, (1998), but the forest bulk density in this research work was slightly higher than forest soil values reported by Page-Dumose *et al*., (1999) for the foam and radiation methods in which the authors found bulk densities to be 1.10 to 1.24 mgm^{-3} at 0-15 cm and 1.11 to 1.21 mgm^{-3} at 15 to 30 cm. On the older reclaimed forested site, bulk densities of 1.07 to 1.22 mgm^{-3} were determined in the upper cm using a core method (Zeleznik and Skousen 1996). This research study also employed the core method, yet the findings did not tally with those above. The factor that could account for the observed difference was probably some key environmental conditions and methodology.

Over all, the mean bulk density of the forest sites was assessed and it was discovered that Mamu Forest Reserve has the highest bulk density while Osomari Forest Reserve has the least bulk density. Also when the bulk density of the forest were assessed by their different depths, it was discovered to be highest in the soil depth of 30-45 cm and least in the soil depth of 0-15 cm.

In the assessment of the CEC of the experimental forests, it was found that Ukpor Community Forest recorded highest (9.431 cmol/kg) in the depth of 0-15 cm followed by Iyiocha Shrine Forest (8.413 cmol/kg) while Ngene Shrine Forest recorded the lowest CEC value (1.477 cmol/kg). In the soil depth of 15-30cm, Ukpor Community Forest also recorded the highest value (52.340 cmol/kg) while Ngene Shrine Forest recorded the lowest value (1.160 cmol/kg). In the soil depth of 30-45 cm, Ogugu-Nza Shrine Forest however recorded highest CEC value (16.105 cmol/kg) while Ngene Shrine Forest recorded lowed CEC value (1.133 cmol/kg). The analysis of variance indicated a significant difference in the CEC between the forest ($p<0.05$) and between soil depths ($p<0.05$). There was also interaction between soil depths and forest ($p<0.05$). Also, when the overall CEC was determined, it was observed that Ukpor Community Forest had the highest CEC while Ngene Shrine Forest had the lowest CEC. When the CEC was analysed by soil depth, the CEC was highest in the soil depth of 0-15 cm and lowest in the soil depth of 30-45cm.

However, the Cation Exchange Capacity (CEC) of a given soil is determined by the relative amounts of different colloids in that soil and by the CEC of each of these colloids. Brady and Weil (2002) stated that sandy soils have lower CECs than clay soil because the coarse textured soils are commonly lower in both clay and humus content. They have worked extensively on a number of soils from different location in the United States and have been able to demonstrate the general relationship between soil texture (mostly the clay content) and CEC. They observed that the Cecil clay from Alabama dominated by 1:1-type clays and Fe, Al oxide has a CEC of only 4.0cmol/kg. The CEC of a second clay soil from the same state in which 2:1-type colloids are dominant is much higher (34.2 mol/kg). When compared with this present work especially with the forest that has the highest CEC at the ploughable layer (0-15 cm) depth, there was a great difference (9.43 cmol/kg). The conceivable factors that could account for these disparities are environmental factors such as weather condition and soil type. Meanwhile, Page-Dumroese *et al.* (1999) agreed that the specific exchangeable cations associated with soil colloids differ from one climatic region to another.

The organic matter content of the forest sites assessed in the depth of 0-15 cm, Ukpor Community Forest recorded the highest organic matter content (32.500 g/kg) while Mamu Forest Reserved recorded lowest organic matter (4.167 g/kg). In the soil depth of 15-30 cm, Ukpor Community Forest also recorded the highest organic matter (22.667 g/kg) while Mamu Forest Reserve recorded the lowest (3.167 g/kg). In the soil depth of 30-45 cm, Iyiocha Forest however has the highest organic matter content (15.667 g/kg) while Mamu Forest Reserve recorded the lowest organic matter content (1.667 g/kg). Meanwhile, the analysis of variance indicated a significant difference in the organic matter content between the forests ($p<0.05$) but no significant difference between soil depths ($p<0.05$). There is interaction however between soil depths and forests ($p<0.05$). The mean organic matter content was taken of all the forests and it was discovered that Ukpor Community Forest has the highest organic matter content while Mamu Forest Reserve has the least organic matter content. Also, the organic matter content was analysed by soil depths and it was found out that organic matter content was highest in the soil depth of 0-15 cm. The implication of this is that the soil is good for agricultural potentials because of the availability of organic matter for the growth and development of plants

It has been suggested that small particle with a relatively large specific surface are specifically effective in stabilizing soil organic matter (Christein, 1992; Cheshire *et al*. 1990; Leinweber *et al.* 1993) and hence in the formation of organomineral associations. They suggested that such fractions can preserve large amount of soil organic matter in biologically resistant forms and thus provide a pool of moderately available nutrients. However, their findings was in consonant with this present research work in the sense that Ukpor Community Forest that recorded the highest organic matter content (32.5 g/kg) also had the highest record of stem height (80.1 m) and also the highest stem girth (6.0 cm). Partiff *et al*. (1997) noted that in arid and semi-arid zones, water erosion processes can lead to a substantial loss of these fine fractions.

The organic carbon was investigated and it was discovered that in the soil depth of 0-15 cm, Iyiocha Forest recorded the highest organic carbon content (3.517 g/kg) while Mamu Forest recorded the lowest organic carbon (0.073 g/kg). In the soil depth of 15-30 cm, Iyiocha Shrine Forest recorded highest organic carbon (0.178 g/kg) while Osomari Forest Reserve and Ukpor Community Forest recorded the lowest (0.048 g/kg) respectively. In the soil depth of 30-45 cm, Osomari Forest however recorded highest organic carbon (0.099) while Ukpor Community Forest has the lowest organic carbon (0.018). The analysis of variance indicated no significant difference in the organic carbon between the forests and between soil depths ($p>0.05$). There was no interaction however, between soil depth and forest ($p<0.05$). The mean organic carbon content was shown to be highest in Iyiocha Shrine Forest while Unenzu and Mamu Forests had the lowest organic carbon content. Also, the analysis of the organic carbon content of the forest sites by soil depths proved that in the soil depth of 0-15 cm, organic carbon was highest and was lowest in the soil depth of 30-45 cm. However, the extant literature from Bohn (1976) stated that earlier in this century, the organic carbon in the world's soil was estimated at 710 x 1015 g/kg. This estimate was based on the carbon content of Nine North American soils. Bohn (1976); Dudal (1978), had it that the decay of soil organic carbon is one of the depth of 1 to 1.5 m; but Schlesinger (1983) believed that most organic carbon is found in a surface layer of 1 to 20 cm and this collaborate this research work because the highest organic carbon content which was recorded in Iyiocha Shrine Forest was found in the soil depth of 0-30 cm.

The percentage sand content of the forest sites were examined and it was observed that in the soil depth of 0-15 cm, Achala Forest recorded the highest percentage sand (81.800 %), followed by Mamu Forest Reserve (74.00 %), while Osomari Forest Reserve recorded the lowest (36.87 %). In the soil depth of 15-30 cm, Achala Forest Reserve recorded highest percentage sand (75.60 %), while Osomari Forest Reserve has the lowest percentage sand (43.60 %). In the soil depth of 30-45 cm, Achala Forest Reserve also recorded the highest percentage sand (71.200 %), followed by Iyiocha Shrine Forest while Osomari Forest Reserve recorded the lowest percentage sand (17.93 %). The analysis of variance indicated a significant difference between soil depth ($p>0.05$). There is interaction however between soil depths and forests ($p<0.05$). When the mean percentage sand of the forest sites was taken, it was discovered that Achala Forest Reserve had the highest percentage sand while Osomari Forest Reserve had the lowest percentage sand. The percentage sand by soil depths was also analysed and it was shown that the percentage sand of the forest sites was highest in the depth of 0-15 cm (the ploughable layer). This indicates that the some of the forests tilts towards sandy nature; the forests will have the capability of sustaining agricultural production if properly managed. However, Brady and Weil (2002) stated that sand group includes all soils in which the sand separates make up at least 70% and the clay separate 15% or less of the material by weight. This collaborated the finding in this research, because Ngene Shrine Forest (74.27%), Mamu Forest Reserve (74.00) and Achala Forest Reserve could all be classified as sandy soils.

The percentage silt was shows that in the soil depth of 0-15 cm, Umenzu Community Forest recorded the highest percentage silt (28.83%) while Achala Forest Reserve recorded the lowest (2.67%). In the soil depth of 15-30cm, Ogugu-Nza Shrine Forest recorded the highest percentage silt (47.93) while Achala Forest Reserve recorded the lowest % silt (6.067%). In the soil depth of 30-45cm, Osomari Forest Reserve has the highest percentage silt (46.00%) while Achala Forest Reserve recorded the lowest (11.33%). The analysis of variance indicated a significant difference in the percentage silt between the forests ($p<0.05$), but no significant difference between soil depths and forests ($p>0.05$). The mean percentage silt of the forests was determined, and it was shown that Osomari Forest Reserve has the highest percentage silt (32.07%) while Achala Forests Reserve has the lowest % silt. Also, the percentage silt content was analysed by soil depth and it was discovered that the percentage of the forests was highest in the soil depth of 0-15 cm. This research work contrasted heavily with the findings of Brady and Weil (2002) with states that the silt group includes soils with at least 80% silt and 12% or less clay. The forest soils contain silt content within the range of tropical forest as observed in this research work.

The percentage clay content of the forest sites was determined, and it was discovered that in the soil depth of 0-15cm, Osomari Forest Reserve recorded highest percentage clay (25.267%) while Iyiocha Forest recorded lowest (5.933%). In the soil depth of 15-30cm, Osomari Forest Reserve also recorded the highest percentage clay content (36.067) while Mamu Forest Reserve and recorded lowest percentage clay (11.267%). Meanwhile, in the soil depth of 30-455cm, Osomari Forest Reserve also recorded the highest percentage clay (46.467%), while the least was recorded by Mamu forest reserve (12.400%). The analysis of variance indicated a significant difference in the percentage clay content between the forests and between soil depths ($p<0.05$). There is also interaction between soil depths and forests ($p<0.05$). When the mean percentage clay content of all the forest site was taken, it was evident that Osomari Forest Reserve has the highest percentage clay content (35.93%), followed by Achala Forest Reserve and the lowest record was found in Mamu Forest Reserve (23.30%). Also, the percentage by soil depth was analysed and it was discovered that the percentage clay content was higher in the soil depth of 30-45 cm and lowest in the soil depth of 0-15 cm. However, soils are designated clay when they contain at least 35% clay separate and in most cases, not less than 40% (Brady and Weil, 2002). Some of the forest soils are clayey, having greater than 40% clay while others with less than 40% belong to other textural classes.

The soil pH of all the forest sites were determined and it was found that in the soil depth of 0-15 cm, Achala Reserve recorded highest soil pH (6.253) while Ogugu-Nza shrine Forest recorded lowest soil pH (4.075). In the soil depth of 15-30 cm, Achala Forest Reserve also recorded highest soil pH (6.403) while Osomari Forest Reserve and Ukpor Community Forest recorded lowest soil pH (4.048) respectively. In the soil depth of 30-45cm, Odengwu Community Forest recorded highest pH (7.950) while Ukpor Community Forest recorded lowest pH (4.018). The analysis of variance indicated a significant difference in the pH between the forests ($p>0.05$). There is no interaction between soil depth and forest ($p>0.05$). The mean soil pH of all the forests was taken and it was discovered that Odengwu Community Forest has the highest soil pH (6.55) while Ukpor Community Forest and Ogugu-Nza Shrine Forest have the lowest soil pH (4.03). The soil pH by soil depth was also determined and it was discovered that the soil pH of the forest sites was highest in the depth of 30-45 cm (4.02) and lowest in the depth of 0-15 cm (3.70). However, Brady and Weil (2002) noted that most forest trees seem to grow well over a wide range of soil pH level which indicates they have at least some tolerance of acid soil. Forests exist as natural vegetation on regions of acid soils. In terms of pH, a range of perhaps 6.0-7.2 is most suitable for most crop plants (Brady and Weil, 2002). This is in consonant with the present research work, because the pH value (6.253) found at the plaughable layer (0-15 cm) of Achala Forests Reserve highly supports the tanngya farming practiced by the local people. Also, the pH value of (4.02) observed to be peculiar to all the forests favour the forest tree species especially those that can withstand slightly high degree of acidity. No other single chemical soil characteristics are more important in determining the chemical environment of higher plants and soil microbes than the pH. Soil pH is largely controlled by soil colloids and their exchangeable cations (Brady and Weil, 2002).

The soil phosphorus in the forests was accessed and it was found that in the soil depth of 0-15 cm, Mamu Forests Reserve recorded highest phosphorus (48.197 mg/kg) while Osomari Forest Reserve has the lowest phosphorus (2.56 mg/kg). In the soil depth of 15.30 cm, Mamu Forest Reserve also recorded highest phosphorus (60.214 mg/kg) while Osomari Forest Reserve recorded the lowest Phosphorus (2.117 mg/kg). In the soil depth of 30-45 cm, Mamu Forest Reserve also recorded highest phosphorus (58.523 mg/kg) while Osomari Forest Reserve recorded lowest phosphorus (1.905 mg/kg). The analysis of variance, however, indicated a significant difference in the Phosphorus between the forest ($p<0.05$) but no significant difference between soil depths (p>0.05). There is no interaction between soil depth and forest (p>0.05). The mean available phosphorus of the forest sites was determined and it was discovered that Mamu Forest Reserve had the highest phosphorus (55.64 mg/kg) while Osomari Forest Reserve had the lowest (2.21 mg/kg). Also, the available phosphorus content was accessed by soil depth, it was discovered that the available phosphorus of the forest sites was highest in the soil depth of 15-30 cm and lowest in the soil depth of 0-15 cm. However, Brady and Weil (2002) stated that in most soils, the amount of phosphorus in the available form at any time is very low, seldom exceeding about 0.01% of the total phosphorus in the soil. This attests to the veracity of this finding which proved that phosphorus is extremely very low in the plaughable layer (0-15cm). Thus, available Phosphorus levels must be supplemented on most soils by adding chemical fertilizers. Unfortunately, much of such added phosphorus is converted to the less available secondary mineral forms, from which it too is released very slowly and becomes useful to plants only over a period of years. Brady and Weil (2002) also opined that fertilizer practices in many areas illustrate the problem of phosphorus unavoidability. So, to obtain high yields, farmers commonly apply more phosphorus in fertilizers than is removed by the crops.

The assessment of the soil Potassium content in the forest sites proved that in the soil depth of 0-15 cm, Unenzu Forest recorded highest available Potassium (44.41cmol/mg) while Osomari Forest Reserve recorded the lowest potassium (2.819 cmol/mg). In the soil depth of 15-30 cm, Odengwu Community Forest recorded the highest available Potassium (37.26 cmol/mg) while Mamu Forest Reserve recorded lowest available Potassium (8.631 cmol/mg). In the depth of 30-45 cm, Odegwu Community Forest has the highest Potassium (17.316) while Ngene Forest recorded lowest available Potassium content (8.611 cmol/mg). The analysis of variance indicated no significant difference in the Potassium content between the forests and between soil depths (p>0.05). Also, when the mean Potassium content was assessed, it was found out that Unenzu Forest has the highest potassium (24.59 cmol/mg) while Mamu Forest Reserv has the lowest Potassium content (10.99 cmol/mg). Meanwhile, the Potassium content by soil depth of the sampled forests was assessed and it was discovered that the Potassium content was highest in soil depth of 15-30 cm and lowest in the soil depth of 30-45 cm. However, Brady and Weil (2002) held that in contrast to Phosphorus, Potassium is found in comparatively high levels in most mineral soils, yet the quantity of Potassium held in an easily exchangeable condition at any one time often is very small. From this research, it was discovered that the availability of Potassium was minimal within the plaughable layer and highest in the soil depth of 15-30 cm where only plants with deep rooted system can have access to it. Therefore, one can assert that the situation in respect to Potassium utilization parallels that of Phosphorus and Nitrogen at least in one way. A very large portion of all three of these elements in the soil is insoluble and relatively unavailable to growing to plants.

The soil Nitrogen content of the forest sites was assessed and it showed that in the soil depth of 0-15 cm, Ogugu-Nza Shrine Forest recorded the highest Nitrogen content (2.819 g/kg) while Iyiocha Shrine Forest recorded lowest available Nitrogen (1.81 g/kg). In the soil depth of 15-30cm, Mamu Forest Reserve recorded the highest available (2.800 g/kg) while Unenzu Community Forestt lowest nitrogen (1.457 g/kg). In the soil depth of 30-45cm, Iyiocha Shrine Forest however recorded the highest available Nitrogen (2.651 g/kg) while Odengwu Community Forest recorded the lowest available Nitrogen content (1.116 g/kg). The analysis of variance indicated no significant difference in the nitrogen content between the forests and between soil depths ($p>0.05$). There is also no interaction between the soil depths and forests ($p>0.05$). The mean Nitrogen content was also assessed and it was discovered that Unenzu Community Forest has the highest nitrogen while Achala Forest Reserve has the lowest available nitrogen. The soil Nitrogen was assessed by soil depths, and it was found out that the available Nitrogen content of the sampled forests was highest (3.11 g/kg) in the soil depth of 30-45 cm and lowest in the soil depth of 15-30 cm. However, Anderson and Paul (1984) and Christensen (1998) both agreed that Nitrogen is generally low in agricultural soil (0-15 cm, which is the plaughable layer). Although this may have been partly the result of the inputs of Nitrogen during nitrogen fertilization, it is accepted that the accumulation of Nitrogen is independent of the input of the inorganic nitrogen (Elliot 1986, Hassink and Neeteson 1991, Hassink 1997). In forested soils, Hassink and Neeteson (1991) noted that available Nitrogen between 20-45cm depth was on average 13.6 which varied greatly with this research work that recorded (3.11 g/kg) be tween 30-45 cm depth. The implication of this may be that Nitrogen depletes with increase in soil depths. It also confirms the veracity of the unavailability of Nitrogen to agricultural soils.

The soil Calcium content was determined and it was shown that in the soil depth of 0–15 cm, Odengwu Community Forest recorded the highest Calcium (52.124 g/kg), while Osomari Forest Reserve recorded lowest available calcium content (3.153 g/kg). In the soil depth of 15–30 cm, Odengwu Community Forest also recorded highest Calcium (77.509 g/kg), while Ukpor Community Forest recorded lowest Calcium content (10.688 g/kg). In the soil depth of 30 – 40cm, Ngene Shrine Forest recorded highest soil Calcium content (50.106 g/kg) while Osomari Forest Reserve recorded the lowest Calcium content (11.256 g/kg). The analysis of variance indicated a significant difference in the Calcium content between the forest and the soil depths ($p < 0.05$). There was interaction between soil depth and forest ($p < 0.05$). The mean available Calcium content of the forest sites was accessed and found that Odegun Community Forest has the highest Calcium content while Ukpor Community Forest has the lowest available calcium content. The soil Calcium content by soil depth was analysed, it was discovered that the available calcium content was highest in the soil depth of 15–30 cm and lowest in the soil depth of 0–15 cm.

The correlation and regression analysis between the soil properties of the forest sites was carried out, it was discovered that there was an indication of a significant positive relationship between CEC and Organic Matter (0.483), between % sand and soil pH (0.447), between Phosphorus and Nitrogen (0.260) and between Potassium and Calcium (0.569).

There was however a significant negative relationship between soil pH and CEC (-0.388), between soil pH and calcium (-0.336), between Organic matter and soil pH (-0.320), between organic matter and phosphorus (-0.303), between organic matter and calcium (-0.244), between sand and silt (-5.455), between sand and clay (-0.679), between silt and soil pH (-0.294), between silt and calcium (-0.256), between clay and soil pH (-0.338) and between clay and calcium (-0.224).

The regression result of soil properties on species diversity proved that only the coefficients of cation exchange capacity and percentage clay are significant. The coefficient of CEC which is about 0.122 indicate that holding other variables constant, a percentage point increase in CEC of the forest sites increases species diversity by 0.122. The coefficient of clay which is about -0.339 indicate that holding other variables constant, a percentage point increase in clay content of the forest sites decreases species diversity by 0.339.

The regression of soil properties on spp number proved that only the coefficient of CEC % clay and soil Potassium were significant. The coefficient of CEC which is about 0.0008 indicated that holding other variable constant, a percentage point increase in CEC of the forest sites increases spp number by 0.0008. The coefficient of clay which is about -0.0016 indicated that holding other variables constant, a percentage point increase in clay content of the forest sites decreases species number by -0.0016. The coefficient of Potassium which is about 0.0007 indicated that holding other variables constant, a percentage point increase in Potassium content of the forest sites increases species number by 0.0007.

5.4 CONCLUSION

This study revealed that forests in Anambra State have high species diversity. Families of trees noted with dominant species in the study areas included: Fabaceae and Verbenaceae. A great deal of the species was quite more in abundance than other species probably due to their ability to cope with the environmental conditions prevalent in the study sites.

From the PCA, it was established that certain groups of species were common in all the sampled sites, while some were particularly unique to some sampled sites. It was also established that a great deal of soil chemical parameters formed strong associations and are critical to the determination of the growthand species diversity of the sampled sites. By virtue of the association of some soil parameters and some sampled sites, it was established that those sites possess similar soil characteristics, and in turn those soil parameters are presumed to play a vital role in the growth and development of the sampled sites.

This study showed, to a great extent some variations in the distribution pattern of species in the study sites. The abundance of the trees which was evident in the shrine and community forests proved that those forests are relatively natural vegetations and most seedlings were adapted to grow close to the mother plants.

The dominant species in the forest sites included the following: *Tectona grandis, Gmelina arborea*, *Newbouldia laevis*, *Pterocarpus species*, *Afzelia africana*, and *Spondias mombin* among others. The least encountered species were *Milletia zachiana, Borassus aethiopicum, Dialium guineense, Datarium microcarpum, Rauvolfia vomitoria, Prosopis africana, Buchholzia coriaceae,* and *Sensepalum dulcificum.* Over exploitation or harvesting for the market and livelihood support of the local communities could have accounted for the paucity of these least encountered species. Nevertheless, the presence of many species in the lower girth classes (though not accounted for) gives the sampled forests the potential for regeneration. This indicated that effective conservation and sustainable management of the forests would make it possible for the said forests to continue providing adequate plant genetic resources both for short and long term purposes.

The soil physical and chemical characteristics of the forest sites revealed low moisture availability in some of the sampled sites; this could inhibit carbon (IV) oxide production in the soils. Sufficient moisture content permits significant root and microbial carbon (IV) oxide production.

The lowest bulk density which was observed in the soil plaughable depth of the forest sites, indicated that the soils are good for agricultuaral production especially for annual crops. High bulk density of soils impedes the root penetration into the soil and thus hampers adequate absorption of moisture as well as other mineral nutrients from the soil. Also, the highest cation exchange capacity was observed at the depth of 0-15 cm and 15-30 cm. These depths are within the plaughable layers confirming what was observed in the case of bulk density. The highest soil organic matter observed in the depth of 30-45cm in some of the soils indicated that it is only plants that are deeply rooted that can have access to the organic matter. It has been noted that small particles with relatively large surface area are effective in stabilizing soil organic matter. It can preserve large amount of organic matter in biologically resistant forms and thus provide a pool of moderately available nutrients. Increase in soil carbon is facilitated when the land is irrigated. Most organic carbons were observed in a surface layer of 1-30 cm, which is within the plaughable layer and hence the tendency to enhance agricultural development.

All the forest sites differed greatly in their composition of soil particles. Some were observed to be sandy while a great deal tilted towards silt and clay, a sure proof of the enormous agricultural potentiality of the forested lands. Also some of the sampled sites had low pH values, especially the community and shrine forests, while the rest ranges from moderate to neutral values.

This study revealed that the forest sites had a very low amount of phosphorus in the plaughable layers. It is obvious that the amount of Phosphorus in the available form at any given time is very low, seldom exceeding about 0.01% of the total phosphorus in the soil. Thus, available phosphorus levels must be supplemented on most of the forest soils by the addition of chemical fertilizers. The application of fertilizers in many areas illustrates the problem of Phosphorus unavailability. So, to obtain high yields taungya farmers are advised to apply more Phosphorus rich fertilizers in their farms.

Observation from this study proved that the availability of Potassium was minimal within the plaughable layer and highest in the depth of 30-45 cm where only plants with deep root system can have access to it. Therefore one can infer that the situation with respect to Potassium utilization parallels that of Phosphorus and nitrogen at least in one way. All of them are insoluble and relatively unavailable to growing plants and hence the need for supplementation.

This study also revealed high growth in majority of the forest sites especially the forest reserves or plantations. This could be as a result of the tributaries of water courses that feed these forest reserves. The proximity of these forest reserves to streams and other water bodies makes room for adequate supply of moisture to these forests all the year round.

5.5 RECOMMENDATION

This research has elucidated so many facts about the forests of Anambra State and by virtue of these glaring facts, suggestion have been proffered on how these resources could be managed sustainably.

Anambra State just like many other states in the South-Eastern Nigeria, is obviously in a period of industrial expansion and high rate of urbanization, which calls for more lands for buildings, wood products in construction and other home and business needs. It behoves the government and other stake holders to make corporate efforts in strategizing means for rational exploitation of these forest resources for sustainability. Some areas should be set out for forest reserves and parks.

"Grow timber as a crop" has been the rallying cry and the clarion call of most states, Federal and private ecologists with foresights for many years. Actually the intensity of forest management on small holdings has varied considerably over time. Some forest owners have managed their forest lands for long term timber production, others have not.

Apart from the high species richness and diversity reported in these forest sites, it is still highly advocated that government, concerned individuals, community leaders and corporate entities should make conscious efforts in restocking the forests with both indigenous and exotic tree species. This restocking exercise should not be limited to the government-protected areas alone; it should be extended to other categories of forests (community and shrine forests) within the state.

In our increasingly industrialized society, with increasing population, demands for all types of wood products, is rising. Hence, the need for sustainable management of these forest products cannot be over emphasized.

Annually, there are drains on these forests for housing, construction of dams, high way roads, preserves and other land uses. Thus, it is necessery to opt for the application of more intensive management practices to the remnants of these forested lands. To some extent, our standard of living is dependent on the care given to these forest lands in the production of timber, and other forest values, including water, wild life, grazing and recreation.

Obviously, the forests must be protected from indiscriminate logging, fire, insects and diseases. Idle or unproductive lands must be reforested and resoscitated. And the forest must be properly managed and the optimum yield concept could be applied in harvesting the trees to meet the increasing wood needs of our society now and in the future.

More so, local farmers and community leaders need to be involved in key decision making as regards the sustainable use of these forests. Farmers must be intimately involved in the diagnosis of the problems and in devising improvement strategies. Agricultural technologies and policies are complementary means of improving agricultural productivity. The extent to which a farming system fulfills the household needs depends among other things, on managerial skills in most areas, considerable luck with the weather and other uncertain environmental elements outside household control.

It is worthy of note that African environment is being seriously degraded as a result of the over exploitation of forests and crop land. The degradation of cropland can best be halted by improving soil fertility, limiting soil erosion and introducing water harvesting and dry land farming techniques. Options include:

- Replacing shifting cultivation with perennial tree crops
- Growing crops between alleys of leguminous trees and shrubs, and supplementing the nitrogen and organic matter they supply with farm yard manure.
- Using zero or minimum tillage systems to minimize soil erosion.
- Adopting integrated plant nutrition to supply nitrogen by using animal manure alone or mixed with mineral fertilizers, or by growing leguminous crops and constructing physical barriers to prevent soil erosion, such as earth bunds, bench terraces and tied ridges.

Where population pressure has forced people to cultivate hill sides with marginal soils, or to settle in semi-arid areas better suited for pastoralism, four simple measures can reduce degradation: the construction of small dams to conserve water, tree planting on upper slopes, the use of dry land farming technique, and finally the use of short-season, drought resistant cultivars. Adding new organic matter every year is perhaps the most important way to improve and maintain soil quality and productivity.

Regular additions of organic matter improve soil structure, enhance water and nutrient holding capacity, protect soil from erosion and compaction, increased infiltration and water-holding capacity, increased cation exchange capacity and support a healthy community of soil organisms.

In conclusion, apart from soil conservation programmes to combat soil erosions and some production oriented developments particularly in the affected parts of the state, relatively few programmes have been implemented with domestic funding to encourage sustainable agricultural development at local or community level. Things must be put right if relevant strategies to encourage sustainable agricultural development are to be developed and implemented to meet the target of millennium development goals.

5.6 Limitations of the Research

During the course of this research, the following limitations were encountered. These include:

- Limited source of documents (Literature)

Available documents on the Forest Resource Situation are few, fragmentary, frought with many discrepancies and are scattered in different forest zonal offices of the state.

- Lack of complete and up-to-date information on forest resources

The most current information on the Forest Resource Situation in Anambra State was provided in scanty drafted hand over reports by some of the forest officers. This implies that their reports were yet to be appraised by the state government; also such reports lacked scientific relevance because it cannot be subjected to statistical analysis.

- Limited coverage of the whole forests in Anambra State because of financial constraint.

Some of the forest zones have more than three forest reserves (including the proposed) and many other types of forests. There is no doubt that this research is capital intensive, so the researcher was constrained by financial resources to cover just nine forests in three zones.

- Accessible extant literature was also devoid of current information about the status of forest resources of other states from various locations in Nigeria for the purposes of comparison.

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APPENDICES

Appendix 1

OSOMARI-EAST FOREST RESERVE STRATA 1

Sampling Point	Quarter No.	Distance (m)	Species encountered	Diameter at base (cm)
1	1	13.8	*Beitsclemeidia manii*	48.3
	2	21.3	*Tectona grandis*	18.5
	3	28.4	*Gmelina arborea*	22.5
	4	16.5	*Datarium microcarpium*	55.1
2	1	10.8	*Gmelina arborea*	16.4
	2	16.5	*Melicia excelsa*	12.3
	3	10.4	*Daniella oliveri*	18.1
	4	5.5	*Tectona grandis*	10.9
3	1	22.6	*Daniella oliveri*	38.4
	2	20.5	*Vitex doniana*	28.1
	3	18.1	*Gmelina arborea*	16.5
	4	23.4	*Parkia bigglobosa*	44.2
4	1	14.8	*Gmelina arborea*	30.0
	2	16.1	*Tectona grandis*	62.3
	3	10.5	*Adansonia digitata*	48.1
	4	19.6	*Hildegardia barteri*	40.3
5	1	17.8	*Gmelina arborea*	28.1
	2	11.1	*Enantia chlorantha*	39.3
	3	9.8	*Gmelina arborea*	25.5
	4	6.9	*Draecena arborea*	8.4
Total		314.4		

Appendix 2

OSOMARI-EAST FOREST RESERVE OSEAKWASTRATA 2

Sampling Point	**Quarter No.**	**Distance (m)**	**Species Encountered**	**Diameter at base (cm)**
1	1	6.8	*Tectona grandi*	75.6
	2	3.4	*Dracaena arborea*	28.4
	3	4.5	*Nauclea latifolia*	38.1
	4	8.9	*Gmelina arborea*	40.3
2	1	6.1	*Tectona grandis*	69.1
	2	10.5	*Pterocarpus spp.*	28.3
	3	28.5	*Gmelina arborea*	20.4
	4	20.3	*Adansonia digitata*	72.5
3	1	22.6	*Gmelina arborea*	38.4
	2	20.5	*Tectona grandis*	10.3
	3	18.1	*Beitschemeidia manii*	48.3
	4	23.4	*Dracaena arborea*	40.5
4	1	16.4	*Piptadeniastrum africana*	39.6
	2	18.1	*Gmelina arborea*	12.6
	3	26.5	*Aubrevillea kerstingii*	55.3
	4	22.1	*Nauclea latifolia*	33.9
5	1	16.9	*Tectona grandis*	11.0
	2	22.3	*Nauclea latifolia*	25.3
	3	17.1	*Adanonia digitata*	20.5
	4	19.3	*Gmelina arborea*	28.8
Total		296.8		

Appendix 3

OSOMARI-EAST FOREST RESERVE OSEAKWASTRATA 3

Sampling Point	Quarter No.	Distance (m)	Species Encountered	Diameter at base (cm)
1	1	29.5	*Pentaclethra macrophylla*	84.1
	2	12.6	*Gmelina arborea*	28.3
	3	18.3	*Adanonia digitata*	66.3
	4	20.1	*Daniella oliveri*	44.5
2	1	4.5	*Vitex doniana*	33.6
	2	12.8	*Gmelina arborea*	28.5
	3	13.9	*Irvingia gabonensis*	44.6
	4	10.5	*Parkia biglobosa*	36.3
3	1	11.1	*Borassus aethiopicum*	10.6
	2	16.5	*Gmelina arborea*	23.4
	3	18.4	*Tectona grandis*	26.0
	4	10.5	*Adanonia digitata*	33.4
4	1	16.4	*Beitschemeidia manii*	65.4
	2	18.1	*Datarium macrocapium*	48.3
	3	26.5	*Milletia thorningii*	55.7
	4	22.1	*Afzelia Africana*	69.8
5	1	16.9	*Gmelina arborea*	14.6
	2	22.3	*Tectona grandis*	7.8
	3	17.1	*Anthocleista djalonensis*	29.3
	4	19.3	*Delonix regia*	44.6
Total		491.3		

Appendix 4

OSOMARI-EAST FOREST RESERVE OSEAKWASTRATA 4

Sampling Point	Quarter No.	Distance (m)	Species Encountered	Diameter at base (cm)
1	1	6.8	*Gmelina arborea*	33.3
	2	9.3	*Tectora grandis*	18.3
	3	3.8	*Ceiba pentandra*	48.7
	4	4.5	*Melicia excels*	55.6
2	1	4.8	*Gmelina arborea*	16.5
	2	8.6	*Myrianthus arboreus*	24.7
	3	5.3	*Tetrapleura tetraptera*	68.3
	4	7.4	*Gmelina arborea*	37.4
3	1	11.7	*Melicia excelsa*	77.8
	2	14.6	*Vitex doniana*	54.6
	3	8.9	*Daniella oliveri*	34.9
	4	4.3	*Adansonia digitata*	61.4
4	1	3.8	*Tectona grandis*	45.7
	2	4.9	*Pentaclethra macrophylla*	65.8
	3	5.7	*Adonsonia digitata*	69.3
	4	8.8	*Pterocaprus Spp.*	42.2
5	1	4.8	*Melicia excelsa*	67.1
	2	9.1	*Vitex doniana*	26.3
	3	3.8	*Daniella oliveri*	18.6
	4	8.9	*Gmelina arborea*	16.3
Total		139.8		

Appendix 5

OGUGU-NZA SHRINE FOREST STRATA 1

Sampling Point	Quarter No.	Distance (m)	Species encountered	Diameter at base (cm)
1	1	2.9	*Irvingia gabonensis*	38.5
	2	3.8	*Prosopis africana*	28.6
	3	10.1	*Delonix regia*	33.5
	4	8.3	*Newbouldia laevis*	44.8
2	1	4.5	*Dacroydes edulis*	38.1
	2	6.8	*Melicia excelsa*	76.8
	3	4.4	*Pterocarpus Spp.*	65.3
	4	4.2	*Gambeya albida*	55.4
3	1	12.3	*Spondias mombin*	16.3
	2	11.1	*Ficus capensis*	10.6
	3	10.5	*Datarium microcarpium*	28.0
	4	3.1	*Enantia chlorantha*	45.1
4	1	6.5	*Delonix regia*	37.8
	2	8.3	*Myrianthus arboreus*	58.1
	3	10.5	*Hildegardia barteri*	63.5
	4	9.1	*Parkia biglobosa*	68.3
5	1	5.6	*Aftzelia africana*	66.6
	2	8.7	*Ficus capensis*	34.9
	3	10.1	*Buchholzia coriacea*	53.4
	4	3.9	*Newbouldia levis*	38.1
Total		144.7		

Appendix 6

OGUGU-NZA SHRINE FOREST STRATA 2

Sampling Point	Quarter No.	Distance (m)	Species encountered	Diameter at base (cm)
1	1	8.9	*Syzigium guineense*	47.6
	2	6.4	*Prosopis africana*	38.4
	3	9.6	*Newbouldia levis*	44.1
	4	6.1	*Parkia biglobosa*	60.2
2	1	4.3	*Melicia excelsa*	68.3
	2	8.4	*Adansonia digitata*	59.6
	3	7.3	*Newbouldia levis*	33.5
	4	5.8	*Pterocarpus Spp.*	45.2
3	1	6.1	*Dacroydes edulis*	16.3
	2	10.5	*Draecena arborea*	10.6
	3	13.8	*Anthocleista djalonensis*	28.0
	4	8.1	*Tetrapleura tetraptera*	45.1
4	1	12.3	*Afzelia africana*	67.3
	2	14.4	*Gambeya albida*	89.1
	3	18.6	*Irvingia garbonesis*	45.9
	4	3.5	*Prosopis africana*	38.5
5	1	5.6	*Hildegardia barteri*	28.3
	2	11.1	*Ceiba pentandra*	44.8
	3	4.8	*Myrianthus arboreus*	56.1
	4	8.3	*Newbouldia levis*	37.8
Total		173.9		

Appendix 7

OGUGU-NZA SHRINE FOREST STRATA 3

Sampling Point	Quarter No.	Distance (m)	Species encountered	Diameter at base (cm)
1	1	6.8	*Newbouldia laevis*	23.4
	2	3.9	*Irvingia gabonensis*	38.4
	3	4.3	*Prosopis africana*	48.3
	4	10.5	*Pentaclethra macrophylla*	75.8
2	1	6.3	*Syzigium guineense*	61.5
	2	8.4	*Gambeya albida*	68.0
	3	6.1	*Dacroydes edulis*	56.5
	4	9.3	*Hildegardia barteri*	48.3
3	1	9.1	*Afzelia africana*	83.1
	2	11.5	*Ficus capensis*	60.3
	3	6.4	*Pterocarpous Spp.*	75.6
	4	12.5	*Newbouldia levis*	38.3
4	1	10.3	*Parkia biglobosa*	33.8
	2	11.8	*Dialum guineese*	45.4
	3	7.3	*Enantia chlorantha*	31.6
	4	14.5	*Anthocleista djalonensis*	28.3
5	1	5.8	*Pterocarpus Spp.*	65.2
	2	9.5	*Sensepalum dulcificum*	34.5
	3	14.8	*Aubrevillea kerstingii*	33.6
	4	6.1	*Newbouldia laevis*	27.6
Total		175.3		

Appendix 8

OGUGU-NZA SHRINE FOREST STRATA 4

Sampling Point	**Quarter No.**	**Distance (m)**	**Species encountered**	**Diameter at base (cm)**
1	1	4.8	*Melicia excelsa*	85.5
	2	3.9	*Spondias mombin*	44.5
	3	10.5	*Irvingia gabonensis*	40.1
	4	12.6	*Newbouldia levis*	48.3
2	1	14.9	*Pterocarpus Spp.*	55.3
	2	12.3	*Gambeya albida*	60.4
	3	10.4	*Pentaclethra macrophylla*	68.1
	4	4.6	*Ceiba pentandra*	33.3
3	1	3.9	*Myrianthus arboreus*	34.8
	2	3.4	*Ficus capensis*	28.3
	3	4.8	*Adansonia digitata*	69.3
	4	5.3	*Daniella oliveri*	45.8
4	1	8.6	*Syzigium guineense*	49.3
	2	14.4	*Dacroydes edulis*	45.4
	3	18.6	*Elaeis guineense*	33.5
	4	3.5	*Draccena arborea*	47.6
5	1	10.4	*Enantia chlorantha*	56.3
	2	8.5	*Anthocleista djalonensis*	50.4
	3	3.7	*Nauclea latifolia*	38.1
	4	7.5	*Afzelia africana*	66.3
Total		166.6		

Appendix 9

UKPO COMMUNITY FOREST STRATA 1

Sampling Point	Quarter No.	Distance (m)	Species encountered	Diameter at base (cm)
1	1	9.5	*Milletia thorningii*	33.6
	2	6.3	*Piptadeniastrum africana*	46.2
	3	7.1	*Hildegardia barteri*	40.5
	4	4.5	*Datarium microcarpium*	38.3
2	1	3.1	*Irvingia gabonensis*	36.1
	2	6.6	*Adansonia digitata*	58.3
	3	14.1	*Vitex doniana*	28.6
	4	18.4	*Dacroydes edulis*	38.6
3	1	16.3	*Rauvolfia vomitoria*	10.8
	2	12.1	*Buchholzia coriaceae*	39.3
	3	17.6	*Myrianthus arboreus*	30.5
	4	8.4	*Ficus exasperate*	33.8
4	1	4.8	*Anthocleista djalonensis*	43.4
	2	6.9	*Milletia thoningii*	38.6
	3	4.3	*Nauclea latifolia*	28.5
	4	3.6	*Ceiba pentandra*	66.1
5	1	11.1	*Gambeya albida*	56.2
	2	9.9	*Pentaclethra macrophylla*	72.9
	3	8.4	*Aubrevillea kerstingii*	61.3
	4	6.1	*Afzelia africana*	54.8
Total		179.1		

Appendix 10

UKPO COMMUNITY FOREST STRATA 2

Sampling point	**Quarter No.**	**Distance (m)**	**Species encountered**	**Diameter at base (cm)**
1	1	3.8	*Pentaclethra macrophylla*	49.5
	2	7.5	*Afzelia africana*	65.7
	3	5.4	*Dialium guineense*	54.3
	4	8.3	*Hildegardia barteri*	38.6
2	1	4.9	*Pterocarpus Spp*	45.6
	2	4.1	*Melicia excelsa*	73.4
	3	6.3	*Irvingia gabonensis*	56.5
	4	3.8	*Ceiba pentandra*	67.6
3	1	10.9	*Gambeya albida*	44.7
	2	12.4	*Enantia chlorantha*	40.8
	3	4.8	*Draecena arborea*	38.1
	4	14.1	*Nauclea latifolia*	50.5
4	1	12.5	*Ficus exasperata*	18.3
	2	13.0	*Prosopis africana*	35.5
	3	8.8	*Tetrapleura tetraptera*	61.3
	4	9.1	*Newbouldia laevis*	38.9
5	1	3.8	*Pterocarpus spp*	33.4
	2	4.0	*Spondias monbin*	28.6
	3	7.3	*Adansonia digitata*	68.8
	4	10.1	*Myrianthus arboreus*	38.7
Total		154.9		

Appendix 11

UKPOR COMMUNITY FOREST STRATA 3

Sampling Point	Quarter No	Distance (m)	Species encountered	Diameter at base (cm)
1	1	3.1	*Delonix regia*	38.1
	2	8.4	*Syzigium guineense*	23.5
	3	12.5	*Parkia biglobosa*	28.3
	4	5.1	*Prosopis africana*	18.3
2	1	6.0	*Vitex doniana*	35.6
	2	3.5	*Delonix regia*	40.5
	3	6.3	*Daniella oliveri*	48.6
	4	7.3	*Dacroydes edulis*	25.3
3	1	8.9	*Ceiba pentandra*	45.3
	2	17.4	*Pentaclethra macrophylla*	66.8
	3	4.6	*Sensepalm dulcificum*	51.4
	4	13.4	*Buchholzia coriaceae*	43.2
4	1	4.8	*Vitex doniana*	39.3
	2	7.6	*Pitadeniastrum africana*	40.4
	3	9.1	*Nanclea latifolia*	38.2
	4	3.9	*Ficus exasperata*	18.8
5	1	16.3	*Beitschemeidia manii*	55.6
	2	12.4	*Datarium microcarpium*	49.3
	3	14.1	*Gambeya albida*	60.4
	4	13.0	*Adansonia digitata*	69.2
Total		177.7		

Appendix 12

UKPOR COMMUNITY FOREST NNEWI STRATA 4

Sampling Point	Quarter No	Distance (m)	Species encountered	Diameter at base (cm)
1	1	6.9	*Borassus aethiopicum*	18.3
	2	4.3	*Parkia biglobosa*	28.5
	3	8.6	*Syzigium guineense*	38.1
	4	10.1	*Delonix regia*	33.8
2	1	15.1	*Tetrapleura tetraptera*	55.3
	2	19.3	*Datarium microcarpium*	49.4
	3	3.6	*Hildegardia barteti*	44.5
	4	9.4	*Proposis africana*	35.6
3	1	8.3	*Newbouldia levis*	25.6
	2	6.4	*Pterocarpus spp*	66.1
	3	12.6	*Irvingia gabanensis*	58.4
	4	11.1	*Myrianthus arboreus*	48.6
4	1	10.3	*Sensepalum dulcificum*	35.8
	2	7.4	*Anthocleista djalonensis*	39.3
	3	14.8	*Draecena arborea*	44.9
	4	11.3	*Nauclea latifolia*	34.2
5	1	7.3	*Buchholzia coriaceae*	39.6
	2	9.4	*Ceiba pentandra*	68.3
	3	3.6	*Pantaclethra macrophylla*	63.5
	4	5.5	*Enantia chlorantha*	22.5
Total		185.3		

Appendix 13

ODENGWU COMMUNITY FOREST IGBARIAM STRATA 1

Sampling Point	Quarter No	Distance (m)	Species encountered	Diameter at base (cm)
1	1	18.6	*Vitex doniana*	34.8
	2	12.3	*Daniella oliveri*	48.3
	3	20.5	*Prosopis africana*	23.4
	4	18.9	*Myrianthus arboreus*	18.9
2	1	19.5	*Datarium microcarpium*	45.8
	2	14.6	*Ceiba pentandra*	64.6
	3	12.8	*Afzelia africana*	86.5
	4	17.3	*Tetrapleura tetraptera*	75.4
3	1	10.5	*Parkia bigbobosa*	56.1
	2	8.6	*Pterocaspus spp*	34.5
	3	11.5	*Dialium guineense*	26.3
	4	14.3	*Daniella oliveri*	37.8
4	1	3.4	*Ceiba pentandra*	65.8
	2	8.6	*Vitex doniana*	48.1
	3	3.9	*Tetrapleura tetraptera*	61.3
	4	4.5	*Newbouldia levis*	34.2
5	1	4.8	*Sensepalum duleificum*	11.4
	2	3.9	*Adansonia digitata*	68.3
	3	2.3	*Irvingia gabonensis*	41.5
	4	18.4	*Parkia biglobosa*	34.5
Total		229.2		

Appendix 14

ODENGWU COMMUNITY FOREST IGBARIAM STRATA 2

Sampling Point	Quarter No	Distance (m)	Species encountered	Diameter at base (cm)
1	1	10.8	*Melicia excelsa*	66.4
	2	6.3	*Pterocarpus spp*	23.1
	3	5.1	*Ceiba pentandra*	75.4
	4	6.1	*Nauclea latifolia*	18.3
2	1	3.8	*Newbouldia levis*	25.1
	2	14.6	*Tetrapleura tetraptera*	48.3
	3	20.5	*Parkia biglobosa*	33.6
	4	18.6	*Ficus capensis*	28.3
3	1	16.6	*Elaise guineense*	26.3
	2	14.3	*Buchholzia coriaceae*	33.4
	3	25.1	*Enantia chllorantha*	44.6
	4	18.5	*Milletia zachiana*	38.7
4	1	10.8	*Afzelia africana*	84.3
	2	14.1	*Newbouldia levis*	28.4
	3	17.8	*Ceiba pentandra*	66.1
	4	16.3	*Hildegardia barteti*	43.2
5	1	4.5	*Irvingia gabonensis*	10.2
	2	8.9	*Piptadeniastrum africana*	25.3
	3	11.4	*Pterocarpus spp*	28.4
	4	13.3	*Borassus aethiopicum*	48.1
Total		257.4		

Appendix 15

ODENGWU COMMUNITY FOREST IGBARIAM STRATA 3

Sampling Point	Quarter No	Distance (m)	Species encountered	Diameter at base (cm)
1	1	10.8	*Elaeis guineense*	26.3
	2	14.9	*Irvingia gaboneensis*	38.2
	3	8.5	*Delonix regia*	45.6
	4	6.4	*Syzigium guineense*	23.1
2	1	13.1	*Parkia bigbobosa*	18.3
	2	16.4	*Myrianthus arboreus*	16.4
	3	3.8	*Datarium microcarpium*	38.9
	4	10.5	*Gambeya albida*	65.1
3	1	6.1	*Adansonia digitata*	68.3
	2	8.4	*Ceiba pentandra*	59.1
	3	13.5	*Ficus exasperata*	33.4
	4	17.1	*Pterocaspus spp*	24.6
4	1	16.5	*Dacroydes edulis*	19.6
	2	14.6	*Newbouldia laevis*	26.4
	3	18.1	*Prosopia africana*	33.9
	4	25.2	*Parkia biglobosa*	17.1
5	1	20.1	*Rauvolfia vomitoria*	8.1
	2	18.3	*Daniella oliveri*	20.3
	3	9.5	*Vitex doniana*	31.6
	4	11.6	*Irvingia gabonensis*	11.4
Total		263.4		

Appendix 16

ODENGWU COMMUNITY FOREST IGBARIAM STRATA 4

Sampling Point	**Quarter No**	**Distance (m)**	**Species encountered**	**Diameter at base (cm)**
1	1	8.9	*Pterocarpus spp*	24.5
	2	10.5	*Newbouldia levis*	35.3
	3	7.2	*Ceiba pentandra*	51.8
	4	3.5	*Petaclethra macrphylla*	67.3
2	1	3.8	*Gambeya albida*	44.1
	2	4.9	*Dacroydes edulis*	48.3
	3	10.6	*Tetrapleuara tetraptera*	63.2
	4	12.1	*Hildegardia barteri*	75.6
3	1	13.8	*Irvingia gabonensis*	43.4
	2	18.5	*Elaise guineense*	23.5
	3	16.4	*Anthocleista djalonensis*	18.1
	4	12.5	*Afzelia africana*	67.0
4	1	12.8	*Delonix regia*	10.6
	2	8.3	*Syzigium guineense*	18.3
	3	11.3	*Parkia biglobosa*	13.5
	4	5.5	*Newbouldia laevis*	16.9
5	1	4.4	*Pterocarpus spp*	32.6
	2	5.5	*Spondias mombin*	28.3
	3	6.8	*Dacroydes edulis*	38.5
	4	9.8	*Afzelia africana*	69.4
Total		187.1		

Appendix 17

MAMU FOREST RESERVE STRATA 1

Sampling Point	Quarter No	Distance (m)	Species encountered	Diameter at base (cm)
1	1	6.8	*Tectona grandis*	22.3
	2	10.5	*Gmelina spp*	18.5
	3	15.4	*Adansonia digitata*	45.5
	4	11.6	*Prosopis africana*	34.1
2	1	12.5	*Irvingia gabonensis*	36.3
	2	8.9	*Ceiba pentandra*	44.4
	3	4.1	*Tectona grandis*	55.3
	4	13.3	*Newbouldia laevis*	38.1
3	1	7.9	*Daniella oliveri*	35.3
	2	10.8	*Ficus spp*	30.1
	3	12.1	*Vitex doniana*	45.3
	4	9.5	*Dacroydes edulis*	45.6
4	1	8.9	*Tectona grandis*	18.1
	2	15.3	*Gmelina aborea*	65.6
	3	13.2	*Parkia biglobosa*	33.4
	4	6.9	*Vitex doniana*	28.1
5	1	3.5	*Tectona grandis*	44.1
	2	5.2	*Gmelina aborea*	30.3
	3	8.7	*Vitex doniana*	18.3
	4	6.3	*Daniella oliveri*	22.5
Total		191.4		

APPENDIX 18

MAMU FOREST RESERVE STRATA 2

Sampling Point	Quarter No	Distance (m)	Species encountered	Diameter at base (cm)
1	1	4.8	*Tectona grandis*	20.1
	2	6.9	*Gmelina arborea*	33.6
	3	3.8	*Milletia thoningii*	44.8
	4	4.1	*Daniella oliveri*	28.3
2	1	10.9	*Gmelina arborea*	36.3
	2	8.5	*Tectona grandis*	25.1
	3	9.9	*Melicia excelsa*	66.3
	4	7.5	*Daniella oliveri*	39.7
3	1	16.4	*Daniella oliveri*	56.3
	2	8.3	*Tectona grandis*	44.5
	3	12.5	*Vitex doniana*	48.3
	4	13.5	*Pterocarpus spp*	39.5
4	1	17.9	*Myrianthus arboreus*	35.8
	2	14.4	*Dialium guineens*	44.1
	3	8.8	*Tectona grandis*	28.3
	4	6.3	*Gmelina arborea*	25.4
5	1	8.9	*Enantia chlorantha*	38.6
	2	13.3	*Afzelia africana*	68.3
	3	9.1	*Tectona grandis*	30.3
	4	16.3	*Ficus capensis*	33.6
Total		202.1		

APPENDIX 19

MAMU FOREST RESERVE STRATA 3

Sampling Point	Quarter No	Distance (m)	Species encountered	Diameter at base (cm)
1	1	7.8	*Tectona grandis*	8.5
	2	6.5	*Gmelina arborea*	10.4
	3	18.2	*Ceiba pentandra*	28.6
	4	25.8	*Rauvolfia vomitoria*	23.4
2	1	3.8	*Tectona grandis*	6.5
	2	4.6	*Gmelina arborea*	8.8
	3	6.9	*Daniella oliveri*	5.9
	4	10.8	*Pentaclethra machrophyla*	12.3
3	1	26.5	*Enantia chlorantha*	39.0
	2	12.9	*Gmelina arborea*	25.6
	3	22.8	*Elais guineense*	18.4
	4	10.3	*Tectona grandis*	9.9
4	1	19.5	*Hildegardia barteri*	44.8
	2	16.9	*Dialium guineense*	56.3
	3	10.7	*Tectona grandis*	18.1
	4	7.8	*Gmelina arborea*	12.3
5	1	12.9	*Melicia excelsa*	78.5
	2	10.3	*Adansonia digitata*	67.6
	3	18.5	*Sensepalum dulcipficum*	48.1
	4	15.6	*Anthocleista djalonensis*	33.5
Total		269.1		

APPENDIX 20

MAMU FOREST RESERVE STRATA 4

Sampling Point	Quarter No	Distance (m)	Species encountered	Diameter at base (cm)
1	1	6.3	*Daniella oliveri*	13.0
	2	4.5	*Gmelina arborea*	16.5
	3	5.8	*Tectona grandis*	10.3
	4	3.9	*Adansonia digitata*	16.9
2	1	8.3	*Borassus acthiopicum*	28.3
	2	12.9	*Pterocarpus spp*	56.4
	3	16.4	*Pentaclethra macrophylla*	74.8
	4	12.6	*Daniella oliveri*	45.7
3	1	10.8	*Tectona grandis*	13.8
	2	28.5	*Newbouldia levis*	18.7
	3	13.4	*Daniella oliveri*	9.5
	4	18.6	*Gmelina arborea*	10.3
4	1	21.8	*Gambeya albida*	58.4
	2	18.9	*Datarium microcarpium*	45.5
	3	28.2	*Chlorophora excelsa*	70.5
	4	22.5	*Elais guineense*	28.3
5	1	10.2	*Sensepalum dulcificum*	33.4
	2	13.6	*Ptesocarpus spp*	55.6
	3	19.3	*Dacroydes edulis*	46.5
	4	14.6	*Irvingia gabonensis*	56.1
Total		291.1		

APPENDIX 21

NGENE SHRINE FOREST, STRATA 1

Sampling Point	Quarter No	Distance (m)	Species encountered	Diameter at base (cm)
1	1	25.6	*Adansonia digitata*	66.3
	2	18.4	*Ficuss spp*	30.1
	3	22.9	*Irvingia gabonensis*	38.2
	4	20.5	*Spondias mombin*	28.5
2	1	18.9	*Dacroydes edulis*	18.1
	2	16.6	*Adansonia digitata*	67.2
	3	19.4	*Pterocarpus spp*	41.3
	4	26.5	*Melicia exelsa*	71.4
3	1	31.5	*Gambeya albida*	48.5
	2	35.4	*Ceiba pentandra*	42.2
	3	30.5	*Datarium microcapium*	40.1
	4	26.4	*Chlorophora exelsa*	61.3
4	1	33.3	*Dacroydes edulis*	38.1
	2	26.9	*Ceiba pentandra*	49.2
	3	10.8	*Spondias mombin*	33.3
	4	9.1	*Dacroydes edulis*	28.5
5	1	15.6	*Ficus spp*	16.1
	2	19.4	*Duchholzia coriaceae*	26.3
	3	18.5	*Enantia chlorantha*	38.9
	4	27.4	*Newbouldia lavis*	25.5
Total		453.6		

APPENDIX 22

NGENE SHRINE FOREST STRATA 2

Sampling Point	**Quarter No**	**Distance (m)**	**Species encountered**	**Diameter at base (cm)**
1	1	16.6	*Newbouldia lavis*	18.3
	2	13.4	*Irvingia gabonensis*	16.4
	3	8.9	*Ficus spp*	10.1
	4	10.1	*Pterocarpus spp*	23.5
2	1	12.5	*Newbouldia lavis*	28.4
	2	10.6	*Spondias mombin*	33.8
	3	13.8	*Dacroydes edulis*	39.6
	4	8.5	*Adansonia digitata*	69.1
3	1	4.9	*Melicia excelsa*	76.2
	2	8.6	*Pterocapus spp*	56.0
	3	14.9	*Gambeya albida*	66.1
	4	18.4	*Dialium guineens*	23.4
4	1	13.5	*Elaise guineens*	28.3
	2	16.8	*Rauvolfia vomitoria*	39.1
	3	18.3	*Myrianthus arboreus*	44.6
	4	28.5	*Delonix regia*	29.5
5	1	19.6	*Newbouldia lavis*	34.9
	2	14.8	*Spondias mombin*	18.3
	3	10.9	*Pterocapus spp*	45.1
	4	8.4	*Melicia excelsa*	55.5
Total		272		

APPENDIX 23

NGENE SHRINE FOREST, STRATA 3

Sampling Point	Quarter No	Distance (m)	Species encountered	Diameter at base (cm)
1	1	6.5	*Spondias mombin*	16.8
	2	10.9	*Newbouldia lavis*	27.1
	3	4.7	*Gambeya albida*	49.3
	4	8.6	*Ceiba pentandra*	55.8
2	1	12.8	*Parkia biglobosa*	38.2
	2	15.3	*Enantia chlorantha*	29.6
	3	10.4	*Pterocapus spp*	48.6
	4	9.6	*Ficus spp*	37.3
3	1	6.6	*Prosopia africana*	43.4
	2	9.3	*Delonix regia*	56.3
	3	12.4	*Dalium guineense*	29.1
	4	2.8	*Ceiba pentandra*	66.5
4	1	3.9	*Irvingia gabonensis*	48.2
	2	4.5	*Hildegardia barteri*	54.3
	3	2.3	*Monodora myristica*	39.5
	4	7.4	*Melicia excelsa*	58.0
5	1	2.8	*Newbouldia lavis*	37.6
	2	3.1	*Afzelia africana*	67.3
	3	13.4	*Ficus capensis*	34.4
	4	10.5	*Irvingia gabonensis*	30.5
Total		157.8		

APPENDIX 24

NGENE SHRINE FOREST, STRATA 4

Sampling Point	Quarter No	Distance (m)	Species encountered	Diameter at base (cm)
1	1	10.3	*Ficus exasperata*	18.3
	2	11.5	*Newbouldia lavis*	23.5
	3	8.6	*Irvingia gabonensis*	36.1
	4	9.5	*Dacroydes edulis*	38.0
2	1	10.5	*Melicia excelsa*	39.2
	2	3.4	*Afzelia africana*	33.1
	3	6.8	*Parkia biglobosa*	28.5
	4	8.5	*Delonix regia*	34.6
3	1	5.5	*Elais guinensis*	28.6
	2	6.5	*Buchholzia coriaceae*	39.5
	3	7.8	*Ceiba pentandra*	44.3
	4	3.9	*Afzelia africana*	65.1
4	1	6.6	*Monodora myristica*	29.5
	2	7.8	*Spondias mombin*	23.4
	3	4.4	*Newbouldia lavis*	36.1
	4	6.5	*Parkia biglobosa*	43.3
5	1	3.4	*Elais guineense*	30.1
	2	3.8	*Datarium microcarpium*	45.0
	3	4.5	*Sensepalum dulcificum*	38.9
	4	6.4	*Enantia chlorantha*	50.1
Total		136.2		

APPENDIX 25

ACHALA FOREST RESERVE STRATA 1

Sampling Point	**Quarter No**	**Distance (m)**	**Species encountered**	**Diameter at base (cm)**
1	1	2.5	*Vitex doniana*	10.3
	2	4.8	*Daniella oliveri*	8.1
	3	5.3	*Gmelina arborea*	6.4
	4	3.6	*Tectona grandis*	3.4
2	1	4.3	*Tectona grandis*	6.8
	2	8.6	*Irvingia gabonensis*	12.5
	3	3.8	*Draecena arborea*	10.6
	4	3.4	*Milletia zachiana*	12.5
3	1	10.5	*Adonsonia digitata*	68.9
	2	2.8	*Tectona grandis*	21.5
	3	3.5	*Ciba pentandra*	16.4
	4	2.9	*Tetrapleura tetrapera*	10.1
4	1	2.8	*Gmelina arborea*	8.4
	2	4.9	*Tectona grandis*	6.3
	3	3.5	*Ceiba pentandra*	35.8
	4	3.8	*Vitex doniana*	19.6
5	1	4.3	*Melicia excelsa*	76.5
	2	7.6	*Tetrapleura tetraptera*	50.1
	3	6.2	*Tectona grandis*	11.3
	4	5.5	*Irvingia gabonesis*	23.4
Total		94.6		

APPENDIX 26

ACHALA FOREST RESERVE STRATA 2

Sampling Point	Quarter No	Distance (m)	Species encountered	Diameter at base (cm)
1	1	3.5	*Gmelina arborea*	15.6
	2	3.6	*Tectona grandis*	10.1
	3	4.7	*Gmelina arborea*	12.3
	4	5.8	*Tectona grandis*	4.5
2	1	4.3	*Daniella oliveri*	27.8
	2	8.6	*Melicia excilsa*	64.9
	3	3.8	*Tectona grandis*	10.1
	4	3.4	*Gmeliina arborea*	24.7
3	1	3.9	*Irvingia gabonensis*	18.3
	2	4.5	*Draecena aborea*	28.1
	3	2.8	*Milletia zachiana*	26.3
	4	3.1	*Ceiba pentandra*	46.1
4	1	4.8	*Gmelina arborea*	38.7
	2	2.9	*Tectona grandis*	6.4
	3	3.1	*Ceiba pentandra*	10.6
	4	4.1	*Vitex doniana*	29.3
5	1	3.8	*Tectona grandis*	13.4
	2	6.4	*Gmelina arborea*	18.5
	3	8.5	*Adansonia digitata*	48.6
	4	3.6	*Vitex doniana*	33.2
Total		89.2		

APPENDIX 27

ACHALA FOREST RESERVE STRATA 3

Sampling Point	**Quarter No**	**Distance (m)**	**Species encountered**	**Diameter at base (cm)**
1	1	4.3	*Gmelina arborea*	13.8
	2	3.8	*Daniella oliveri*	8.1
	3	2.5	*Gmelina arborea*	16.3
	4	3.1	*Tectona grandis*	19.4
2	1	3.6	*Gmelina arborea*	47.1
	2	3.4	*Draecena arborea*	28.3
	3	6.5	*Tectona grandis*	33.4
	4	7.1	*Tetrapleura tetraptera*	44.6
3	1	9.3	*Ceiba pentandra*	66.5
	2	3.4	*Tectona grandis*	16.3
	3	5.5	*Gmelina arborea*	18.4
	4	3.6	*Milletia thorningii*	39.7
4	1	5.5	*Irvingia gabonensis*	49.3
	2	6.4	*Tetrapleura tetraptera*	68.5
	3	3.8	*Vitex doniana*	36.1
	4	4.4	*Daniella oliveri*	28.3
5	1	4.8	*Melicia excelsa*	39.9
	2	3.9	*Adonsonia digitata*	45.4
	3	6.1	*Tectona grandis*	10.1
	4	8.5	*Daniella oliveri*	12.3
Total		99.5		

APPENDIX 28

ACHALA FOREST RESERVE STRATA 4

Sampling Point	**Quarter No**	**Distance (m)**	**Species encountered**	**Diameter at base(cm)**
1	1	3.5	*Gmelina arborea*	16.3
	2	6.9	*Tectona grandis*	23.5
	3	2.7	*Adonsonia digitata*	45.6
	4	7.3	*Tetrapleura tetraptera*	68.8
2	1	3.5	*Tectona grandis*	8.1
	2	6.1	*Tectona grandis*	10.8
	3	4.3	*Vitex doniana*	34.1
	4	3.9	*Daniella oliveri*	28.3
3	1	2.9	*Tectona grandis*	16.4
	2	8.4	*Gmelina arborea*	11.3
	3	6.5	*Irvingia gabonensis*	33.4
	4	9.1	*Melicia excelsa*	58.3
4	1	3.4	*Tectona grandis*	18.9
	2	2.5	*Gmelina arborea*	12.3
	3	2.5	*Tectona grandis*	6.5
	4	10.1	*Melicia excelsa*	44.8
5	1	3.6	*Tectona grandis*	20.6
	2	4.7	*Irvingia gabonensis*	37.8
	3	8.6	*Gmelina arborea*	10.3
	4	6.1	*Daniela oliveri*	8.4
Total		106.6		

APPENDIX 29

IYI-OCHA SHRINE FOREST STRATA 1

Sampling Point	Quarter No.	Distance (m)	Species	Diameter at base (cm)
1	1	6.8	*Spondias mombin*	20.6
	2	4.3	*Newbouldia levis*	27.3
	3	10.4	*Ficus exasperata*	18.4
	4	13.1	*Dialium guineense*	16.2
2	1	2.8	*Piptadeniastrum africana*	41.6
	2	4.3	*Aubrevillea kerstingii*	37.3
	3	3.1	*Nauclean latifolia*	41.0
	4	5.5	*Delonix regia*	31.3
3	1	5.1	*Pterocarpus spp*	34.6
	2	6.4	*Dacroydes edulis*	44.3
	3	10.3	*Gambeya albida*	56.1
	4	12.1	*Syzigium guineense*	43.6
4	1	3.8	*Borassus aetheopicum*	31.7
	2	6.9	*Delonix regia*	28.3
	3	3.1	*Parkia biglobosa*	25.3
	4	4.3	*Pterocarpus spp*	34.5
5	1	4.1	*Newbouldia levis*	37.8
	2	3.9	*Adonsonia digitata*	67.9
	3	6.8	*Melicia excelsa*	78.4
	4	15.6	*Nauclea latofolia*	28.1
Total		121.2		

APPENDIX 30

IYI-OCHA SHRINE FOREST STRATA 2

Sampling Point	Quarter No.	Distance (m)	Species Encountered	Diameter at base (cm)
1	1	3.6	*Ficus carpensis*	19.5
	2	4.3	*Newbouldia levis*	16.0
	3	3.9	*Anthocleista djalonensis*	33.6
	4	5.8	*Enantia chlorantha*	25.9
2	1	3.9	*Parkia biglobosa*	45.6
	2	6.8	*Dacroydes edulis*	40.5
	3	8.9	*Syzigium guineense*	38.7
	4	7.5	*Newbouldia levis*	45.3
3	1	2.9	*Newbouldia levis*	28.5
	2	3.4	*Irvingia gabonensis*	36.1
	3	5.8	*Syzigium guineense*	39.3
	4	6.9	*Delonix regia*	40.5
4	1	10.5	*Delonix regia*	39.6
	2	3.1	*Pterocarpus spp*	46.1
	3	9.3	*Nauclea latifolia*	22.3
	4	8.5	*Aubrevillea kerstingii*	19.5
5	1	6.8	*Buchholzia coriaceae*	23.5
	2	7.1	*Piptadeniastrum africana*	36.0
	3	10.3	*Aubrevillea kerstingii*	18.8
	4	8.4	*Newbouldia laevis*	23.6
Total		127.7		

APPENDIX 31

IYI-OCHA SHRINE FOREST STRATA 3

Sampling Point	**Quarter No.**	**Distance (m)**	**Species Encountered**	**Diameter at base (cm)**
1	1	8.3	*Spondias mombin*	39.1
	2	4.5	*Ficus exasperata*	37.4
	3	6.9	*Pterocarpus spp*	44.8
	4	3.8	*Newbouldia laevis*	28.3
2	1	2.9	*Newbouldia laevis*	38.1
	2	4.4	*Dacroydes edulis*	41.6
	3	1.9	*Pterocapus spp*	55.3
	4	3.6	*Gambeya albida*	58.4
3	1	10.8	*Syzigium guineense*	28.1
	2	4.9	*Delonix regia*	23.5
	3	5.8	*Newbouldia laevis*	21.3
	4	6.3	*Pterocapus spp*	38.1
4	1	4.3	*Nauclea latifolia*	18.6
	2	3.8	*Borassus aethiopicum*	23.7
	3	6.1	*Ficus exasperata*	16.3
	4	8.5	*Melicia excelsa*	68.5
5	1	6.1	*Dacroydes edulis*	55.1
	2	9.1	*Monodora myristica*	37.2
	3	3.4	*Irvingia gabonensis*	25.4
	4	5.5	*Newbouldia levis*	26.8
Total		110.9		

APPENDIX 32

IYI-OCHA SHRINE FOREST STRATA 4

Sampling Point	**Quarter No.**	**Distance (m)**	**Species Encountered**	**Diameter at base (cm)**
1	1	6.3	*Melicia excelsa*	56.3
	2	4.1	*Spondias mombin*	23.6
	3	3.5	*Newbouldia levis*	18.9
	4	2.9	*Delonix regia*	20.8
2	1	3.8	*Borassus aetheopicum*	29.4
	2	4.1	*Parkia biglobosa*	25.6
	3	11.1	*Newbouldia levis*	36.3
	4	5.6	*Ficus exasperata*	16.8
3	1	2.8	*Pterocarpus spp*	38.6
	2	3.1	*Dacroydes edulis*	44.6
	3	6.8	*Syzigium guineense*	59.6
	4	4.4	*Irvingia gabonensis*	45.3
4	1	4.8	*Anthocleista djalonensis*	33.6
	2	6.1	*Hildegardia barteri*	43.0
	3	3.5	*Ficus carpensis*	30.5
	4	5.5	*Newbouldia laevis*	29.5
5	1	2.5	*Hildegardia barteri*	40.6
	2	3.8	*Irvingia garbonensis*	46.7
	3	3.1	*Nauclea latifolia*	37.5
	4	3.6	*Delonix regia*	28.3
Total		91.4		

APPENDIX 33

UNENZU COMMUNITY FOREST STRATA 1

Sampling Point	Quarter No.	Distance (m)	Species encountered	Diameter at base (cm)
1	1	18.9	*Anacardium ocidentalis*	34.1
	2	13.3	*Daniella oliveri*	43.6
	3	15.6	*Spondias mombin*	26.3
	4	12.8	*Dacroydes edulis*	37.7
2	1	17.4	*Ficus exasperata*	21.5
	2	10.6	*Gambeya albida*	48.3
	3	13.9	*Irvingia gabonensis*	41.5
	4	10.5	*Dacroydes edulis*	38.7
3	1	10.6	*Newbouldia levis*	30.0
	2	12.7	*Vitex doniana*	27.6
	3	18.3	*Borassus aetheopicum*	16.4
	4	8.9	*Prosopis africana*	13.1
4	1	13.4	*Delonix regia*	28.2
	2	9.7	*Anacardium oceidentalis*	32.6
	3	9.9	*Dalium guineense*	44.7
	4	10.2	*Elacis guineense*	23.4
5	1	6.5	*Anacardium occidentalis*	16.3
	2	10.8	*Buchholzia coriacea*	18.4
	3	11.3	*Dacroydis edulis*	10.5
	4	6.7	*Athocleista djalonensis*	16.1
Total		247		

APPENDIX 34

UNENZU COMMUNITY FOREST STRATA 2

Sampling Point	Quarter No.	Distance (m)	Species Encountered	Diameter at base (cm)
1	1	15.8	*Gambeya albida*	45.6
	2	13.4	*Pantaclethra macrophylla*	56.1
	3	15.5	*Ceiba Pentandra*	46.2
	4	12.3	*Dacroydes edulis*	33.4
2	1	7.8	*Anacardium occidentalis*	39.4
	2	3.9	*Ficus spp*	24.5
	3	14.5	*Pterocarpus spp*	33.1
	4	12.2	*Melicia excelsa*	67.2
3	1	10.1	*Pterocarpus spp*	26.5
	2	22.5	*Newbouldia levis*	18.2
	3	18.3	*Monodora myristica*	19.3
	4	16.4	*Elaise guineense*	22.3
4	1	19.3	*Datalium microcarpium*	36.1
	2	20.1	*Daniella oliveri*	44.3
	3	9.1	*Hildegardia barteri*	41.6
	4	12.5	*Spondias mombin*	37.8
5	1	13.8	*Ceiba pentandra*	59.7
	2	17.4	*Tetrapleura tetraptera*	55.3
	3	19.5	*Dialium guinerense*	28.9
	4	8.8	*Dracena arborea*	27.1
Total		283.2		

APPENDIX 35

UNENZU COMMUNITY FOREST STRATA 3

Sampling Point	Quarter No.	Distance (m)	Species Encountered	Diameter at base (cm)
1	1	7.4	*Irvingia gabonensis*	33.4
	2	9.5	*Monodora myrtistica*	29.1
	3	6.8	*Spondians mombin*	37.6
	4	10.6	*Vitex doniana*	41.5
2	1	13.8	*Newbouldia laevis*	38.1
	2	10.9	*Pterocapus spp*	34.3
	3	4.8	*Irvingia gabonensis*	29.5
	4	7.3	*Pterocapus spp*	26.4
3	1	3.8	*Anacardium occidentalis*	10.4
	2	4.3	*Datarium macrocarpium*	18.1
	3	8.4	*Dacroydes edulis*	27.6
	4	9.9	*Milletia zechiana*	34.3
4	1	4.5	*Nauclea latifolia*	45.6
	2	8.6	*Afzelia africana*	75.8
	3	6.3	*Newbouldia laevis*	48.3
	4	7.9	*Ficus capensis*	49.2
5	1	5.8	*Pterocapus spp*	39.2
	2	3.9	*Rauvolfia vomitoria*	55.4
	3	8.2	*Delonix regia*	66.1
	4	10.3	*Prosopis africana*	61.3
Total		153		

APPENDIX 36

UNENZU COMMUNITY FOREST STRATA 4

Sampling Point	Quarter No.	Distance (m)	Species Encountered	Diameter at base (cm)
1	1	10.3	*Newbouldia laevis*	44.6
	2	6.5	*Prosopis africana*	35.2
	3	9.4	*Pterocarpus spp*	55.4
	4	12.8	*Daniella oliveri*	65.3
2	1	9.2	*Dacroydes edulis*	38.1
	2	7.7	*Spondias mombin*	35.3
	3	13.6	*Ficus spp*	28.5
	4	4.8	*Irvingia gabonensis*	45.6
3	1	11.4	*Irvingia gabonensis*	45.6
	2	16.2	*Borassus aethiopicum*	40.1
	3	8.3	*Parkia biglobosa*	38.3
	4	5.6	*Vitex doniana*	56.9
4	1	8.8	*Anthocleista djalonensis*	71.5
	2	9.1	*Dracena arborea*	45.6
	3	13.5	*Afzelia africana*	88.3
	4	9.5	*Nauclea latifolia*	66.4
5	1	7.6	*Afzelia africana*	61.6
	2	10.4	*Ficus spp*	28.1
	3	6.6	*Newbouldia laevis*	21.5
	4	8.5	*Pterocarpus spp*	33.4
Total		189.8		

APPENDIX 37

SAMPLE COMPUTATION OF DATA

Osomari East Forest Reserve: Strata I

Total Distance = 314.4m

Mean Distance = $\frac{314.4}{20}$ = 15.72m

Absolute Density = $\frac{Area}{D^2}$

Where D = Mean Distance

Number of trees per $100m^2$ = $^{100}/_{(15.72)^2}$ = $^{100}/_{247.1}$ = 0.40

Absolute Dominance = Mean BA per tree x no of tree in spp

No of tree in Species =

Table 1: Calculation of Density

Species	**No in Quarters**	**Densities**
Beitschemeidia manii	$^1/_{20}$ = 0.05	0.05 x 0.40 = 0.02
Tectona grandis	$^3/_{20}$ = 0.15	0.15 x 0.40 = 0.06
Gmelina arborea	$^6/_{20}$ = 0.3	0.3 x 0.40 = 0.12
Datarium microcapium	$^1/_{20}$ = 0.05	0.05 x 0.40 = 0.02
Daniella oliveri	$^2/_{20}$ = 0.1	0.1 x 0.40 = 0.02
Vitex doniana	$^1/_{20}$ = 0.05	0.05 x 0.40 = 0.02
Parkia biglobosa	$^1/_{20}$ = 0.05	0.05 x 0.40 = 0.02
Melicia excels	$^1/_{20}$ = 0.05	0.05 x 0.40 = 0.02
Adansonia digitata	$^1/_{20}$ = 0.05	0.05 x 0.40 = 0.02
Hildegardia barteri	$^1/_{20}$ = 0.05	0.05 x 0.40 = 0.02
Enantia chlorantha	$^1/_{20}$ = 0.05	0.05 x 0.40 = 0.02
Dracena arborea	$^1/_{20}$ = 0.05	0.05 x 0.40 = 0.02
Total Density		**0.40**

Table 2: Calculation of Relative Density

Relative Density = $\frac{\text{No of individual density of a sp}}{\text{Total density of a spp}} \times \frac{100}{1}$

Species		Rel. density
Beitschemeidia manii	$^{0.02}/_{0.40} \times {}^{100}/_{1}$	5%
Tectona grandis	$^{0.06}/_{0.40} \times {}^{100}/_{1}$	15%
Gmelina arborea	$^{0.12}/_{0.40} \times {}^{100}/_{1}$	30%
Datarium microcarpium	$^{0.02}/_{0.40} \times {}^{100}/_{1}$	5%
Daniella oliveri	$^{0.04}/_{0.40} \times {}^{100}/_{1}$	10%
Vitex doniana	$^{0.02}/_{0.40} \times {}^{100}/_{1}$	5%
Parkia biglobosa	$^{0.02}/_{0.40} \times {}^{100}/_{1}$	5%
Melicia excels	$^{0.02}/_{0.40} \times {}^{100}/_{1}$	5%
Adansonia digitata	$^{0.02}/_{0.40} \times {}^{100}/_{1}$	5%
Hildegardia barteri	$^{0.02}/_{0.40} \times {}^{100}/_{1}$	5%
Enantia chlorantha	$^{0.02}/_{0.40} \times {}^{100}/_{1}$	5%
Draecena arborea	$^{0.02}/_{0.40} \times {}^{100}/_{1}$	5%
Total		**100%**

Table 3: Mean Basal Area by spp for the 20 Trees

Beischlemeidia manii		*Tectona grandis*		*Gmelinaar borea*		*Datarium microcapium*		*Daniella oliveri*		*Vitex doniana*		*Parki biglobosa*		*Melicia excelsa*		*Adansonia digitata*		*Hildagardia Barteri*		*Enantia chlorantha*		*Dracena arborea*	
Diameter (cm)	**BA (cm^2)**	**Diameter (cm)**	**BA (cm^2)**	**Diameter (cm)**	**BA (cm^2)**	**Diameter (cm)**	**BA (cm^2)**	**Diameter (cm)**	**BA (cm^2)**	**Diameter (cm)**	**BA (cm^2)**	**Diameter (cm)**	**BA (cm^2)**	**Diameter (cm)**	**BA (cm^2)**	**Diameter (cm)**	**BA (cm^2)**	**Diameter (cm)**	**BA (cm^2)**	**Diameter (cm)**	**BA (cm^2)**	**Diameter (cm)**	**BA (cm^2)**
48.3	1832	18.3	260	22.5	398	55.1	2385	38.4	1158	28.1	620	44.2	1535	62.3	3049	48.1	1817	40.3	1276	39.3	539	8.4	55
	-	12.3	119	16.4	211	-	-	25.5	511	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	10.9	93	18.1	257	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	16.5	214	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	30.0	707	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	28.1	620	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total BA	**1832**		**472**		**2207**		**2385**		**1669**		**620**		**1535**		**3049**		**1817**		**1276**		**539**		**55**
Mean BA	**1832**		**157**		**368**		**2385**		**835**		**620**		**1535**		**3049**		**1817**		**1276**		**539**		**55**

Table 4: Calculation of Dominance

Dominance = Density of each sp x Mean BA of that sp

Species				Dominance	Rank
Beitschlemeidia manii	=	1832 x 0.02	=	36.64cm^2	4
Tectona grandis	=	157 x 0.06	=	9.42cm^2	11
Gmelina arboria	=	368 x 0.12	=	44.16cm^2	3
Datarium microcarpium	=	2385 x 0.02	=	47.7cm^2	2
Daniella oliveri	=	835 x 0.04	=	33.4cm^2	6
Vitex doniana	=	620 x 0.02	=	12.4cm^2	9
Parkia biglobosa	=	1535 x 0.02	=	30.7cm^2	7
Melicia excelsa	=	3049 x 0.02	=	60.78cm^2	1
Adansonia digitata	=	1817 x 0.02	=	36.34cm^2	5
Hildegardia barteri	=	1276 x 0.02	=	25.52cm^2	8
Enantia chlorantha	=	539 x 0.02	=	10.78cm^2	10
Draecena arborea	=	55 x 0.02	=	1.1cm^2	12
Total Dominance	**=**	**348.94cm^2/100m^2**			

Table 5: dominance ranking

Dominance	Value	Ranks
Melicia excelsa	= 60.78cm^2	1
Datarium microcapium	= 47.7cm^2	2
Gmelina arborea	= 44.16cm^2	3
Beitschlemeidia manii	= 36.34cm^2	4
Adansonia digitata	= 36.34cm^2	5
Daniella oliveri	= 33.4cm^2	6
Parkia biglobosa	= 30.7cm^2	7
Hildegardia barteri	= 25.52cm^2	8
Vitex doniana	= 12.4cm^2	9
Enantia chlorantha	= 10.78cm^2	10
Tectona grandis	= 9.42 cm^2	11
Draecena arborea	= 1.1cm^2	12

Table 6: Calculation of Relative Dominance

$$\text{Relative Dominance} = \frac{\text{Dominance of a sp}}{\text{Total dominance of all spp}} \times \frac{100}{1}$$

Species		percentage dominance
Beitschlemeidia manii	$^{36.64}/_{348.94} \times {}^{100}/_{1}$	10.5%
Tectona grandis	$^{9.42}/_{348.94} \times {}^{100}/_{1}$	2.7%
Gmelina arborea	$^{44.16}/_{348.94} \times {}^{100}/_{1}$	12.7%
Datarium microcarpium	$^{47.7}/_{348.94} \times {}^{100}/_{1}$	13.7%
Daniella oliveri	$^{33.4}/_{348.94} \times {}^{100}/_{1}$	9.6%
Vitex doniana	$^{12.4}/_{348.94} \times {}^{100}/_{1}$	3.6%
Parkia biglobosa	$^{30.7}/_{348.94} \times {}^{100}/_{1}$	8.8%
Melicia excels	$^{60.78}/_{348.94} \times {}^{100}/_{1}$	17.4%
Adansonia digitata	$^{36.34}/_{348.94} \times {}^{100}/_{1}$	10.4%
Hildegardia barteri	$^{25.52}/_{348.94} \times {}^{100}/_{1}$	7.3%
Enantia chlorantha	$^{10.78}/_{348.94} \times {}^{100}/_{1}$	3.1%
Draecena arborea	$^{1.1}/_{348.94} \times {}^{100}/_{1}$	0.31%
Total		**100.1%**

Table 7: Calculation of Absolute Frequency

$$\text{Absolute Frequency} = \frac{\text{No of points with spp}}{\text{Total Points}} \times \frac{100}{1}$$

Species		**frequency**
Beitschemeidia manii	$^{1}/_{5} \times {}^{100}/_{1}$	20%
Tectona grandis	$^{3}/_{5} \times {}^{100}/_{1}$	60%
Gmelina arboria	$^{6}/_{5} \times {}^{100}/_{1}$	120%
Datarium microcarpium	$^{1}/_{5} \times {}^{100}/_{1}$	20%
Daniella oliveri	$^{2}/_{5} \times {}^{100}/_{1}$	40%
Vitex doniana	$^{1}/_{5} \times {}^{100}/_{1}$	20%
Parkia biglobosa	$^{1}/_{5} \times {}^{100}/_{1}$	20%
Melicia excels	$^{1}/_{5} \times {}^{100}/_{1}$	20%
Adansonia digitata	$^{1}/_{5} \times {}^{100}/_{1}$	20%
Hildegardia barteri	$^{1}/_{5} \times {}^{100}/_{1}$	20%
Enantia chlorantia	$^{1}/_{5} \times {}^{100}/_{1}$	20%
Draecena arborea	$^{1}/_{5} \times {}^{100}/_{1}$	20%
Total Frequency		**400%**

Table 8: Calculation of Relative Frequency

$$\text{Relative Frequency} = \frac{\text{Frequency of a sp}}{\text{Total Frequency of spp}} \times \frac{100}{1}$$

Species		Rel. frequency
Beitschlemeidia manii	$^{20}/_{500} \times {}^{100}/_{1}$	4%
Tectona grandis	$^{60}/_{500} \times {}^{100}/_{1}$	12%
Gmelina arboria	$^{120}/_{500} \times {}^{100}/_{1}$	24%
Datarium microcarpium	$^{20}/_{500} \times {}^{100}/_{1}$	4%
Daniella oliveri	$^{40}/_{500} \times {}^{100}/_{1}$	8%
Vitex doniana	$^{20}/_{500} \times {}^{100}/_{1}$	4%
Parkia biglobosa	$^{20}/_{500} \times {}^{100}/_{1}$	4%
Melicia excels	$^{20}/_{500} \times {}^{100}/_{1}$	4%
Adansonia digitata	$^{20}/_{500} \times {}^{100}/_{1}$	4%
Hildegardia barteri	$^{20}/_{500} \times {}^{100}/_{1}$	4%
Enantia chlorantha	$^{20}/_{500} \times {}^{100}/_{1}$	4%
Draecena arborea	$^{20}/_{500} \times {}^{100}/_{1}$	4%
Total		**78%**

Table 9: Importance value index (IVI) = Σ (all the relative values)

Species	Rel D.	Rel Dom	Rel Freg	IVI	IVI Rank
Beischlemeidia manii	5	10.5	4	19.5	6
Tectona grandis	15	2.7	12	29.7	2
Gmelina arborea	30	12.7	24	66.7	1
Datarium microcarpium	5	13.7	4	22.7	5
Daniella oliveri	10	9.6	8	27.6	3
Vitex doniana	5	3.6	4	12.6	10
Parkia biglobosa	5	8.8	4	17.8	8
Melicia excelsa	5	17.4	4	26.4	4
Adansonia digitata	5	10.4	4	19.4	7
Hildegardia barteri	5	7.3	4	16.3	9
Enantia chlorantha	5	3.1	4	12.1	11
Draecena arborea	5	0.3	4	9.3	12
Total					**12**

Species Diversity of the sample sites with Shanon Wiener Index

Ukpor community forest has high species diversity (3.555), with 35 number of plant species recorded in the forest. In Ukpor community forest, the dominant species are *Ceiba pentandra, Sarcocephalus latifolius* and *Pentaclethra macrophylla* (**Table 19)**

Table 19: Species Diversity of Ukpor Community Forest

Species	N	N	Pi	In(pi)	pi*In(pi)	-Σ(pi)*In(pi)
Adansonia digitata	3	80	0.0375	-3.28341	-0.12313	H^1=3.47176
Afzelia africana	2	80	0.025	-3.68888	-0.09222	
Aubrevillea kerstingii	1	80	0.0125	-4.38203	-0.05478	H_{max}= Ins (ln35)
Anthocleista djalonensis	2	80	0.025	-3.68888	-0.09222	3.55535
Beitsclemeidia manii	1	80	0.0125	-4.38203	-0.05478	
Borassus aethiopicum	1	80	0.0125	-4.38203	-0.05478	
Buchholzia coriaceae	3	80	0.0375	-3.28341	-0.12313	
Ceiba pentandra	4	80	0.05	-2.99573	-0.14979	Equitability=
Melicia excelsa	1	80	0.0125	-4.38203	-0.05478	(H^1/H_{max})=
Gambeya albida	3	80	0.0375	-3.28341	-0.12313	0.97649
Dacroydes edulis	2	80	0.025	-3.68888	-0.09222	
Daniella oliveri	1	80	0.0125	-4.38203	-0.05478	
Datarium macrocarpium	3	80	0.0375	-3.28341	-0.12313	
Pointiana regia	3	80	0.0375	-3.28341	-0.12313	
Dialium guineense	1	80	0.0125	-4.38203	-0.05478	
Draecena arborea	2	80	0.025	-3.68888	-0.09222	
Enantia chlorantha	2	80	0.025	-3.68888	-0.09222	
Ficus exasperata	3	80	0.0375	-3.28341	-0.12313	
Hildegardia barteri	3	80	0.0375	-3.28341	-0.12313	
Irvingia gabonensis	3	80	0.0375	-3.28341	-0.12313	
Milletia thorningii	2	80	0.025	-3.68888	-0.09222	
Myranthus arboreus	3	80	0.0375	-3.28341	-0.12313	
Sarcocephalus latifolius	4	80	0.05	-2.99573	-0.14979	
Newboudia laevis	2	80	0.025	-3.68888	-0.09222	
Parkia biglobosa	2	80	0.025	-3.68888	-0.09222	
Pentaclethra macrophylla	4	80	0.05	-2.99573	-0.14979	
Piptadeniastrum africanum	2	80	0.025	-3.68888	-0.09222	
Prosopis africana	3	80	0.0375	-3.28341	-0.12313	
Pterocarpus sp	3	80	0.0375	-3.28341	-0.12313	
Rauvolfia vomitoria	1	80	0.0125	-4.38203	-0.05478	
Sensepalum dulcificum	2	80	0.025	-3.68888	-0.09222	
Spondias mombin	1	80	0.0125	-4.38203	-0.05478	
Syzigium guineense	2	80	0.025	-3.68888	-0.09222	
Tetrapleura tetraptera	2	80	0.025	-3.68888	-0.09222	
Vitex doniana	3	80	0.0375	-3.28341	-0.12313	
Total					**3.47176**	

Achala forest Reserve has species diversity of (2.485), the dominant species are *Tectona grandis* and *Gmelina arborea* (**Table 20)**

Table 20: Species Diversity of Achala Forest Reserve

Species	N	N	Pi	In(pi)	pi*In(pi)	-Σ(pi)*In(pi)
Adansonia digitata	4	80	0.05	-2.99573	-0.14979	H^1=2.16962
Melicia excelsa	5	80	0.0625	-2.77259	-0.17329	H_{max}= Ins (ln12)
Ceiba pentandra	4	80	0.05	-2.99573	-0.14979	2.48491
Daniella oliveri	5	80	0.0625	-2.77259	-0.17329	
Draecena arborea	3	80	0.0375	-3.28341	-0.12313	
Gmelina aborea	15	80	0.1875	-1.67398	-0.31387	Equitability=
Irvingia gabonensis	6	80	0.075	-2.59027	-0.19427	(H^1/H_{max})=
Milletia thorningii	2	80	0.025	-3.68888	-0.09222	0.87312
Milletia zechiana	2	80	0.025	-3.68888	-0.09222	
Tectona grandis	24	80	0.3	-1.20397	-0.36119	
Tetrapleura tetraptera	5	80	0.0625	-2.77259	-0.17329	
Vitex doniana	5	80	0.0625	-2.77259	-0.17329	
Total					**2.16962**	

Iyiocha shrine forest has species diversity of (2.892), the dominant species are *Newbouldia laevis, Pterocarpus sp* and *Pointiana regia* (**Table 21)**

Table 21: Species Diversity of Iyi-Ocha Shrine Forest

Species	N	N	Pi	In(pi)	pi*In(pi)	-Σ(pi)*In(pi)
Adansonia digitata	1	80	0.0125	-4.38203	-0.054775333	H^{1}=2.89221
Aubrevillea kerstingii	2	80	0.025	-3.68888	-0.092221986	
Anthocliesta djalonensis	2	80	0.025	-3.68888	-0.092221986	H_{max}= Ins (ln24)
Borassus aetheopicum	3	80	0.0375	-3.28341	-0.123128038	3.17805
Buchholzia coriaceae	1	80	0.0125	-4.38203	-0.054775333	
Melicia excelsa	3	80	0.0375	-3.28341	-0.123128038	
Gambeya albida	2	80	0.025	-3.68888	-0.092221986	Equitability=
Dacroydes edulis	5	80	0.0625	-2.77259	-0.173286795	(H^{1}/ H_{max})=
Pointiana regia	7	80	0.0875	-2.43612	-0.213160192	0.91006
Dialum guineense	1	80	0.0125	-4.38203	-0.054775333	
Enantia chlorantha	1	80	0.0125	-4.38203	-0.054775333	
Ficus carpensis	2	80	0.025	-3.68888	-0.092221986	
Ficus exasperata	4	80	0.05	-2.99573	-0.149786614	
Hildegardia barteri	2	80	0.025	-3.68888	-0.092221986	
Irvingia gabonensis	4	80	0.05	-2.99573	-0.149786614	
Monodora myrtstica	1	80	0.0125	-4.38203	-0.054775333	
Sarcocephalus latifolius	5	80	0.0625	-2.77259	-0.173286795	
Newbouldia laevis	14	80	0.175	-1.74297	-0.305019628	
Parkia biglobosa	3	80	0.0375	-3.28341	-0.123128038	
Piptadeniastrum africanum	2	80	0.025	-3.68888	-0.092221986	
Pterocarpus sp	8	80	0.1	-2.30259	-0.230258509	
Spondias mombin	3	80	0.0375	-3.28341	-0.123128038	
Syzigium guineense	3	80	0.0375	-3.28341	-0.123128038	
Total					**2.892209253**	

Ogugu- Nza shrine forest has species diversity of (3.229), the dominant species are *Newbouldia laevis, Pterocarpus* sp, *Gambeya albida, Afzelia africana, Dacroydes edulis, Ficus capensis, Irvingia gabonensis, Parkia biglobosa* and *Prosopis africana* (**Table 22)**

Table 22: Species Diversity of Ogugu-Nza Shrine Forest

Species	N	N	Pi	In(pi)	pi*In(pi)	-Σ(pi)*In(pi)
Adonsonia digitata	2	80	0.025	-3.68888	-0.092221986	H^1=3.22916
Afzelia africana	4	80	0.05	-2.99573	-0.149786614	
Anthocleista djalonensis	3	80	0.0375	-3.28341	-0.123128038	
Aubrevillea kerstingii	1	80	0.0125	-4.38203	-0.054775333	H_{max}= Ins (ln30)
Buchholzia coriaceae	1	80	0.0125	-4.38203	-0.054775333	3.40120
Ceiba pantandra	2	80	0.025	-3.68888	-0.092221986	
Melicia excelsa	3	80	0.0375	-3.28341	-0.123128038	
Gambeya albida	4	80	0.05	-2.99573	-0.149786614	
Dacroydes edulis	4	80	0.05	-2.99573	-0.149786614	Equitability=
Daniella oliveri	1	80	0.0125	-4.38203	-0.054775333	(H^1/ H_{max})=
Datarium microcarpium	1	80	0.0125	-4.38203	-0.054775333	0.94942
Poitiana regia	2	80	0.025	-3.68888	-0.092221986	
Dialium guineense	1	80	0.0125	-4.38203	-0.054775333	
Draecena arborea	2	80	0.025	-3.68888	-0.092221986	
Elaeis guineensis	1	80	0.0125	-4.38203	-0.054775333	
Enantia chlorantha	3	80	0.0375	-3.28341	-0.123128038	
Ficus capensis	4	80	0.05	-2.99573	-0.149786614	
Hildegardia barteri	3	80	0.0375	-3.28341	-0.123128038	
Irvingia gabonensis	4	80	0.05	-2.99573	-0.149786614	
Myrianthus arboreus	3	80	0.0375	-3.28341	-0.123128038	
Sarcocephalus latifolius	1	80	0.0125	-4.38203	-0.054775333	
Newbouldia laevis	9	80	0.1125	-2.1848	-0.245790231	
Parkia biglobosa	4	80	0.05	-2.99573	-0.149786614	
Pentaclethra macrophylla	2	80	0.025	-3.68888	-0.092221986	
Prosopis africana	4	80	0.05	-2.99573	-0.149786614	
Pterocarpus sp	4	80	0.05	-2.99573	-0.149786614	
Sensepalum dulcificum	1	80	0.0125	-4.38203	-0.054775333	
Spondias mombin	2	80	0.025	-3.68888	-0.092221986	
Syzigium guineense	3	80	0.0375	-3.28341	-0.123128038	
Tetraplura tetraptera	1	80	0.0125	-4.38203	-0.054775333	
Total					**3.229161283**	

Osomari forest Reserve has species diversity of (2.511), the dominant species are *Tectona grandis* and *Gmelina arborea* (**Table 23)**

Table 23: Species diversity of Osomari Forest Reserve

Species	**N**	**N**	**Pi**	**In(pi)**	**pi*In(pi)**	**-Σ(pi)*In(pi)**
Adansonia digitata	4	80	0.05	-2.99573	-0.14979	H^1=2.51078
Afzelia africana	1	80	0.0125	-4.38203	-0.05478	
Arithocleista djalonensis	1	80	0.0125	-4.38203	-0.05478	H_{max}= Ins (ln23)
Aubreillea kerstingii	1	80	0.0125	-4.38203	-0.05478	3.13549
Beistschlemeidia manii	4	80	0.05	-2.99573	-0.14979	
Borassus aethiopicum	1	80	0.0125	-4.38203	-0.05478	
Melicia excelsa	2	80	0.025	-3.68888	-0.09222	
Daniella oliveri	5	80	0.0625	-2.77259	-0.17329	Equitability=
Datarium macrophylla	3	80	0.0375	-3.28341	-0.12313	(H^1/ H_{max})=
Poitiana regia	1	80	0.0125	-4.38203	-0.05478	0.80076
Draecena arborea	3	80	0.0375	-3.28341	-0.12313	
Enantia chlorantha	2	80	0.025	-3.68888	-0.09222	
Gmelina arborea	24	80	0.3	-1.20397	-0.36119	
Hildegardia barteri	2	80	0.025	-3.68888	-0.09222	
Irvingia gabonensis	1	80	0.0125	-4.38203	-0.05478	
Milletia thoriningii	1	80	0.0125	-4.38203	-0.05478	
Sarcocephalus latifolius	1	80	0.0125	-4.38203	-0.05478	
Parkia biglobosa	3	80	0.0375	-3.28341	-0.12313	
Pentaclethra macrophylla	1	80	0.0125	-4.38203	-0.05478	
Piptadeniastrum africanum	1	80	0.0125	-4.38203	-0.05478	
Pterocarpus sp	1	80	0.0125	-4.38203	-0.05478	
Tectona grandis	14	80	0.175	-1.74297	-0.30502	
Vitex doniana	3	80	0.0375	-3.28341	-0.12313	
Total					**2.51078**	

Ngene shrine forest has species diversity of (3.258), the dominant species are *Newbouldia laevis, Pterocarpus* sp *Spondias mombin, Dacroydes edulis, Ficus capensis, Irvingia gabonensis, Melicia excelsa, Ceiba pantandra* (**Table 24)**

Table 24: Species Diversity of Ngene Shrine Forest

Species	**N**	**N**	**Pi**	**In(pi)**	**pi*In(pi)**	**-Σ(pi)*In(pi)**
Adansonia digitata	3	80	0.0375	-3.28341	-0.12313	H^1 =3.06798
Afzelia africana	3	80	0.0375	-3.28341	-0.12313	
Buchholzia coriaceae	2	80	0.025	-3.68888	-0.09222	H^1_{max}= Ins (ln26)
Ceiba pantandra	5	80	0.0625	-2.77259	-0.17329	3.25810
Melicia excelsa	6	80	0.075	-2.59027	-0.19427	
Gambeya albida	3	80	0.0375	-3.28341	-0.12313	
Dacroydes edulis	5	80	0.0625	-2.77259	-0.17329	Equitability=
Dialium guineense	2	80	0.025	-3.68888	-0.09222	(H^1 / H^1_{max})=
Datarium microcarpum	2	80	0.025	-3.68888	-0.09222	0.94165
Poitiana regia	3	80	0.0375	-3.28341	-0.12313	
Elaeis guineensis	3	80	0.0375	-3.28341	-0.12313	
Enantia chlorantha	3	80	0.0375	-3.28341	-0.12313	
Ficus exasperata	1	80	0.0125	-4.38203	-0.05478	
Ficus capensis	4	80	0.05	-2.99573	-0.14979	
Hildegardia barteri	1	80	0.0125	-4.38203	-0.05478	
Irvingia gabonensis	5	80	0.0625	-2.77259	-0.17329	
Monodora myristica	2	80	0.025	-3.68888	-0.09222	
Myrianthus arboreus	1	80	0.0125	-4.38203	-0.05478	
Newbouldia laevis	9	80	0.1125	-2.1848	-0.24579	
Parkia biglobosa	3	80	0.0375	-3.28341	-0.12313	
Prosopis africana	1	80	0.0125	-4.38203	-0.05478	
Pterocarpus sp	4	80	0.05	-2.99573	-0.14979	
Rauvolfia vomitoria	1	80	0.0125	-4.38203	-0.05478	
Sansepalum dulcificum	1	80	0.0125	-4.38203	-0.05478	
Spondias mombin	6	80	0.075	-2.59027	-0.19427	
Total					**3.06798**	

Unenzu Community Forest has high species diversity (3.258), In Unenzu community forest; the dominant species are *Anacardium occidentalis, Dacroydes edulis, Irvingia gabonensis, Newbouldia laevis* and *Pterocarpus sp* (**Table 25)**

Table 25: Species Diversity of Unenzu Community Forest

Species	N	N	Pi	In(pi)	pi*In(pi)	-Σ(pi)*In(pi)
Afzelia africana	3	80	0.0375	-3.28341	-0.12313	H^1 =3.25857
Anacardium occidentalis	5	80	0.0625	-2.77259	-0.17329	
Anthocleista djalonensis	2	80	0.025	-3.68888	-0.09222	H_{max}= Ins (ln31)
Borassus aethiopicum	2	80	0.025	-3.68888	-0.09222	3.43399
Buchholzia coriaceae	1	80	0.0125	-4.38203	-0.05478	
Melicia excelsa	1	80	0.0125	-4.38203	-0.05478	
Gambeya albida	2	80	0.025	-3.68888	-0.09222	Equitability=
Ceiba pentandra	2	80	0.025	-3.68888	-0.09222	(H^1 / H_{max})=
Dacroydes edulis	6	80	0.075	-2.59027	-0.19427	0.94892
Dalium guineense	2	80	0.025	-3.68888	-0.09222	
Daniella oliveri	3	80	0.0375	-3.28341	-0.12313	
Datariun microcarpum	2	80	0.025	-3.68888	-0.09222	
Poitiana regia	2	80	0.025	-3.68888	-0.09222	
Dracena arborea	2	80	0.025	-3.68888	-0.09222	
Elaeis guineensis	2	80	0.025	-3.68888	-0.09222	
Ficus carpensis	2	80	0.025	-3.68888	-0.09222	
Ficus exasperata	3	80	0.0375	-3.28341	-0.12313	
Hildegardia barteri	1	80	0.0125	-4.38203	-0.05478	
Irvingia gabonensis	5	80	0.0625	-2.77259	-0.17329	
Milletia zechiana	1	80	0.0125	-4.38203	-0.05478	
monodora myristica	2	80	0.025	-3.68888	-0.09222	
Sarcocephalus latifolius	2	80	0.025	-3.68888	-0.09222	
Newbouldia laevis	6	80	0.075	-2.59027	-0.19427	
Parkia biglobosa	1	80	0.0125	-4.38203	-0.05478	
Pentaclethra macrophylla	1	80	0.0125	-4.38203	-0.05478	
Prosopis africana	3	80	0.0375	-3.28341	-0.12313	
Pterocarpus sp	7	80	0.0875	-2.43612	-0.21316	
Rauvolfia vomitoria	1	80	0.0125	-4.38203	-0.05478	
Spondias mombin	4	80	0.05	-2.99573	-0.14979	
Tetrapleura tetraptera	1	80	0.0125	-4.38203	-0.05478	
Vitex doniana	3	80	0.0375	-3.28341	-0.12313	
Total					**3.25857**	

Odengwu Community Forest has high species diversity (3.353). In Odengwu Community Forest, the dominant species are *Parkia biglobosa*, *Irvingia gabonensis*, *Ceiba pentandra* and *Pterocarpus* sp (**Table 26)**

Table 26: Species Diversity of Odengwu community Forest

Species	n	N	Pi	In(pi)	pi*In(pi)	-Σ(pi)*In(pi)
Adansonia digitata	2	80	0.025	-3.68888	-0.09222	H^1=3.35298
Afzelia africana	4	80	0.05	-2.99573	-0.14979	
Anthocleista djalonensis	1	80	0.0125	-4.38203	-0.05478	H_{ma}= Ins (ln36)
Borassus aethiopicum	1	80	0.0125	-4.38203	-0.05478	3.583518938
Buchholzia coriaceace	1	80	0.0125	-4.38203	-0.05478	
Syzigium guineense	1	80	0.0125	-4.38203	-0.05478	
Ceiba pentandra	5	80	0.0625	-2.77259	-0.17329	
Melicia excelsa	1	80	0.0125	-4.38203	-0.05478	Equitability=
Gambeya albida	2	80	0.025	-3.68888	-0.09222	(H^1 / H_{max})=
Ceiba pentandra	1	80	0.0125	-4.38203	-0.05478	0.93567
Dacroydes edulis	3	80	0.0375	-3.28341	-0.12313	
Daniella oliveri	3	80	0.0375	-3.28341	-0.12313	
Datarium microcarpium	2	80	0.025	-3.68888	-0.09222	
Poitiana regia	2	80	0.025	-3.68888	-0.09222	
Dialium guineense	1	80	0.0125	-4.38203	-0.05478	
Elaeis guineense	3	80	0.0375	-3.28341	-0.12313	
Enantia chlorantha	1	80	0.0125	-4.38203	-0.05478	
Ficus capensis	1	80	0.0125	-4.38203	-0.05478	
Ficus exeperata	1	80	0.0125	-4.38203	-0.05478	
Hildegardia barteri	2	80	0.025	-3.68888	-0.09222	
Irvingia gabonensis	5	80	0.0625	-2.77259	-0.17329	
Milletia zachiana	1	80	0.0125	-4.38203	-0.05478	
Myrianthus arboreus	2	80	0.025	-3.68888	-0.09222	
Sarcocephalus latifolius	1	80	0.0125	-4.38203	-0.05478	
Newbouldia laevis	6	80	0.075	-2.59027	-0.19427	
Parkia biglobosa	6	80	0.075	-2.59027	-0.19427	
Pentaclethera macrophyllum	1	80	0.0125	-4.38203	-0.05478	
Piptadenrastrum africanum	1	80	0.0125	-4.38203	-0.05478	
Prosopis africana	2	80	0.025	-3.68888	-0.09222	
Pterocapus sp	6	80	0.075	-2.59027	-0.19427	
Raurolfra vomitoria	1	80	0.0125	-4.38203	-0.05478	
Sensepalum dulcificum	1	80	0.0125	-4.38203	-0.05478	
Spondias mombin	1	80	0.0125	-4.38203	-0.05478	
Syzigium guineense	1	80	0.0125	-4.38203	-0.05478	
Tetrapleura tetraptera	4	80	0.05	-2.99573	-0.14979	
Vitex doniana	3	80	0.0375	-3.28341	-0.12313	
Total					**3.35298**	

Mamu Forest Reserve has species diversity of (3.472), the dominant species are *Ceiba pentandra*, *Pentaclethra macrophylla*, and *Sarcocephalus latifolius* (**Table 27)**

Table 27: Species Diversity of Mamu Forest Reserve

Species	n	N	Pi	In(pi)	pi*In(pi)	-Σ(pi)*In(pi)
Adansonia digitata	3	80	0.0375	-3.28341	-0.12313	H^1=3.47176
Afzelia africana	2	80	0.025	-3.68888	-0.09222	
Aubrevillea kerstingii	1	80	0.0125	-4.38203	-0.05478	H^1_{max}= Ins (ln35)
Anthocleista djalonensis	2	80	0.025	-3.68888	-0.09222	3.5553
Beitschlemeidia manii	1	80	0.0125	-4.38203	-0.05478	
Borassus aethiopicum	1	80	0.0125	-4.38203	-0.05478	
Buchholzia coriaceae	3	80	0.0375	-3.28341	-0.12313	
Ceiba pentandra	4	80	0.05	-2.99573	-0.14979	Equitability=
Melicia excelsa	1	80	0.0125	-4.38203	-0.05478	(H^1 / H_{max})=
Gambeya albida	3	80	0.0375	-3.28341	-0.12313	0.97649
Dacroydes edulis	2	80	0.025	-3.68888	-0.09222	
Daniella oliveri	1	80	0.0125	-4.38203	-0.05478	
Datarium macrocarpium	3	80	0.0375	-3.28341	-0.12313	
Pointiana regia	3	80	0.0375	-3.28341	-0.12313	
Dialium guineense	1	80	0.0125	-4.38203	-0.05478	
Draecena arborea	2	80	0.025	-3.68888	-0.09222	
Enantia chlorantha	2	80	0.025	-3.68888	-0.09222	
Ficus exasperata	3	80	0.0375	-3.28341	-0.12313	
Hildegardia barteri	3	80	0.0375	-3.28341	-0.12313	
Irvingia gabonensis	3	80	0.0375	-3.28341	-0.12313	
Milletia thorningii	2	80	0.025	-3.68888	-0.09222	
Myrianthus arboreus	3	80	0.0375	-3.28341	-0.12313	
Sarcocephalus latifolius	4	80	0.05	-2.99573	-0.14979	
Newboudia laevis	2	80	0.025	-3.68888	-0.09222	
Parkia biglobosa	2	80	0.025	-3.68888	-0.09222	
Pentaclethra macrophylla	4	80	0.05	-2.99573	-0.14979	
Piptadeniastrum africanum	2	80	0.025	-3.68888	-0.09222	
Prosopis africana	3	80	0.0375	-3.28341	-0.12313	
Pterocarpus sp	3	80	0.0375	-3.28341	-0.12313	
Rauvolfia vomitoria	1	80	0.0125	-4.38203	-0.05478	
Sensepalum dulcificum	2	80	0.025	-3.68888	-0.09222	
Spondias mombin	1	80	0.0125	-4.38203	-0.05478	
Syzigium guineense	2	80	0.025	-3.68888	-0.09222	
Tetrapleura tetraptera	2	80	0.025	-3.68888	-0.09222	
Vitex doniana	3	80	0.0375	-3.28341	-0.12313	
Total					**3.47176**	

PLATES

Plate 1: Mamu River that feeds Mamu forest reserve.

Plate 2: A deforested portion of Mamu forest reserve for turngya farming

Plate 3: Road network created inside Mamu forest reserve

Plate 4: River that feeds Achala forest reserve

Plate 5: Trees cut for fire wood in Achala forest reserve

Plate 6: Erosion site close to Achala forest reserve as a result deforestation

Plate 7: The Iyiocha Deity, located at Iyiocha Shrine forest

Plate 8: The River that feeds osomari-east forest reserve (Ulasi River)

Plate 9: Trees cut for firewood at Osomari-east forest reserve

Plate 10: premature woods of tectona grandis cut for scaffolding by the natives

Plate 11: The researcher taking soil sample for analysis in one of the forests

Plate 12: The oracle of Ngene shrine forest