PROFILE DISTRIBUTION OF SOIL PROPERTIES OF SOILS IN DEFORESTED HILL SUMMITS OF SIMILAR LITHOLOGY IN BENIN CITY, NIGERIA

BY

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UNIVERSITY OF BENIN

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OCTOBER, 2023.

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A RESEARCH PROJECT SUBMITTED TO THE DEPARTMENT OF GEOGRAPHY AND REGIONAL PLANNING, FACULTY OF SOCIAL SCIENCES, UNIVERSITY OF BENIN, BENIN CITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE DEGREE(B.Sc) IN GEOGRAPHY AND REGIONAL PLANNING

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CERTIFICATION

This is to certify that this project work was carried out by **EZEIFEJAFOR GERALD CHUKWUEMEKA** with matriculation number **SSC1809527** in partial fulfillment of the requirement for the award of Bachelor of Science (B.Sc.) Degree in the Department of Geography and Regional Planning, University of Benin, Benin City, Edo State, Nigeria.

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DEDICATION

This project work is dedicated to the ALMIGHTY GOD who has kept me up and doing well to this moment and also to my dearest and Godly family members for their care, love and support that has seen me through my stay in this University.

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With utmost gratitude, I thank God almighty, for giving me the grace, knowledge, strength and understanding to be able to this feat. His love and grace has been sufficient enough for my sustenance.

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ABSTRACT

The study was carried out to assess the profile distribution of morphological, physical, chemical and biological properties in Idunowina and University of Benin which are the study areas and a profile sample was dug in both study areas. The morphological study was carried out in the field, while the physical, chemical and biological properties drawn from genetic soil horizons were carried out in the laboratory. The morphological properties show that the soil colour was moisture dependent because of the differences in soil value and chroma when dry and when moist. The soils were mostly moderate and weak in structure in Idunowina and weak, medium in Uniben. The bulk density was found to be within acceptable limit (1.41 and 1.31Mgm^{-3}) while the WHC was highest in the subsoil horizons than in the space soil. There were a lot of fine roots and artefacts and burrows in both study areas. The organic matter was majorly low as well as the basic cations, the micronutrients (Fe, Mn, Cu, Zn) were moderate but not in quantities that pose danger to the soil. The pH of the soil was slightly acidic to neutral. The level of nitrogen and carbon were also observed as they tend to support heterogeneous bacteria and fungi activities. The soil contained high levels of heterogeneous bacteria and fungi with microbial activities being high at the topsoil, there was evidence of eluviation, illuviation, leaching and translocation of minerals in the soils. There was high variability in soil physical properties than in the chemical. Correlation studies revealed that positive significant relationship ($P<0.05$) exist between SOM and cations (Ca, Mg, K, Na) and negative relationship between sand and WHC, pH and Fe, Cu at Idunowina. At Uniben a high positive relationship exist between THBC and micronutrients and a negative correlation between pH and EA. The soil was classified as Ruptic-Alfic Eutrudept (Orlu Clayey) in Idunowina and as Typic-Eutrudept (Alagba-Clayey). The soil recommend implementing a good water and drainage system in the area as well as strategy that will enhance the organic matter content of the area and planting of trees is another conservative strategy that is encouraged.

CHAPTER ONE

INTRODUCTION

Background of study

Soil can be described as one of the most important environmental natural resources for sustaining life. It's role in maintaining the quality of ecological environment and human health cannot be overemphasized. According to Soil Survey Staff (2014), soil is a natural body made up of solids (minerals and organic matter), liquids, and gases that occur on the land surface, occupies space, and is characterized by one or both of the following; horizons or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy and matter or the ability to support rooted plants in a natural environment. Leeper and Uren (1993) also explained soil as the loose surface material that covers most land and consists of organic and inorganic matter. Botanists and agriculturists regard soil as the framework on which most plant life thrives. It comprises of water, gases, dissolved nutrients, and organic matter which are necessary for the survival of plant life. Soils differ in their morphological, chemical and physical properties as well as their biological properties. The different activities that occur naturally or by activities and actions of human help in developing soil and provide the basis on how soil can differ from one location to another.

The vertical section of the soil from the ground surface downwards to where the soil meets the underlying rock can be defined as soil profile. An undisturbed soil had its own distinguished soil profile. According to Brady and Weil (1999) a soil profile is a vertical exposure of the earth's crust that includes pedological altered layers at the time of soil formation. The importance of soil profile to any soil related research is paramount as it allows the researcher have a look at the different variations in soil colours and properties.

There are three primary soil horizons, called master horizons in a mature soil profile. They are A, B, and C horizons. These are part of a system for naming soil horizons in which each layer is identified by a code: O, A, E, B, C, and R. The O horizon is an organic layer made up of partially decayed plant and animal debris. It generally occurs in undisturbed soil, such as in a forest. The A horizon is often referred to as the topsoil and is the surface layer where organic matter accumulates. Over time, this layer loses clay, iron, and other materials because of leaching. The movement of organic matter, chemical substances, and mineral particles from the upper horizons of soil to the lower horizons by the downward movement of water is called eluviation. The A horizon provides the best environment for the growth of plant roots, microorganisms, and other life. The E horizon is the zone of greatest eluviation. As the clay, soil nutrients, and organic matter are leached, the colour of the E horizon becomes very light. This horizon often occurs in sandy forest soils with great amounts of moisture. The B horizon is often referred to as the subsoil and it is often called the zone of accumulation because chemicals leached from the A and E horizons accumulate there. The collection of organic matter, nutrient substances, and mineral particles in the lower horizons of soil from the upper horizons as a result of the downward movement of water is called illuviation. The B horizon has often less organic matter and greater clay content than the A horizon. Together, the A, E, and B horizons are known as the solum. This is where most of the plant roots grow. The C horizon is referred to as substratum. It lacks the properties of the A and B horizons as the soil-forming processes act slowly there, it is usually the parent material of the soil. The R horizon which is found beneath the C horizon is the bedrock, such as limestone, sandstone, or granite.

A hill is a naturally elevated area of the earth's surface, usually lower than mountains. A hill summit is the top parts of the hill, it literally refers to the highest point of the given hill. In soil studies, it has been shown that soil composition and properties both physical, biological and chemical can differ at the summit of a high rising or elevated area and the area at its base. This is because of transportation of movement of soil materials from one point to another by water, wind or even human activities. Another common feature of hills is their steepness that enables them intercept rain drops and create diverse soil properties and habitats.

1.2 Statement of research problem

Soil can be seen as a framework for sustainable economic and social development. It is one of the most valuable natural resources of a country (Tang, 2014). There are even some school of thought that suggests that the environment greatly influences our life, and that soil is a great component of our environment. Human activities like agriculture and building of shelter takes place in it.

Profile distribution and differences in colour and other properties are due to transportation of materials from one point to another by either anthropogenic activities or other factors like climate in the form of rainfall, wind over time. Erosion, which is the washing of top surface of the soil, can also accelerate the transport activities of soil materials from one location to another. Hence, an elevated area often influence variations in soil morphological, physical, chemical, minerological and biological properties.

This research is being done to study the variation in soil properties found in deforested hill summit. Although there are some existing literature, this study also wish to highlight the biological and morphological features of hill summit soils.

1.3 Research Questions

The following research questions will be considered in the study:

1. What are the states or qualities of the morphology, physical, chemical and biological properties of the soils in the hill summit?

2. Are there factors responsible for any differences in the soil status?

3. Are there any significant variations among the soil properties in the hill summit?

4. What is the role of soil colour in a hill summit?

5. Are there significant relationships between soil properties on hill summits?

1.4 Aim and Objectives

The main aim of the project is to find out the profile distribution of colour, physical and biological properties of soils in deforested hill summits of similar lithology in Benin, Nigeria. The specific objectives are to:

I. determine the qualities of colour, physical, chemical and biological properties of the hill summits.

II. determine if there is any factor responsible for differences in soil colour.

III. determine if there are significant variations in the soil properties.

IV. ascertain if significant relationship exists between the physical and biological properties under each soil profile on the hill summit

V. recommend suitable management strategies for soils in deforested hill summits.

1.5 Research Hypothesis

1. There is no significant variation in the physicochemical and biological properties of soils in the hill summit.
2. There is no significant relationship between the physicochemical and biological properties of soils on the hill summit .

1.6 Scope of the study

This research concerns itself with the soil profiles and properties within them in hill summits in Benin City. Areas of study include Idunowina area of Benin City and Capitol area of the University of Benin. Some morphological, physical, chemical and biological properties are to be examined such as colour, structure, bulk density, total porosity, soil pH, Effective Cation Exchange Capacity (ECEC), soil texture (sand, silt and clay), total Nitrogen, and base saturation. It also entails knowing the relationship and variations within the soil profiles in the hill summits and making relevant recommendation on the ways to improve the soil for agricultural purposes.

The soil profile is an important tool in nutrient management. By examining a soil profile, we can gain valuable insight into the soil fertility and productivity. As the soil weathers and organic matter decomposes, the profile of the soil changes. For instance, a highly weathered, infertile soil usually contains a light-coloured layer in the subsurface soil from which nutrients have leached away. On the other hand, a highly fertile soil often has a deep surface layer that contains high amounts of organic matter. With clues provided by soil profile, we can begin to predict how a soil will perform under certain nutrient management conditions.

The physical properties of soil, which are important for ecosystem services such as crop production, are texture, structure, bulk density, porosity, consistency, temperature, colour and resistivity. Soil texture is determined by the proportion of the three mineral particles, called soil separates: sand, silt, and clay. Soil bulk density, when determined at standardized moisture conditions, is an estimate of soil compaction Soil porosity consists of the void part of the soil occupied by gases or water. Soil consistency is the ability of soil materials to stick together. Soil colour is self-defining.

Chemical properties of soil refer to the various minerals and the certain levels at which they are present in the soil. It is also important to note that the chemical composition of soils can influence the physical appearance of soils, for examples studies show that the presence of iron(Fe) is usually characterized with the soil having reddish brown colour. Other important chemical soil properties include phosphorus, nitrogen, carbon, major cations (calcium, magnesium, sodium, potassium), sulphur, trace metals and elements), pH, cation exchange capacity cation exchange capacity, base saturation, salinity, sodium.

The biological properties of soils consist of organic matter made up of materials which can include fungi, bacteria and even broken down materials from animals and plants remains. Soil nutrients are needed in adequate proportions in the soil as they are important to agriculture and agricultural practices, biodiversity and ecosystem survival. The soil properties are also indirectly important to humans general survival.

1.7 Significance of study

The constant study of soils is important for human general survival, from supporting plant growth to providing minerals that can serve as natural resources The need for the awareness that soils are essential components of the earth's biosphere has inspired studies on soil quality (Adeboye, 2011). Knowledge about soil physical, chemical and biological properties are of great importance as they help to know how to manage the soils. A fertile soil might end up not being productive because of wrong usage.

Most hill top soils evolve slowly and are shallow occasioned by the low temperatures limit the biological activities, the soil genesis and evolution. Hill summit soils are generally defined as poorly developed, skeletal, shallow, acidic and relatively infertile. They are also highly diverse and can vary significantly within limited areas due to different curvatures and steepness. In general, they become less fertile and less developed as elevation increases. In cold mountain areas, freeze-and-thaw cycles reduce the aggregation of soils which affect their stability, fertility and water retention. Many plants, have adapted to grow on hill summits which are often covered with lush vegetation that has several fundamental roles. In most cases, hilly soils are less productive than lowland soils and their agricultural activities are more labour intensive. Where the land is very steep, farmers build terraces and similar structures to limit erosion and land degradation.

Therefore, this study on hill summits should be characterized and classified. This study is meant to help us see changes or the variability that may occur within the soil profile and their relevance to agricultural products. Adamu *et al.*, (2015) opined that farmers cannot easily modify some physical characteristics such as texture and soil depth which conditions the sustainability of a soil for various activities. The study would also help to provide valuable resources for other research in pedology and soil geography of similar regions.

1.8 Study Area

1.8.1 Location, topography and drainage

The two locations picked for this study is situated in Benin City, Nigeria [fourth largest city after Lagos, Kano and Ibadan] which is located between latitudes 06°19I E and 6°21I E and longitude 5°34 E and 5°44I E with an average elevation of 77.8 m above sea level. It has a population of about 1,500,000 as at 2016.

Edo State topography is mainly swampy mangrove forests with numerous creeks and rivers dissecting the land area. In the southwest, there are sandy plains with many rivers and streams. This region, has a few hills and the land is drained by the lkpoba, Orhionmwon and Osse Rivers. Going northwards is the Esan Plateau, which is an extension of the plateaux and ranges that are found in the far north areas of the state. They are mainly sandstone plateaux whose heights range from 200 to 300 metres above sea level. There is a gradual fail into the Orle and Niger Valleys from the north and south, while the landmass in the south and west descends gradually to the Benin Lowlands. The Orle Valley, which runs from the west to east, was formed by a river that cut a ridge in the sandstone sub-strata of the Northern and Esan Plateaux. The area is drained by the

Owan and Orle rivers. The Northern Plateau has ranges that are between 180 and 300 metres of basement rock. Granite peaks are found at random, sometimes rising above 600 metres. The southern portion of this plateau is mainly sandstone.

The drainage system in Benin is made up of three rivers. They are the Ikpoba River, the Ogba River and Owigie-Ogbovben River systems. They are small in size being (1 - 5 m) wide and (0.5 - 3.0 m) deep. Ikpoba River acts as the major drainage channel in Benin. Its' headstream originates from the N.E outside Benin region and flows east to west across the northern quarter of the region and then south and south east, this change in direction is due to some structural control. There is a prominent artificial man-made lake referred to as the Ikpoba Lake along its course in Okhoro. The lake is about 1 km^2 in area and is used mainly for municipal water supply for drinking, fishing and recreation. The south western part of the Region is drained by the Ogba River Basin. It originates from Oko-Ugbor environment. The three rivers constitute a dendrite drainage pattern.

1.8.2 Climate

Benin City belongs to the Af category of Koppen's climatic classification. The climate is tropical, characterized by wet and dry seasons. The rainfall depends on the interaction between warm moist tropical maritime air mass and the hot and dry tropical continental air mass.

The rainfall of Benin City is concentrated in the months of April and October, though heavy in the month of June and July. Surprisingly, there is a break in rainfall in August which is considered to be an anomaly in the climatology of southern Nigeria despite it's great figure of humidity (>70%). This abnormal period of little dry season is called "August break" locally. According to Ugwa et al (2016a), mean annual rainfall is about 2,255 mm and 25 °C and 29 °C for mean minimum and maximum temperatures respectively. Relative humidity is generally above 72%. The highest relative humidity occurs between the month of July and September, while the area is characterized by moderate wind speed and sunshine of between 2 and 7 hours per day during the wet and dry days respectively (Ugwa et al, 2016b). Duration of sun ship is significant for agricultural activities.

1.8.3 Soil and Geology

Benin city soils are made of reddish clay soils, which show the high presence of iron oxides. Ugwa et al (2017) reported that the soil is made up of largely reddish-brown sandy latrine as a result of unconsolidated sedimentary deposit of the miocene-pleistocene period. The Benin region is underlain by sedimentary formation of the South Sedimentary Basin. The term Benin sand was used by Ojanuga et al. (1981) to describe the reddish earth underlain by sands, sandy clays and ferruginized sandstone.

1.8.4 Vegetation

Benin City lies within the zone of tropical rainforest vegetation belt. Two main cash crops that are cultivated here are oil palm and rubber. The presence of trees like Rubber (*Hevea brasiliensis*) and also plants like Spear grass (*Imperata cylindrical*) and Siam weed (*Chromolaena odorata*) is also seen along this areas. The vegetation to the north of Benin City is mainly savannah where the palm oil grows in the wild. The eastern table land is made up of diverse vegetation, savannah in the north and forest in the south. Where deforestation has occurred, as in the study areas, African pear (*Dacryodes edulis*) are seen on the fallow lands and secondary growth grow reasonably well. The Benin lowlands, initially covered with vast rain forest, have been mostly displaced by rubber plantations. The riverine communities in the south have mainly mangrove swamp vegetation.

Agriculture is the mainstay of the Edo state economy. The economic activities are mainly farmers, producing cash and food crops such as rubber, oil (i.e., palm, cocoa, yam, cassava, maize, rice, and plantain), cashew, palm oil derivative products, groundnut, soya bean, tomatoes, cotton, and tobacco. Fruits like pineapples, coconuts, oranges, and avocados, as well as green leafy vegetables, all grow abundantly state-wide. Trading is also a common activity within the state, as most traders buy and sells food crops, textiles materials, and products (e.g., cosmetics), while in the riverine areas of the south, fishing is a key sector. They are also known for engaging in brass casting, wood carving, and blacksmith forging. Major markets located within Benin City include Oba, New Benin, Oliha, Uselu, Agbado, and Edaiken.

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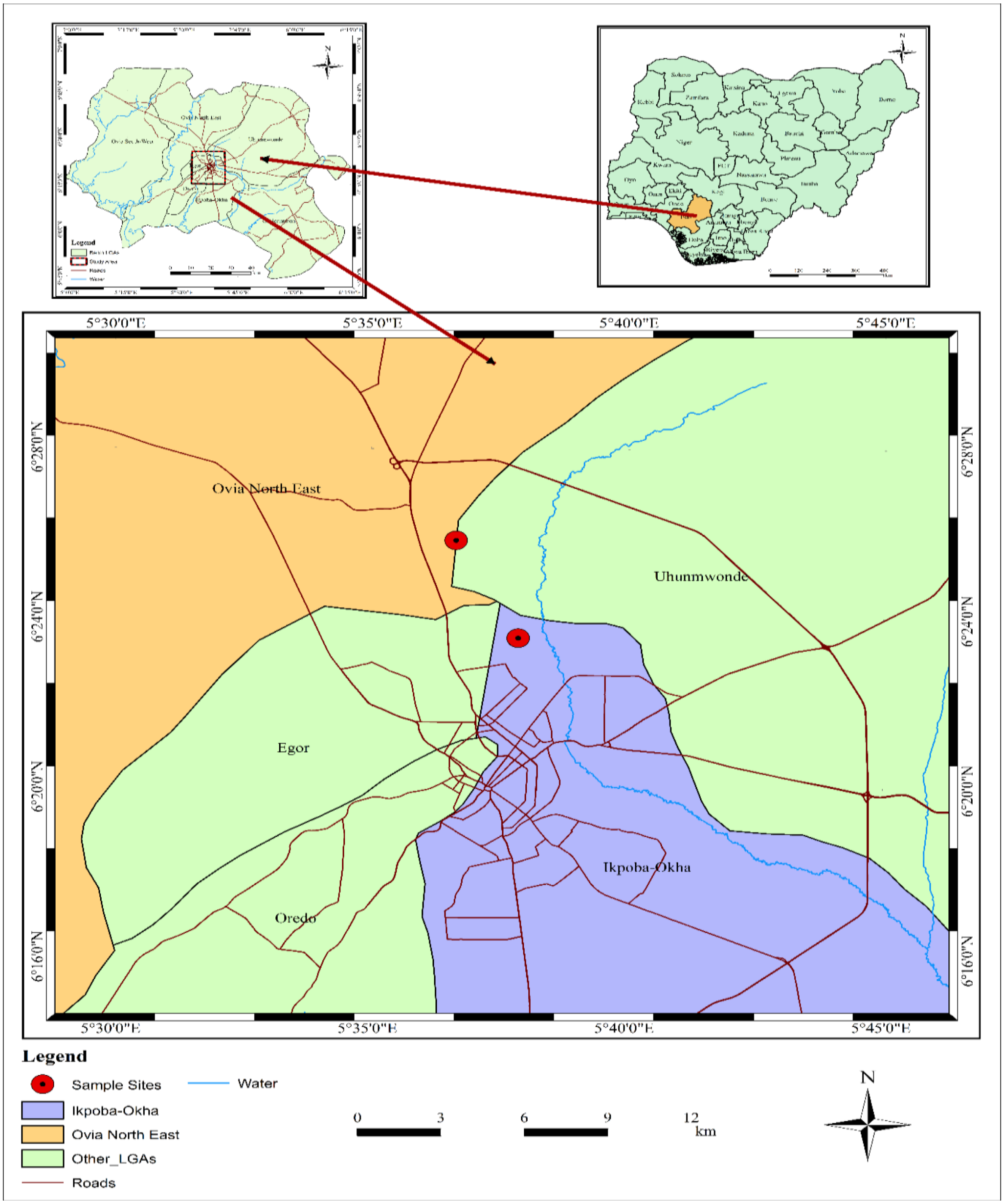

Figure 1.0 Study Area Showing the Sample points. Inset, Nigeria and Edo South.

Source: ArcGIS Online.

CHAPTER TWO

CONCEPTUAL DEFINITIONS AND LITERATURE REVIEW

2.0 Conceptual Framework

Soil characteristics consist of those physical, biological and chemical attributes that can be used to describe a soil (Ugwa *et al.* 2016a). Soil formation is a process that occurs over a very long period of time and different geomorphic processes occur in the formation of soils. The breaking down of parent materials to smaller particles is an essential process in soil formation. The rate at which parent materials are broken down depends on temperature and even moisture, temperature is very important to speed up chemical processes that leads to the breaking down process. Transportation of materials from one point to another is an important process in soil formation and this is greatly influenced by slope and drainage, a steeper slope ensures that materials are transported at a faster rate (Brady and Weil, 2002). Soil moisture, sunlight and good soil properties are important in the ability of a soil to yield retain essential plant nutrients.

GLOBE (2014) reported that soils are characterized by their texture, consistency, colour, structure, and rock fragments which allow for the interpretation of their ecological functions, and provides understanding for sustainable use of the soil. Soil physical properties affect the colour and feel of the soil while soil chemistry is dominated by the interaction between the soil solids components and its water phase. The physical, chemical and biological properties collectively affect every agriculture producers' decision about how to manage the land (Brady and Weil, 2002)

Soil classification is done on the basis of the physical, chemical, biological and even morphological properties. It is therefore important to clarify the terms associated with these properties and also establish the possible relationships between them.

2.1 Physical Properties:

2.1.1Soil Colour:

Soil colour is the most noticeable morphological feature of any given soil as it is the first thing to be seen the moment a look or glance is taken at the soil. Colour can be a useful indicator of some of the general properties of a soil, as well as some of the chemical processes that are occurring beneath the surface. Most times the top soil is usually darker than other layers of the soil because the top soil is where organic matter accumulates (Leeper and Uren, 1993).

Soil colour can also help give an indication to the various processes going on in the soil as well as the minerals present in it. Ugwa *et al.* (2016a) reported that soil development often gives rise to changes in colour due to iron oxide minerals and as the weathering continues, kaolinite and quartz are mainly left behind.

Soil colour varies as regards to the parent materials, the duration of the soil forming process and even the environment itself. The Munsell colour chart is used to explain soil colour. The chart shows the soil colour in regards to the hue, value and chroma. Soil colour varis according to the moisture content of the soil.

2.1.2Soil Texture:

Soil texture refers to the different proportions of the sized particles in a given soil (Birkeland, 1974). This could refer to sand, silt or clay particles. Light soils generally refers to soils with more sand particles while but the presence of more clay particles would automatically make a soil heavy.

Soil texture so many studies has been seen as a variable indicator of soil porosity (Pattison et al., 2008). Soil texture along with soil structure are often regarded to as “master variables”. This means how soil texture and soil structure play a very huge determination in the general properties of a given soil. Christopherson (2011) describes soil texture as the combination of sizes of soil particles and the ratio of their sizes, particles with diameter less than 2 mm are considered part of the soil but the larger particles are considered gravel, cobbles and are separate from the soil.

Soil texture is an essential physical property for characterizing soil (Pattison et al., 2008). This is because soil texture determines the rate at which air and moisture can move through the soil and be present for plants intake. Soil with larger particles allows for water, moisture and air to move easily and be available to plants but soils whereas smaller particles are compact and do not easily allow for easy access to moisture and air by plants.

2.1.3 Soil Bulk Density:

Bulk density is defined as the mass of solids per unit volume of the soil. Bulk density is defined as the oven-dry mass per unit volume of a soil (Brady and Weil, 2002). Bulk density measures can help to describe the permeability of a soil, as the bulk density helps to defines the soil drainage characteristics (Arya and Paris, 1981), they also reported bulk density furthermore is critical in soil carbon studies, this is because it helps to ascertain the amount or volume of carbon present in a given soil or soil sample at a given point.

2.1.4 Total Porosity:

This can be defined as the pore volume to soil volume ratio. The porosity of a given soil determines its ability to hold or store water, heat, gases and sometimes how well roots of plants can move within the soil.

Although Porosity can determine how much of the soil volume roots and water can occupy (Pagliai and Vignozzi, 2002), it does not account for the number, size or shape of pores within the soil. Pores are the gaps present between soil particles and aggregates. Without the presence of these pores, survival of plants, animals and organisms may be compromised. Coarse textured soils have macro-pores because the particles are big and loosely arranged, where as fine textured soils have micro-pores as their particles are tightly arranged. It is important to note that porosity can be modified by management, water and chemical processes. Porosity can also be enhanced by actions of animals burrowing into the soil and even agricultural practices carried out by humans.

2.1.5 Soil Structure

The arrangement of soil particles into a definite shape or aggregate is known as soil structure (Buol et al, 1973). Structured arrangements can be naturally or made by human. Structured stability is the capacity to resist wetting and drying, wind and actions such as tillage. Biological factors which can influence aggregate stability include fungal hyphae, macro fauna activities and organic matter content. The structure of soil is characterised by the peds and they are categorised based on their shape into platy, blocky, spheroidal or prismatic. Not all soils develop into true structure because some soils especially those composed of mainly sand do not amass into peds but silt and clay particles mostly amass into peds. The formation of peds easily occur in moist soil and is less likely in dry ones. The shape, size and relative firmness of peds have a clear effect on how easily water, organisms, plants roots penetrates the soil hence the influence of structure on soil fertility (Hess, and Tasa, 2013).

2.2 Chemical Properties

Soil chemical properties refer to the characteristics of soil that pertain to its chemical composition, nutrient content, acidity or alkalinity (pH), and various chemical reactions that occur within the soil. These properties are critical for understanding soil fertility, nutrient availability to plants, and the overall health of the soil. Here are some key soil chemical properties:

pH (Acidity or Alkalinity): Soil pH is a measure of the soil's acidity or alkalinity on a scale from 0 to 14. A pH of 7 is considered neutral, below 7 is acidic, and above 7 is alkaline. Soil pH affects nutrient availability to plants, as different nutrients are more or less soluble at different pH levels.

Effective Cation Exchange Capacity (ECEC): ECEC is a measure of a soils ability to hold and exchange cations (positively charged ions). Soils with higher ECEC can hold more nutrients and make them available to plants over time.

Organic Matter Content:

Organic matter in soil contributes to its chemical properties by improving nutrient retention, water-holding capacity, and cation exchange capacity. It also serves as a source of nutrients as it decomposes.

Base Saturation:

Base saturation is the proportion of exchangeable cations in the soil that are basic (calcium, magnesium, potassium, and sodium). It helps determine soil fertility and the potential for nutrient imbalances.

2.3 Biological Properties:

Human activities have a substantial and ever growing influence on ecosystems to the extent that much of the Earth's land surface has been totally transformed by a suite of global change phenomena (Vitousek et al., 1997). This goes on to show the influence the human has on his environment and the soil. As an example, areas where human has adversely influenced or affected the environment are characterized by pollution or degradation. This could alter or reduce the biological properties present in a soil needed to support life properly and also areas where man or human activities are good, the soil biological properties flourish.

Biological Properties represent the direct and indirect influence of the living organisms inhabiting a particular soil. Soil biological properties help to show how well-suited a soil is to support life and plant survival. Some of the biological organisms include bacteria, fungi, earthworm, remains of plants and animals. The soil biota which includes flora (plants), fauna (animals) and microorganisms that execute function that help soil development, structure and productivity.

Soil Flora and Fauna:

Soil flora and fauna are essential components of all soils. Particularly vital is their role in the retention, breakdown, and incorporation of plant remains, nutrient cycling, and their influence on soil structure and porosity. Soil flora seemed to be more static than the soil fauna. Soils are inhabited by animals, microorganisms and root system of plants.

Microorganisms play foremost role in soil formation and soil ecology because they regulate the cycle of nutrients to plants and fix nitrogen, and ultimately promote detoxification of naturally occurring pollutants in soil. The most numerous microbes in soil are bacteria, fungi, which produce hyphae. The actinomycetes are in-between these two organisms. They are advanced bacteria that can form branches like fungi. Microorganisms are so abundant in the soil that it is estimated one million to one billion microorganisms per one gram of agricultural top soil (Tugel and Lewandowski, 1999). Among the soil microorganisms, bacteria are the smallest and much in number. Bacteria are important in soil organic matter decomposition. Algae like plants are found near the surface. Fungi are microbes that are important in the disintegration of soil organic matter.

Soil fauna includes those animals that have one or more active stages in soil and; some may be temporary occupants of this habitat, as most are permanent. Soil animals participate in the genesis of the habitat in which they live. Examples of soil fauna includes earthworms, collembolans, mites, nematodes, and protozoa. Lee (1985) reported that soil fauna work as soil engineers and help in the breaking down of dead plants and animal material, mixing soil layers and increasing aggregation. Earth are one of the most important soil fauna, because by the process of their burrowing they increase the soil porosity and water infiltration.

2.3 Literature Review:

Soil covers most of the landed and solid parts of the earth. It shows how it is to our survival. It is the zone where roots of plants reside and grow as well as being the support to terrestrial life. Soil supports our economic activities and production.

Soil is normally considered as the fine earth which covers land surfaces as a result of the in situ weathering of rock materials or the accumulation of mineral matter transported by water, wind, or ice. The distinctive feature of soil is that weathered mineral material that is added to organic material. This organic material may be both living and dead. The dead organic matter include little altered and freshly added dead plant roots and leaf and other plant litter, dead fauna, and organic material in various stages of decomposition. (Brady and weil 2002) It is this mixture of mineral and organic material which gives the soils their distinctive characteristics. Across the surface of the earth there are many different types of soil which reflect, at least in part, varying combinations of mineral and organic matter and their differing responses, both separately and often in complex association to different environmental conditions. Indeed, soil together with the plant life it supports, the rock on which it lies, and the climate it experiences, forms a finely balanced system.

According to Esu (1999) may have very different meanings. A simple definition of soil is the material that plants grow in and which provides them with physical support, water, and nutrients. There are other more particular uses of the term soil. To the engineer, soil is the finely divided and relatively loose ‘‘rock’’ material at the earth’s surface, and this overburden is often considered an inconvenience because it must be removed. The geologist calls this layer the regolith and geological investigations frequently begin below. Soil is a natural, dynamic, and three-dimensional body on the Earth's surface, characterized by a unique combination of mineral and organic material, air, water, and living organisms, each of which contributes to its physical, chemical, and biological properties. Soil plays a fundamental role in supporting terrestrial ecosystems, influencing plant growth, nutrient cycling, and water availability, while also serving as a medium for engineering and agricultural activities (Plaster, 2008).

The differences in soil characteristics associated with landscape position are usually attributed to differences in the runoff, erosion and deposition processes which often affect soil genesis. This is because of the movement of parent materials from one point to another. The focus here comprise of hill soils. The hill soils under study mainly occurred on hill summits soils under a deforested vegetation. The degree of surface runoff and soil erosion is mainly related to land physiography and slope gradients. The variation in soil properties might be attributed to topographical variations of hill soils. A broad landscape with gentle slopes will permit rapid vertical movement of water through soil. Such level landscape will have thick soil profiles and well developed horizons. Consequently enhanced infiltration and strong vertical fluxes of water lead to greater rates of soil profile development and of course some deposition of material eroded from adjacent, steeper slopes. In more steeply sloping landscapes, particularly on shoulders slopes, increased rates of erosion and runoff and decreased vertical percolation of water will lead to thin and weakly developed soils.

Soils are part of landscapes with profiles. If a massive trench is dug vertically downwards into the ground, it will be noticed various layers of soil horizons. This cross sectional view is known as soil profile. The profile is made up of layers, running almost parallel to the surface, they are called Soil Horizons (Buol et al., 1973). Each horizon indicates, age, texture and other characteristics of that layer. The layers are divided as top soil layer, sub-soil layer and the bed rock layers.

Soil profile distribution, and its characteristics are caused by a number of factors some of which is human activities. For example, decline in soil quality is commonly caused by improper use by humans which is may be as physical, chemical or biological deterioration. In looking at the soil profile distribution of colours, physical, chemical and biological properties Gabler (1997) opined that there is almost an endless number of factors involved in the development of a soil. Although we have seen that they can be divided into a few general soil-forming process. These are addition process, those that deplete, translocate and lastly, those that transform (Arbogast., 2013).

In the enrichment or addition to a soil or soil profile, organic matter and minerals are added to the soil. On the surface, silt may be added by river floods or dust may settle down due to heavy wind. Below the surface, enrichment may occur when humus is carried from the O horizon to the A horizon by gravitational water (Strahler, 2013). Soil-forming processes as noted by Yaroslav (2013) that deplete or break down materials can be in form of those materials being removed or carried away by action of stream, flood, or even erosion which continuously erode the soil. It can also occur in the form of leaching, which loss of colloids and other soluble substances from the upper horizons of soil by the percolation of water.

During the process of translocation, materials are moved upward and downward within the soil, particles especially colloids and clay particles leaving behind coarse silt. This process is what is known as and it happens in the E horizon of most soils (Brady and

Weil 2002). Somehow, materials eventually are moved from the E horizon that end up being deposited in the B horizon. Such materials include clay particles, sesquioxides of iron and aluminium and humus. This depositional process of translocation within the soil is referred to as illuviation (Arbogast, 2013; Kamalu et al 2014).

The final way in which changes can occur within the soil is the transformation process, minerals and organic matter are decomposed. The decay of leaf and animal litter which leads to the formation of humus, properly exemplify this phenomenon (Arbogast, 2013). These processes therefore show that a lot of factors affect the distribution of soil profile even within areas of same lithology. It is important to note that landscape morphology, slope and topography also affected the distribution of soil profile, soil properties and soil nutrient status in deforested hill summit soils. Higher topography enhances the removal of base cations through leaching and runoff processes, and forest hill soils become gradually acidified. The hill summit soils face severe degradation due to intensive leaching, soil acidification, surface run off, biotic activity, and improper land use systems. Such processes play their pertinent roles and influence the rate at which variation within the soil profile can occur.

Soils of the hills and mountains are defined to be those found in areas with altitude above 300 m above sea level and slope of 18 % and above. They were developed from various rocks. Major vegetation in these soils include forest, grasses, and shrubs. In areas where springs abound, soils are cultivated for upland crops such as rice, corn, sugarcane, fruit trees, and vegetables. The uncultivated areas are either covered with grasses or second growth forest with some primary forest. In general, soils in this group are acidic and are low in fertility occasioned by their steep slope which allows the movement of important soil nutrients and the occurrence of erosion. (Esu, 1999) The soils of the hills and mountains are similarly grouped as in the upland soils, as they occur mostly in high elevation and slopes. According to Buol et al (2003), the soils are grouped according to their parent materials (igneous, sedimentary, or metamorphic). Owing to their high elevation and the natural downward movement of water, the soils are mostly well-drained, some of the soils are also fairly drained and poorly drained soils which certainly exhibit redoximorphic features.

Environmental variables such as topography, climate and soil are the factors determining species richness (Kharakwal et al., 2005). Weather and climate are the critical factor determining the richness at both landscape and regional scale while plant species richness is governed by environmental heterogeneity at local scale (Lavers and

Field, 2006). The weather at the hill summit can be different from that at the base, and therefore is responsible for variations in the soil profile. Topographic factors such as altitude, slope and aspect are often used in predicting soil abundant nutrients. These factors together determine the microclimate and spatial distribution of species. Climatic factors and local topographic variables such as altitude slope, aspect etc. change and create variation in species richness along the elevation gradient. (Birkeland, 1974; Buol et al., 2003) reported that slope also plays an important role in determining the properties of soil through its influence on movement of broken down rocks. Slope has a negative effect on soil richness as high degree of slope results in immense water drainage, soil washing and decrease in fertility of soil.

Birkeland (1974) is of the opinion that lithology is the basis of subdividing rock sequences into individual lithostratigraphic units for the purposes of mapping and correlation between areas. The lithology of a rock unit is a description of its physical characteristics visible at outcrop. Physical characteristics include colour, texture, grain size, and composition. Lithology may refer to either a detailed description of these characteristics, or a summary of the gross physical character of a rock. Examples of lithologies in the second sense include sandstone, slate, basalt, or limestone.

Waroszewski et al. (2015) also referred lithology as the underlying rock or parent materials, it can also refer to areas having similar parent material characteristics. The origin and development of heterogeneous soils has been the subject of many studies. He also opined that soil heterogeneity may be the result of geomorphological activities such as slope processes, surface erosion and deposition and admixture of allochthonous substrates. The heterogeneity within the soil profile according to Kowalska (2013) may be distinguished as a lithological discontinuity, clear or abrupt change of particle size distribution or mineralogical composition within the soil profile and may be an expression of differences in age or origin of soil parent material. Lithological discontinuities have been documented in different climate zones all over the world, and can also be seen at the junction between horizon within the soil Waroszewski et al., (2015)

Physical, chemical and biological properties of soil are all needed for a soil to support crop life (Ugwa et al., 2022) but at hill summits, there is the presence of a slope which lead to the movement of these properties and materials to the lower part of the hill by action of wind, water and sometimes anthropogenic activities. Nature of parent materials strongly determine the texture of the soils (Orabator et al., 2018). Shale results in heavy silt loam or silty clay loam subsoil as soils developed on sandstone have dominant textural class of sandy loams with occasional loamy sand or loam texture. The steepness of the landscape determines the rate of transportation of materials and the depth of the soil. Soils in hill summits are generally shallow in depth, compared to soils in other regions that have topsoil (Buol et al., 1973). Washout materials are deposited at the foot of the hills and lead to soils in that region being enriched in nutrient content.

In terms of the agricultural potential of hill soils, Agbede (2012) reported that it is mainly low for field crops, but it can range between low and high for tree crops. Deep soils on level or gently sloping land have the highest potential. Esu (1999) reported that because of impracticality of irrigation, rainfed crop production is practised in most hill land. Shifting cultivation is practisable in hill regions but due to faulty cultural practices in the hilly regions, the soils are at risk of severe degradation.

A basic step often omitted in our commercial agriculture and land use is the ability to identify and classify the soils of a project area. In the highland areas, the neglect of this fundamental issue has made the areas under review without accurate identifiers and verifications doubtful. However, Ogunkunle (1989) researched on the variations within a taxonomic unit and found out that within a slight highland area at Ibadan environ and of 38 properties in the A and B horizons, 13 showed low variation while it showed high variations in gravel, clay, silt, Mg and K in the A horizon and colour have in the B horizon. Although the soil properties that show low variations were low, but some of them were so important to infer serious adverse effect on the agro technology transfer and in the predictive value of the soil classification. Ojanuga and Awujola (1981) reported the characteristics and classification of the soils of the granite and basaltic area of Jos Plateau, Nigeria. They found that the soils were deep within an epipedon in characteristics with high silt content and clay deficiency in the uppermost horizon while the organic matter content was generally low.

The soil toposequences in southeastern Nigeria and their relation to potential agricultural land use were investigated by Juo and Moormann (1974). They observed that the soils were generally strongly acidic, sandy, gravely and with low inherent fertility. Kaolinite and mica were the most abundant minerals in the area. In view of the high soil degradation, the upper soil areas were considered not well suitable extensive crop production. However, Birkeland (1974) asserted that slope orientation influence pedogenesis and vegetation differences. He argued that topography is one of the factors in explaining soil variation in a site and hence, in a hill summit. He further observed that vegetation correlates with the moisture-temperature trends. Topography has been identified as s variable that brings out differences in soil (Birkeland, 1999; Fawole, 2016). Therefore the gradient of landscapes in hill regions results not only in variation of morphological, physical and chemical properties can also slow or hasten climatic and biotic activities within hil summit soils.

Deforestation of natural Benin City land that can be used for farming has become normal because of its urbanization. The exposure of soils though deforestation of natural forest has led to erosion. The greatest influence of slope aspect has been reported by Hunkler and Schaetzi (1997) as between latitudes 40^0 -60^0. Igwe and Abia (2003) between latitudes 40°-60° (Hunkler and Schaetzi, 1997). Igwe and Abia (2003) reported heightened soil degradation by soil water erosion is frequent in hill regions, while Mbagwu and Obi (2003) attributed it to reduction in soil organic matter and consequent deterioration of soil quality in terms of physical, chemical and biological properties. The situation is worse in hilly topography where soils have high erodibility potentials (Onweremadu, 2006).

Highland regions are characterized by a variety of climatic factors, which result in diverse vegetation in country. Temperature decreases with altitude which reduces efficiency of ecosystems and Bardelli et al. (2017) noted that it slows down the rate of organic matter decomposition. According to Egli and Poulenard (2016), highland soils are highly dynamic systems that may react sensitively to environmental changes. The slope affects the local microclimate. Hill slope aspects can affect species composition of ground flora, and thus indirectly involves the different types of litter fall to the topsoils of contrasting exposures (Jasińka et al., 2019).

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 INTRODUCTION

When carrying out a study on soil or soil samples, the collection of data is inevitable as this data collected would be needed to carry out analysis required in the research. The study of soil characteristics usually involves gathering quantitative data concerning certain parameters of morphological, physical, chemical and biological significance (Burt and National Soil Survey Center (U.S.), 2014). In other to get the right data, careful and adequate measures such as selecting the appropriate site, the amount of samples that will be taken, the depth of the profile to be dug are to be taken.

The aim of this chapter therefore is to show and discuss the different methods used in data collection while on the field and even off the field as well as in the laboratory.

3.1 Types and sources of data

This research depended on both primary and secondary sources of data. Primary data were got through direct field measurements, soil sampling, soil samples analysis.

The secondary data came from articles, journals, past works that were available online and in the library.

3.2 Reconnaissance Survey

Prior to the actual field work, a reconnaissance survey was conducted with the aim of:

i. Familiarizing ourselves with the study sites,
ii. To identify any possible challenge that we might encounter,
iii. Reviewing the existing environmental information on the study area in published and unpublished literature, and
iv. Planning for the fieldwork, programming for the fieldwork and also selection of equipment that would be required.

The instruments used for this research work included, measuring tape, shovel and digger for digging the soil profile, hand trowel, polythene bags for sample collections, white masking tape for labelling each sample, a global positioning system (GPS), field notebook and a pen for recording.

3.3 Field work:

Free soil survey technique was used in field sampling and consequently two modal profile pits were dug in the two locations. The locations were at Ovia North East, Idunowina and university of Benin near Capitol respectively. The study sites and profile pits were geo-referenced with the aid of a hand held GPS (Global Positioning System) model Garmin64st receiver. Various soil horizons of the soil profile were identified using soil colour, texture, structure and other morphological characteristics.

Morphological characteristics and field observations were carried out according FAO (2006) guidelines. Soil samples were collected from the sides of each horizon, the soil samples were air-dried, crushed and sieves through a 2 mm sieve mesh. Soil colour was determined using Munsell colour chart, undisturbed soil sample for determination of bulk density was collected using core samples. A total of eleven soil samples (six from profile A and 5 from profile B respectively) were collected from different horizons of the soils in the studied profiles into a well labeled polythene bags and taken to the laboratory for analysis.

Plate 3.1 depicted the collection of soil samples from the profile at Idunowina, while Plate 3.2 depicted the collection of profile soil samples in the Capitol area of

University of Benin. Plate 3.3 showed the deforested area, and the presence of human activities, it also showed the vegetation which were few trees, grasses and shrubs, there was also presence of stones and concrete. Also plate 3.4 shows the soil lumps and the clayey nature of the soils in Idunowina area, the reddish colour of the soils shows the presence of iron oxide within the soil.

Plate 3.1: Collection of Soil Samples from Profile Pit of Idunowina **Source: Author's fieldwork (2023)**

Plate 3.2: Collection of soil samples from profile pit in University of Benin
Source: Author's fieldwork (2023).

Plate 3.3: View of Uniben study area. **Source: Author's fieldwork (2023).**

Plate 3.4: Soil samples from profile pit of Idunowina area, showing soil lumps, clayey nature and colour. **Source: Author's Field Work 2023**

3.4 Laboratory Analysis

Soil samples collected from the sampling points were air-dried, crushed and sieves properly for the purpose of laboratory analysis. The resulting samples were then taken for proper analysis of physical and chemical properties.

3.4.1 Soil Physical Analysis

Particle size analysis: was done and determined by hydrometer method using sodium hexametaphosphate as dispersing agent (Okalebo et al., 2002).

Silt/Clay ratio: This was calculated by dividing the silt content of the soil by its clay content.

Erodibility Index: This was determined using the equation of:

Erodicity Index = (Sand + Silt)/Clay

WHC: Water holding capacity was determined by passing crushed air-dried soil through a 2 mm sieve. Water was poured into the soil to make it moist and it was then filtered. The weight of the dish and filter paper was noted:

i. Weight of empty dish + filter paper – a gms

ii. Weight of empty dish + filter paper + air dry soil – b gms

iii. Weight of empty dish + filter paper + wet soil – c gms

It was calculated thus:

$$\text{Saturation Moisture \%} = \frac{(c - a)\ (b - a)}{(b-a)} \times 100$$

Bulk Density: The method used to find out bulk density was the coring method. This was done by oven drying of the collected undisturbed core soil samples to a constant weight at the temperature of 105°c and divide by the oven dried weight by the volume of the core sampler.

BD (Mgm^{-3}) = Weight of oven dry soil (Mg)/Volume of soil in core samples (m3)

Total Porosity: Total porosity was derived from the relationship of particle density to the Bulk density using the formula

Percentage pore space = $[1 - Db/Dp\ ] \times 100$

Where each represents a property of the soil

Db = Bulk density

Do = Particle density taken as 2.65Mgm-^{3} in mineral soils

3.4.2 Soil Chemical Analysis

Total Nitrogen: This was determined by micro kjedahl method (Bremmer and Malvaney, 1982).

Organic Carbon: It was determined by wet dichromate acid oxidation method (Nelson and Sommers, 1982).

Soil pH: The pH was determined using 1:1 soil to water suspension and a glass electrode pH meter (Mclean, 1982)

Exchangeable acidity: This was extracted from a soil by 1 NKC1 (Thomas, 1982).

Exchangeable bases: (Ca, Mg, K, Na) were extracted within NH_4OAc buffered at pH 7. Ca and Mg were determined by ethylene diaminetetracetic acid (EDTA) titration while Na and K were determined using flame photo meters.

Effective Cation Exchange Capacity (ECEC): This was determined by the summation of exchangeable base and exchangeable acidity (Anderson and Ingram, 1993).

Base Saturation (BS %): Also known as percentage base saturation, it was calculated as the sum of the exchangeable base divided by ECEC multiplied by 100.

Extractable micronutrients: (Fe, Cu, Mn and Zn) were obtained by leaching the soil with 0.1 HCl and the concentration of the element determined by the atomic absorption spectrophotometer.

Available micronutrients were obtained by leaching the soil with 0.1 NHCl and the concentration of the elements determined by the Atomic Absorption Spectrophotometer (AAS) (Lindsay and Norwell, 1978).

3.4.3 Soil Biological Analysis

Biological analysis show or represent the measure to which organic materials are present in the soil. Heterotrophic bacteria and fungi counts within the gotten soil samples were estimated by spreading aliquots (0.1ml) of decimal serial dilutions of the soil samples onto duplicate nutrient agar plates (pH 7.2). Fungal count was determined using potato dextrose agar (pH 4.5) containing antibiotics to suppress bacterial growth. The decimal serial dilutions of soil samples were subsequently made with sterile mineral salts and aliquots (0.1 ml) inoculated on the mineral salts agar surface spread plate technique.

The method described by Bergey and Holt (2000) for estimating bacterial and fungal counts was used to enumerate the total visible counts of the isolates. The discrete colonies on the nutrient agar and potato dextrose agar plates were selected and counted.

The mean colony counts on the nutrient agar and potato dextrose agar plates of each given dilution was used to estimate the total viable count for the samples in colony forming units per gram (Cfu/g).

3.5 Statistical Analysis

The descriptive and inductive statistical methods were applied in this research. Primary data collected from the laboratory were subjected to statistical analysis using the SPSS 16.0 version. Range, Mean, Standard Deviation and Coefficient of Variability (CV) were computed for all soil parameters in all the profiles. Variability, which gives a normalized measure of spread about the mean value was assessed using Wilding (1985) and classification scheme in which CV value of <15, 25 to 35 and >35% indicated least, moderate and high variability respectively. The higher the CV, the more variable the soil parameter.

Means were separated using LSD at 5% level of probability. A graphic representation of soil fractions across the profiles was made using indicators of the fertility and erodibility of the studied areas. A test to determine if significant relationship existed between the soils physical and chemical properties was done using the Pearson's

CHAPTER FOUR

RESULT AND DISCUSSION

4.0 Introduction

In this chapter the focus is on data representation through tables, interpretation and discussion of findings. The tables would be on the morphological, physical and chemical properties of the soils in study.

4.1 The Study Site

Table 4.1 Location of study sites

Profile sites	GPS coordinates	Curvature	Elevation	Vegetation	Parent material
Idunowina	N06° 23’53.3 E05° 37’53.0	Straight	94m asl	Deforested	Sedimentary rock
Uniben	N06° 25’51.0 E05° 36’39.7	Convex	128 asl	Deforested	Sedimentary rock

Source: Author's fieldwork 2023

The land features of the area are shown in Table 4.1, the study area can be described as the tropical rainforest which belong to the Af category of Koppen's climatic classification (Ekpenkhio, 2022) and can be considered to be area of growing season all the year round. The hot climatic condition Ugwa et al (2016a) described the area of having an average of 120 rainy days annually and could reach up to 140 rainy days in some years, with temperature range of 19 °C to 34 °C. The implication of this climatic figures is that there is evidence of drill erosion and traces of that of sheet. In some areas especially that of Idunowina, there were incisions with depth to an average of 12 to 200 cm in length measurements of sheet erosion. It was observed that the vegetation of the study area has been a function of anthropogenic activities, therefore covered with varieties of grass species and few trees. The variety of plant covers are *Elaesis guineensis* , *Theobroma cocoa, Zea mays, Pueraria phaseloides* and *Centroseme pubescent.* The leguminous covers in the fallow area is essential for maintenance of soil fertility and soil conservation.

The study area is on a hill summit in Uniben and is at sea level in Idunowina. According to Obi et al (2020) summits are characterized with mass movements depending on slope elements and curvatures. Soil texture may also be a factor. Sandy nature of the topsoil as in the case of Uniben often gives way to high infiltration and greater high porosity paving the way to mass movement with its attendant effects such as erosion. The average steepness of the areas is about 12% and consist of unconsolidated medium grain sands portraying them to be subjected to wind and water erosion and flooding.

The parent material material is of sedimentary geological deposits which Akamigbo and Asadu (1983) reported as comprising of subangular, medium grained sandstone and poorly sorted coarse grains. Thus, the area is dominated with weak structure at Uniben site and moderate structure at the Idunowina study area. Field observation, however, showed that there were some patches of degraded areas. It is assumed that the parent material is Uniform in the Study areas since they are have sedimentary origin. (Brady and Weil, 2002) had defined parent material in which a soil is developed and soil profile begins to form. The influence of parent material on soil has been investigated by Buol et al. (2003) as a major soil forming factor that influences the physical and chemical properties of the soil.

4.2 Morphological Properties

4.2.1 Colour

The soils of the study area have varied colours but are predominantly red at Idunowina area and brown at Uniben. This implies that the soil colour is related to specific properties of the soil. Soil Survey Staff (2014) reported that red and yellow colours indicate the presence of free oxides of iron while organic matter presents brown and dark colouration. The morphological characteristics of the study areas are shown in Table 4.2. The colour (dry) of soils in Idunowina is majorly weak red colour (2.5YR4/2) at the topsoil, while the subsoils is generally a red coloured. In Capitol, located within the Uniben the top soil and immediate sub soil had a colour of dark reddish brown (dry) (2.5YR3/3) and (2.5YR3/4) respectively and subsequently the horizon at 37-73 cm, 73-125 cm, 125-180 cm had colours of reddish brown (2.5YR4/4), yellowish red (5YR4/4) and red (2.5YR4/8) respectively.

Soil colour is mostly affected by iron oxides and soil organic matter (Rowell, 2004). The dark colouration of the soil also helps to point at the presence of organic matter and well aerated soil as that is the only way microorganisms can survive. The table 4.2 shows that there are differences between the colour of soils when dry and when it is moist. It shows therefore that soil colour is moisture dependent. Soil colour depend on humidity of the area and some red tropical soils when stored in a cool humid environment tend to lose some of their redness and assume a yellowish red colour. Therefore, it is absolutely important to state the moisture state (dry or moist) when indicating the colour of a soil.

The dominant hue of Idunowina is 2.5YR. It is the dominant spectral colour of the area and it is the attribute that distinguishes a colour from one another. It is the quality that distinguishes red from reddish brown. Value is the quality of light intensity while Chroma refers to the purity of the hue in the soil. The soil colour of Uniben is mostly brown with dark reddish brown colour in the topsoil. It is 2.5YR3/3 and 5YR3/2, dry and moist respectively. It is observed that in Uniben there were quite a lot of differences in the estimates of the value and chroma of the soils. This is not the case in the Idunowina soils. This observation tallies with the reports of colours in the works of Brady and Weil (2002). There were very few medium distinct mottled at the epipedon in the Idunowina summit soils and in between 37-73 cm (endopedon) in the Uniben soils. This is as a result of redox-reduction reaction in the soil occasioned by poor aeration in the horizons.

Table 4.2 Morphological Properties of soil

Horizon	Depth (cm)	Colour dry	Colour moist	Mottling	Texture	Structure (moist)	Consistency	Boundary	Others
IDUNOWINA									
Ap	0-4	2.5YR4/2 (Weak red)	2.5YR2.5/2 (Very dusky red)	f, fn	LS	1, f, g	l	g, w	many roots
Bw_1	14-35	2.5YR3/2 (Dusky red)	2.5YR3/2 (Dusky red)	f, fn	SiL	1, c, abl	fr	c, s	deposits of palm
Bw_2h	35-70	2.5YR3/4 (Dark reddish brown)	2.5YR3/4 (Dark reddish brown)	-	C	2, c, abl	fr	c, s	wall cracks
Bw_3h_2	70-117	10R 4/6 (Red)	10R 3/6 (Dark red)	-	C	2, c, abl	fr	c, s	few roots
Bw_4	117-165	2.5YR 3/6 (Dark red)	2.5YR 2.5/4 (Dark reddish brown)	-	C	2, m, sbk	f	c, s	few coarse roots
Bw5	165-180	2.5YR 4/6 (Red)	2.5YR 3/6 (Dark red)	-	C	2, m, sbk	f	-	animal burrow
UNIBEN									
Ap	0-20	2.5YR 3/3 (Dark reddish brown)	5YR 3/2 (Dark reddish brown)	-	SL	1, m, sbk	f	d, b	many fine roots
Bw_1	20-37	2.5YR¾ (Dark reddish brown)	2.5YR 2.5/4 (Dark reddish brown)	-	SC	1, f, sbk	fr	a, w	fewer roots
Bw_2	37-73	2.5YR 4/4 (Reddish brown)	2.5YR 2.5/3 (Dark reddish brown)	f, m	SL	1, f, sbk	fr	c, s	rabbit hole
Bw_3	73-125	5YR 4/4 (Yellowish red)	2.5YR 2.5/3 (Dark reddish brown)	-	CL	2, m, abl	fr	c, s	charcoal deposits
Bw_4	125-180	2.5YR 4/8 (Red)	10R 3/6 (Dark red)	-	C	2, m, abl	fr	-	medium pores

Key:
Mottling: f= few, fn= fine, m= medium
Texture: C= clay, CL= clay loam, LS= loamy sand, SC= sandy clay, SL= sandy loam, SiL= silty loam
Structure: 1-weak, 2= moderate, c= coarse, f= fine, m=medium, abl= angular blocky, g= granular, sbk = sub angular blocky,
Consistency: f= firm, fr = friable, l = loose
Boundary: a= angular, b= broken, c= clear, d= diffuse, g= gradual, s= smooth, w= wavy

4.2.2 Structure and Consistency

The structure which is the aggregate of individual soil particles into large units (Buol et al., 2003) ranges from weak, fine, granular on topsoil to moderate, medium, sub-angular at the subsoils. At Uniben the structure ranges from weak to moderate and also from sub-angular blocky to angular blocky in Structural type. This is in consonance with the work of Onweremadu (2007), Ugwa et al. (2017) and Ekpenkhio (2020).

The Consistency (moist) at Idunowina progressed from loose, friable to firm at the subsoil, while that of Uniden is firm at the topsoil, becoming friable at the Subsoil. It seems that this loose consistency allows air and water to drain freely in the horizon. The dominant friable Consistency at Uniben shows that the genetic horizons are rich in Carbon which Ugwa et al. (2017) observed that it is good attribute for growing Variety of plants. Nsor and Ibanga (2008) is of the opinion that friable onsistency is the right balance in terms of drainage, the soil Should be well tilled where the consistency is firm when wet to allow good exchange of our and moisture this will help decrease the bulk density of the soil.

4.2.3 Boundary and others

The lowest horizon thickness in Idunowina topsoil (0-14 cm) while the largest is between 70-117 cm (dark red) and 117-165 cm (dark reddish brown). The boundaries of these two genetic horizon are clear and smooth in Idunowina and diffuse, abrupt and wavy in the upper horizon while in the lower horizon it is clear and smooth. These are some of the indications of the development and formation of the soil horizon. The horizon boundary characteristics maybe as a result of the high organic matter content in the Ap horizon. Common ant holes and wall cracks, as well as fine roots are indication of faunal pedoturbation. The deposits of Coal and some artefacts is an indicator of human activities in the area.

4.3 Physical Properties

The physical properties of the soil of the study areas are shown in table 4.3. Most part of Southern Edo state is made up of sedimentary geological deposits made up of coastal plain sands and sand stones, the topography of the entire area generally gently undulating. The profiles are deep to very deep exceeding More than 200 cm, the areas are moderately well drained to well drained. The climatic environmental condition of the area favour deep weathering and leeching to the extent that drainage of the Soils is influenced by the nature of the materials mainly of quartz sands. The texture of the foils is highly clay to sandy clay and clayey loam. Biswas and Mukherjee (1994) and Ukaegbu and Ugwa (2020) had reported that the texture of a soil is a reflection of the parent material. The sand fraction ranges from 50 gkg^{-1} to 750 gkg^{-1} in the area, it seems that Idunowina site has the lowest value of sand fraction (50 gkg^{-1}), the implication of this is that the soils in Idunowina is mostly clayey and that of Uniben varies from Sandy-loam to clay-loam . Silt and Sand particles are primarily of partial weathered primary mineral which constitutes the skeletal soil fabric and influences properties of clay fraction (Biswas and Mukherjee, 1994), silt can therefore be regarded macro sand according to Ugwa et al (2017). The silt fraction ranges from 50 to 100 gkg^{-1} in Idunowina soils, while that of Uniben is from 100 to 400 gkg^{-1}. The proportion of silt tend to fluctuate down the the profile, the high value of silt in the site may be due to be transformation of silt to clay.

An outstanding feature of the study are irrespective of the locations is the high silt content (a mean of 180 and 325 gkg^{-1} at the Uniben and Idunowina respectively) and 200 gkg^{-1} at the epipedon. This observation distinguishes the silt content of the study area from our sedimentary soils of mid western region of Nigeria. This may suggest that there is a transformation of sand fractions to that of silt in a marked weathering and pedogenetic processed in the area

Table 4.3 also shows the range value of silt from 50 to 900 gkg^{-1} it seems that there must have been presence of anthropogenic activities in the past that gives most of the soils a high value of clay. The mean value of clay are 320 and 500 gkg^{-1} in Idunowina and Uniben respectively. This meant that clay having a large specific surface area must be the most reactive fraction of the soil that determines the physical and Chemical properties. Soil drainage and conservation are important management practises that can be applied to this area and so is the case of fertilizer application. The clay value is mostly high, it suggests that the horizon are influenced more by soil wethering, transportation and transformation in the soil. Therefore elluviation and alluvcation process hove taken place resulting in high clay content in the B horizon. The movement of clay fraction is aided by high temperature and moisture and may makes it possible for leaching to take place. This high clay and silt content may not be impediment to crop production, tillage operation as planting of leguminous plant may suffice. Figures 4.1 and 4.2 shows the multiple line graph of clay, silt and sand of the profiles of Idunowina and Uniben respectively.

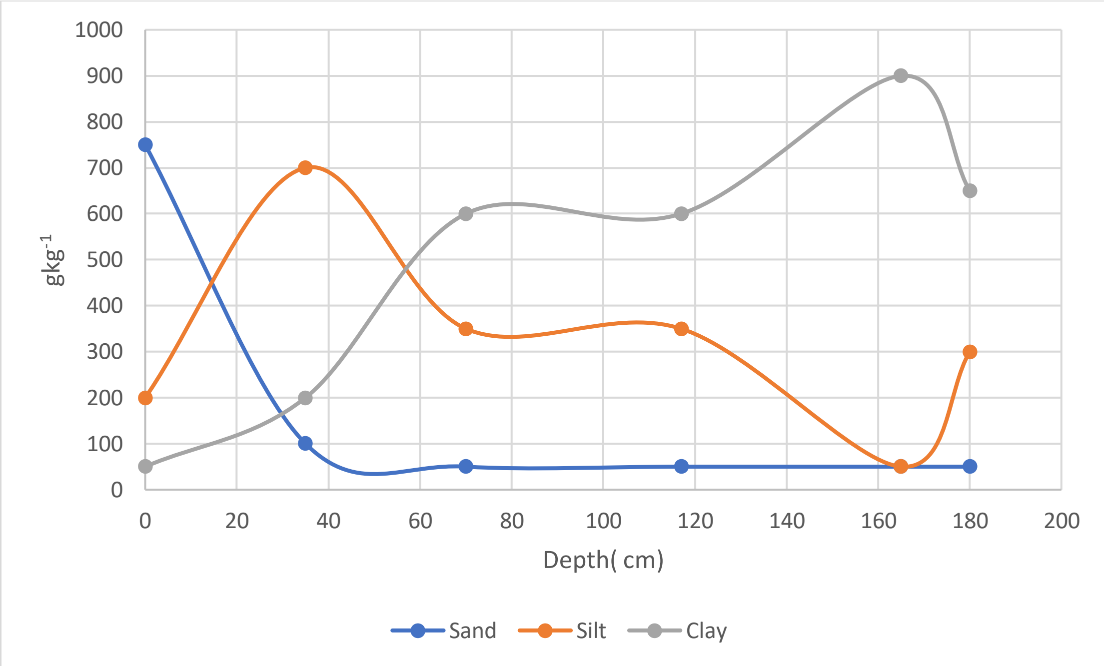

Fig 4.1 A multiple line graph showing proportion of sand, silt and clay in profile of Idunowina soils

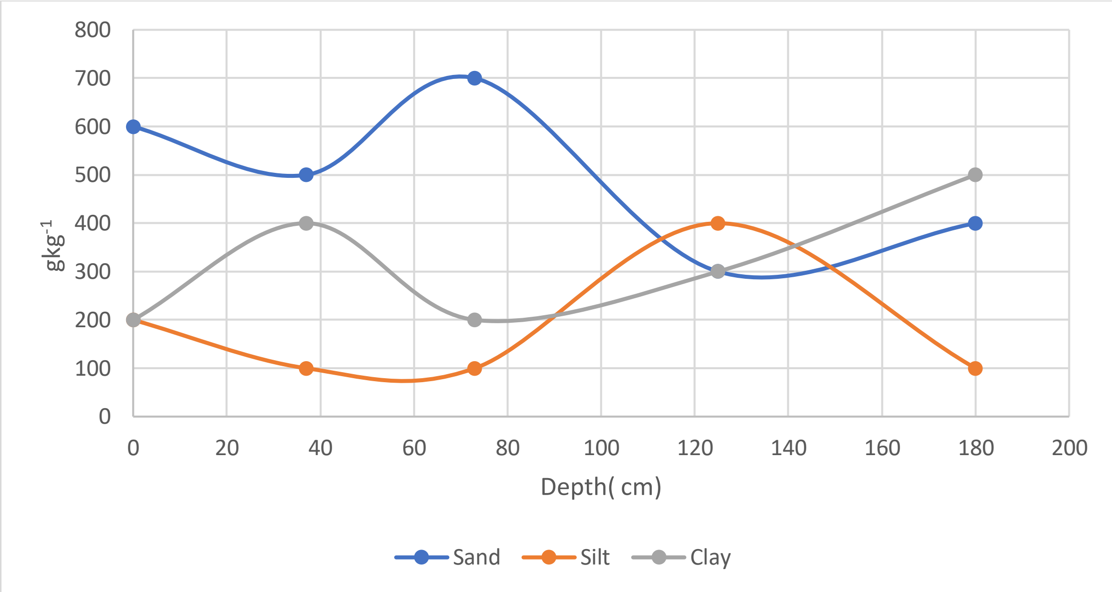

Fig 4.2 A multiple line graph showing proportion of sand, silt and clay in profile of UNIBEN Soils

At Idunowina, the sand was highest at the Ap horizon and falls drastically the at about Bw1 horizon and became constant. The silt has no particular pattern while clay continuously rises and shows curve between 80 and 140 cm which is to show a clay activity. It was about a little bit down the AP horizon that the sand intercepts the silt fraction, this might be the place that the sand transform into silt fraction.

Table 4.3 Physical Properties of soil

Depth (cm)	Sand (gkg^{-1})	Silt	Clay	Silt/Clay Ratio	EI	WHC (%)	BD (Mgm^{-3})	Total Porosity (%)	Texture
IDUNOWINA									
0-14	750a	200bc	50c	4.00a	19a	60c	1.56a	41.13c	LS
14-35	100b	700a	200c	3.50a	4b	80b	1.38b	47.92b	SL
35-70	50b	350b	600b	0.58b	0.66b	84ab	1.31c	50.5a	C
70-117	50b	350b	600b	0.58b	0.66b	90a	1.38b	47.92b	C
117-165	50b	50c	900a	0.05b	0.11b	80b	1.42b	46.41b	C
165-180	50b	300b	650b	0.46b	0.61b	82b	1.39b	47.54b	C
$\bar{x}$	175	325	500	1.53	4.17	79.33	1.41	46.90	
SEM	115.3	88.3	128.5	0.71	3.04	4.153	0.034	1.278	
σ	282.4	216.2	314.6	1.74	7.40	10.17	0.08	3.130	
CV	161.4	66.5	62.9	113.8	177.8	12.82	5.925	6.673	
LSD	213.3	163.3	239.7	1.314	5.624	7.683	0.063	2.364	
UNIBEN									
0-20	600ab	200b	200b	1.00a	4a	64c	1.31c	50.57a	SL
20-37	500b	100b	400ab	0.25b	1.5bc	78b	1.47a	44.52c	SC
37-73	700a	100b	200b	0.50b	4a	96a	1.38b	47.92b	SL
73-125	300c	400a	300a	1.33a	2.33b	80b	1.39b	47.54b	CL
125-180	400bc	100b	500a	0.20b	1c	80b	1.38b	47.92b	C
$\bar{x}$	500	180	320	0.66	2.57	79.6	1.39b	47.67	
SEM	70.7	58.3	58.3	0.220	0.623	5.1	0.025	0.946	
σ	158.1	130.4	130.4	0.49	1.39	11.4	0.06	2.12	
CV	31.62	72.44	40.75	75.06	54.27	14.26	4.101	4.438	
LSD	130.8	107.9	107.9	0.407	1.153	9.9	0.046	1.750	

Key:

BD= Bulk density, WHC= Water holding capacity, EI= Erodability Index

Texture: C= Clay, LS= Loamy Sand, SC= Sandy Clay, SiL= Silty Loam, SL= Sandy Loam. ***Source: Author's field work 2023***

However, at the Uniben site the sand was the highest soil fraction. A Cursory look at the graph shows that it has no definite trend but has its peak the 70 cm soil depth which seems to be at 700 gkg^{-1}. The Clay fraction rises from the 37 cm depth to the 180 cm depth, showing a bump between Bw2.

Silt/Clay ratio, Erodability Index and WHC

Evaluation of the stages of soil development is essential at predicting soil fertility. Silt/clay ratio (Stewart et al. 1970; Ajobeye et al., 2015) is one most common tools to measure the intensity of weathering. One striking point in the study shows that the silt/clay ratio is greater than 0.15. Indicating that the soils are relatively young with a lot of weatherable minerals. Idunowina is less subjected to severe weathering than Uniben soils. Ajiboye et al, (2015) reported that the silt /clay is >0:15 to younger soils, <0.15 in old soils and 0.15 in moderately weathered sols. It was however observed that in Idunowina the weathering ratio value of silt/clay was higher in the Surface than the Subsurface soil while in Uniben it had no constant pattern. It was also seen that the ratio was higher epipedon (topsoil) than the endopedon (Subsoil). It is also surprising that with low clay content the silt/clay ratio shows the importance of clay in weathering.

Erodability index describes the intensity as well the duration of rainfall in a given area. It gives the impression of susceptibility of the soil to be eroded. At Idunowina site the erodability index ranges from 19 in top soil to 0.11 in the subsoil, with a mean value of 4.17 while at Uniben it ranged from 4 at the topsoil to 1 at the subsoil with a mean of 2.57. From from the table 4.3, it is seen that the erodability index at the surface is higher than the critical value of 1.0 but lower than 1.0 at the subsurface, while at Uniben across the profile depth it is higher than 1.0, enabling for high tendency of erosion across all horizons, as soils with erodability index value higher than critical value of 1.0 are easily eroded (Kinell, 1981). It could be seen that in Idunowina the erodability is more in the surface area than in the subsurface area whereas in Uniben it has no pattern but seem to be high between 60 and 80 cm Soil depth. This susceptibility to erosion might be sue to low organic Soil, anthropedological activities in the soil. This goes to confirm that there is significant differences ($P<0.05$) between the surface soil and the sub soils at Idunowina and similarly to Uniben.

Water holding capacity

The water content of the soil could be said to be moderate to high in the study area. This is the extent of limit of percentage of available water held wilting between field capacity(FC) and permanent wilting points(PWP). The water holding capacity

(WHC) ranges from 60-96% and has a mean value of 79.33% and 79.6% at Idunowina and Uniben respectively. This high value is because of the texture of the soil which is majorly clay. It seems that the high level of clay content at the subsoil may have negative effect on the crops, soil drainage may be an option to this especially in the rainy season. There is a Significant difference ($P<0.05$) between the topsoil and the subsoil indicating that the topsoil has a significant content of sand fraction than in the subsoil (Table 4.3). In brevity there is no significant difference among the genetic horizons in the subsoils of both sides.

Bulk Density

Brady and Weil (2007) defined bulk density of the soil as the mass of unit volume of dry soil. The bulk density range from 1.31 -1.56mgm^{-1} at Idunowina area with a mean of 1.41mgm^{-1}, at Uniben it came from 1.31-1.47mgm. It is noted that the topsoil of Idunowina has 1.56mgm^{-1} while that of Uniben has 1.31mgm^{-1}. It is not surprising therefore, there is significant difference between the epipedon and endopedon. In both sides, the bulk density show no definite pattern of occurrence and this be due may due to the sorting out of finer materials down the profile. The range of compact of the soil was generally moderate and constitute hindrance to root penetration. The bulk density value obtained in the study was less than 1.8mgm a value considered not to be permissible limit for root penetration (Ugwa et al., 2017; Osujieke et al., 2018). Subsoils with high bulk density have low pore space and aeration is restricted for agricultural productivity.

The total porosity value was satisfactory having a range of 41.13 - 50.50%. Akinsaya (2015) noted that unsatisfactory soils have less this 40% total porosity, while satisfactory soils have more than 40% total porosity. Any soil volume that has less than 30% total porosity is poor and may not be good for tuber crops. It can be inferred from the soil sites that the area is favourable to good aeration that and free water movement and that the significant variation among the study site and across the soil layer maybe attributed to the variance of soil organic matter concentration and macro faunal activities .

Variations in physical properties of the soil

From the table 4.3, coefficient of variability can be seen across the table for the different properties of the two profiles of Idunowina and Uniben respectively. Coefficient of variability is least when it is below 15%, it is moderate when it is between 15-35% and high when above 35%. From the values, it is seen that the sand, silt and clay have high coefficient of variability. This variation can be as a result of translocation and deposition. of other materials over time. It is also seen that the WHC, BD and TP have least vanation as they hove a variability coefficient of 12.82, 5.925 and 6.673 respectively. In the Uniben area, the variation is notelably moderate under the sand property and high under silt and clay. The variation of sand in the Uniben site is moderate because of its location on a hill summit, unlike the Idunowina area where new materials are often translocated to, the presence of sloped summit enables the movement of sand away area and little or sand materials are added over time that can bring about variation across profile depth.

4.4 Chemical Properties

The chemical properties of the soils are presented in the table 4.4. Soil pH is a measure of acidity or basicity of a soil. Soil pH is a key characteristic that can be used to make informative analysis both quantitative and qualitatively regarding soil characteristics. The soil pH is notably high (8.3) moderate alkaline at the topsoil in Idunowina and in Uniben (7.5) slightly alkaline. The pH range in the study sites is between 5.4 and 8.3. These values show the nature of trace elements differences (Agbede, 2012). This alkaline nature shows the influence of human activities. The areas were deforested and minor farming activities had taken place. Burning has been known to also increase soil pH. The pH value might as well be as a result of the leaf falls and human waste that when decomposed releases the aggregation of H+ and Al+ in the sites.

Exchangeable acidity (EA) ranges from 0.010 to 00.020 $cmolkg^{-1}$ across the study areas. The EA at the topsoil of Idunowina has the least value but increases with depth. There was no definite pattern in the acidity is Uniben site. EA is mostly due to the presence of exchangeable hydrogen and aluminium ions (Onwuka, 2016). The value range of EA has shown that EA is a major contributor to soil acidity of the soil. The mean value of EA in the study area is less than 1.0% of the mean value of ECEC. This explains the relatively high level of pH in the soil. The topsoils are significantly different from the subsoils ($P<0.05$). When exchangeable acidity is high in the soil it affects the soil Condition and many processes in the soil, an example being deficiency in crops.

Organic carbon gives the estimate of the organic matter in the mineral soil (Buol et al, 1973). The range of Org. C is from 1.9 to 5.58 gkg^{-1} across the study areas. It is important to note that Org. C has a good relationship with Total Nitrogen, as an increase in Org. C will also cause an increase Total Nitrogen and this is agreement of the work of Brady and Weil (2002). Chude et al (2011) opined that when Org. C is below 4 gkg^{-1} it is to low, and this can have an adverse effect on soil organic matter and soil fertility in general. There is significant different ($P <0.05$) in the soils of Idunowina except at the middle horizon (70-117 cm). It might be due to the translocation of humic substances.

Total Nitrogen ranges from 0.19 to 0.4 gkg^{-1}. As observed by Eskhade et al (2003), this moderate value of TN can be as a result of ground cover on the study sites. The Table 4.4 Shows the Org. C to be higher then Total Nitrogen therefore encouraging the activities of microbes in order to give Nitrogen to plants. The subsoils have less nitrogen content than the topsoil and hence a significant difference ($P<0.05$) among them.

Table 4.4 chemical properties of the soil

Depth	pH	Org.c	TN	EA	Ca	Mg	Na	K	ECEC	BS	Mn	Fe	Cu	Zn	THBC	THFC
		(gkg^{-1})			($cmolkg^{-1}$)		(%)			(Mg/kg^{-1})						
IDUNOWINA																
0-14	8.3a	2.20c	0.19c	0.010c	3.0bc	0.89b	0.10c	0.12b	4.21c	99.7a	1.34c	130f	0.38d	4.8c	3.1×10^5	1.0×10^3
14-35	7.8ab	11.9c	0.17c	0.012b	2.8b	0.70c	0.10c	0.17c	3.78b	99.7a	1.26c	223e	0.41cd	4.4c	2.9×10^5	1.0×10^3
35-70	6.7b	2.44c	00.2c	0.016ab	3.1bc	0.84b	0.11c	0.19bc	4.26c	99.5a	1.30c	265d	0.46c	5.0c	3.5×10^5	1.1×10^3
70-117	5.6bc	5.0a	0.44a	0.018b	5.8a	1.36a	0.18a	0.34a	7.7a	99.7a	1.86a	310c	0.64a	8.4a	5.2×10^5	1.3×10^3
117-165	5.4c	3.02bc	0.28b	0.020a	3.4b	0.90b	0.12b	0.20bc	4.64b	99.5a	1.42bc	410b	0.64a	5.2c	3.2×10^5	8.0×10^3
165-180	5.4c	3.48b	0.335b	0.020a	3.6b	0.92b	0.12b	0.21b	4.87b	99.5a	1.46b	460a	0.56b	6.1b	3.9×10^5	9.0×10^3
$\bar{x}$	7.0	3.36	0.30	0.06	3.9	1.01	0.13	0.24	5.30	99.7	1.51	304.3	0.48	5.8	3.66×10^5	5.5×10^3
SEM	0.33	0.333	0.03	0.001	0.35	0.068	0.010	0.20	0.442	0.03	0.065	29.37	0.032	0.36	1.87×10^4	1.1×10^3
σ	1.2	1.12	0.10	0.01	0.1	0.22	0.03	0.06	1.42	0.11	0.22	120.7	0.11	1.5	3.5×10^5	3.5×10^3
CV	17.14	33.3	33.33	16.67	2.6	21.78	23.08	25.00	26.79	0.11	14.57	39.66	22.91	25.86	95.63	63.63
LSD	0.62	0.616	0.06	0.002	0.65	0.126	0.019	0.037	0.818	0.06	0.120	54.33	0.059	0.67	3.46×10^4	2.0×10^3
UNIBEN																
0-20	7.5b	5.58a	0.48a	0.013a	6.4a	1.41b	0.20b	0.38a	8.4a	99.8a	1.94a	220b	0.44b	7.4a	3.6×10^5	1.2×10^3
20-37	7.9a	3.02b	0.29b	0.012a	4.1b	1.20c	0.12a	0.25b	55.b	99.7a	1.40b	227b	0.42b	5.1b	3.4×10^5	8.0×10^3
37-73	8.0a	3.02b	0.30b	0.010b	3.9b	1.06c	0.11a	0.23b	5.31b	99.8a	1.51b	312b	0.46b	5.6b	3.6×10^5	8.0×10^3
73-125	7.5b	3.60b	0.32b	0.013a	3.9b	0.92c	0.11a	0.24b	5.18b	99.7ab	1.58b	320b	0.31c	6.0b	4.1×10^5	1.1×10^3
125-180	7.4b	33.6b	0.29b	0.014a	3.2b	1.89a	0.10b	0.19b	4.39b	99.6b	1.52b	420a	0.58a	5.5b	3.8×10^5	9.0×10^3
$\bar{x}$	7.7	3.8	0.34	0.012	4.3	1.10	0.13	0.26	5.38	99.7	1.59	308	0.446	5.9	3.7×10^5	5.46×10^3
SEM	0.12	0.47	0.036	0.006	0.55	0.100	0.018	0.031	0.69	0.04	0.092	33.1	0.043	0.40	1.18×10^4	3.64×10
σ	0.27	1.06	0.08	0.002	1.22	0.22	0.04	0.07	1.52	0.10	0.21	93.98	0.10	0.89	2.65×10^4	3.46×10^3
CV	3.50	27.89	23.53	16.66	28.37	20.00	30.77	26.92	28.43	0.10	13.20	30.51	22.42	15.08	7.16	63.37
LSD	0.22	0.87	0.067	0.0011	1.02	0.185	0.033	0.059	1.28	0.074	0.170	61.24	0.080	0.74	2.18×10^4	6.73×10

Key: EA= Exchangeable acidity, Org. C= Organ carbon, TN= Total nitrogen, ECEC= Effective cation exchange capacity

Exchangeable Bases (Ca, Mg, K, Na), ECEC and Base Saturation

Calcium are essential macronutrients, it is used in cell division and they range from 2.8 to 6.4 cmolkg^{-1} and decreases down profile with increase in the soil depth. It is the highest in the basic cations and the value is such that Ca> K > Na>Mg at Idunowina area, while at Uniben Ca > Mg> K > Ma. The range of Magnesium (0.70 to 1.89 cmolkg^{-1}) might be due to ash content of the area arising from the burning of debris as opined the work of Ugwa et al (2016b). The highest content of Ca might be due to the organic matter content as well the clay nature of the area as observed by Ugwa et al (2017). Table 4.4 indicates that Mg content is low in all the sites, while K is moderate, Na is low and ECEC is low according to Ekpenkhio (2022). The values of ECEC are lower than reported by Orimoloye and Akinbola (2013) perhaps due to the Kaolinite associated with the parent material. The Kaolinite clay minerals are associated with low ECEC in the soils of southern Nigeria. The low basic cation suggest that much periodic fertilization of the soils is essential but should be judicious. That entails that soil test should regularly done in the area. The area shows there is significant difference ($P<0.05$) between the topsoil and subsoil.

Effective cation exchange capacity (ECEC) ranges from 3.78 to 8.4 cmolkg^{-1}. In Idunowina study area, it has no definite pattern across the profile but at Uniben it decreases with increase in soil depth. The ECEC is a good indicator of soil fertility because it reflects the soil ability to supply plant with essential nutrients. The ECEC value for plant productivity tends to differ depending on the plant and its particular requirements needed for growth.

The base saturation across the two soil profiles showed a constant value range between 99.5% and 99.8%. base saturation is an Indication of soil fertility, the ease with which adsorbed minerals (cations) are released to plants depends on base saturation. The base saturation values were in agreement with the work of Aiboni (2011) and Ugwa (2016) as they reported that the BS in southern Nigeria ranges above 70-90%.

Micronutrients (Fe, Mn, Cu, Zn)

From the table 4.4 the range of the micronutrients observed across both study areas were 130 to 460 $mgkg^{-1}$, 1.26 to 1.94 $mgkg^{-1}$, 0.31 $mgkg^{-1}$ and 4.4 to 8.4 $mgkg^{-1}$ for Fe, Mn, Cu and Zn respectively. Fe showed a higher value of available nutrient in both study areas. Despite this, it is important to note that other micronutrients where of sufficient proportion within the soils. Table 4.4 showed that from the mean values of the micronutrients Fe (304.3 and 308 $mgkg^{-1}$) is high, Mn (1.51 and 1.59 $mgkg^{-1}$) is moderate, Cu (0.48 and 0.45 $mgkg^{-1}$) is low and Zn (5.8 and 5.9 $mgkg^{-1}$) is high according to the work of Ekpenkhio (2022).

Fe was observed to be high and could be due to human activities(Amhakhian and Osemwota, 2012). The micronutrients of both study areas show no definite pattern but seems to occur in the following order: Fe>Zn>Mn>Cu for both study areas. Udoh et al., (2015) reported that micronutrients like Mn and Fe often form complexes with other elements so that they can be easily utilized by plants for growth. At Idunowina there are significant differences between the AP and the various horizons down the profile for Fe, Mn, Cu and Zn. It seems that the Bw_2H_2 has significant amount of the micronutrients. At the Uniben site, the trend is also the same. The Bw_2 is enriched by micronutrients. Micronutrients are being given a lot of attention in southern Nigeria because of the increased trend of Introduction of many crop species as well as most fertilizers do not contain enough micronutrients in their formulation.

Variations in chemical properties of the soils

The variation in the soil pH is 17.14 while that of EA is 16.67 indicating that the variability is moderate using Wildling (1985), it is also within the critical limit of soil pH. It could be seen that EA has a contribution to the pH of the soil. Org. C and Total Nitrogen hav variability of 33.33 each which is moderate. The TN value reflects amount of organic matter on the soil. Apart from Ca which has the least variability all other basic cations are moderately variable. The least variability of Ca from Table 4.4 shows that there was no significant difference ($p>0.05$) among Ca along the Soil depth. Since the area is deforested it therefore follows that better a proportion of Ca is more in plant biomass and may not be returned readily to the soil, however these is different from the soils in Uniben that have moderate variation (28.37%). Mg is known as the central core of chlorophyll molecule in plant tissue and when it is deficient, it brings about short and stunted growth. Soil K had significant variations ($P<0.05$) across the both study areas and despite this, it was moderate in available quantity. This variation showed the effect that land uses have on soil K. Na within the soil across both study areas showed significant variation and it is important to note that although soil Na had no definite pattern in Idunowina, it gradually decreased as depth increased in Uniben.

There was little or no variation in the BS of both sites, this not surprising because there was also no significant difference ($P>0.05$) across the horizons. A soil that is moderate as observed the study area will typically have a BS greater than 80%. Among the micronutrients Fe has the highest statue variability. (39.66%) in Idunowina and (30.57%) in Uniben while Cu and Zn are moderately variable respectively. Mn having 14.57% in Idunowina and 13.20% in Uniben is the least variable. This phenomena may be as a result of leaching effect or differences in the pH values across the soil the soil horizons. It may also reflect SOM of the soil.

4.5 Biological Properties

The soil biological properties are shown in Table 4.5. The range of the THBC in Idunowina area is from 2.9 x 10^3 to 5.2 × 10^3 cfu/g while the THFC is from 1·0x10^3 to 9.0 × 10^3 cfu/g . In the Uniben area, the THBC has a range of 3.4 10^3 to 4.1 x 10^5 cfu/g , while the observed THFC range is from 1.1 x10^3 to 9.0 x10^3 cfu/g . Basah and Omorusi (2007) noted that high values of microorganism population may be attributed to the high organic matter in the soil. The medium soil structure and moderate tillage systems observed in the study areas tend to increase the microbial mass especially in the lower horizon. Brady and Weil (2002) had reported that microbes occupy the pore spaces. Plant and animals residues often give rise to high level activities of bacterial and fungal activities of the total porosity is adequate (>45%).

Table 4.5 biological properties

Depth	THBC (cfu/g)	THFC (cfu/g)
	IDUNOWINA	
0-14	3.1×10^5	1.0×10^3
14-35	2.9×10^5	1.0×10^3
35-70	3.5×10^5	1.1×10^3
70-117	5.2×10^5	1.3×10^3
117-165	3.2×10^5	8.0×10^3
165-180	3.9×10^5	9.0×10^3
$\bar{x}$	3.66×10^5	5.5×10^3
SEM	1.87×10^4	1.1×10^3
σ	3.5×10^5	3.5×10^3
CV	95.63	63.63
LSD	3.46×10^4	2.0×10^3
	UNIBEN	
0-20	3.6×10^5	1.2×10^3
20-37	3.4×10^5	8.0×10^3
37-73	3.6×10^5	8.0×10^3
73-125	4.1×10^5	1.1×10^3
125-180	3.8×10^5	9.0×10^3
$\bar{x}$	3.7×10^5	5.46×10^3
SEM	1.18×10^4	3.64×10
σ	2.65×10^4	3.46×10^3
CV	7.16	63.37
LSD	2.18×10^4	6.73×10

Source: Author's field work 2023

The high organic matter (3.02 to 3.60 gkg^{-1}) in the lower horizon is as a result of roots and animal remains and nutrient cycling. It was no surprise that most of the basic cations are higher in values on the subsoils. It is noted that the bacterial population 3.60 x 10 cfu/g exceed the the fungal Court 5.5 x 10^3 cfu/g . This observation Suggests that there is greater variety of nutritional types of bacteria In a given any other type of microbes.

There is a wide variation in the be THBC at Idunowina (95.62%) and Uniben (7.16%). This variability in the bacteria count shows a nature about of Spread about the mean value, it also shows the significant differences ($p<0.05$) of OM across the soil depth .Indeed high organic matter is high in the Bw_2H_2 horizon and this value is high in Org. C ensuring that there will be proliferation of bacteria (5.2 x 10^3 cfu/g). The fungal Count in the study soils shows that the variability in fungi is high (>35"). Fungi is high in the surface soil than the subsoil (Brady and Weil, 2002). The biological population of deforested areas and hill summits is bound to be significantly lower than in the secondary forest (Birkeland, 1974). Organic matter and a suitable micro climate support bacterial abundance.

4.6 Correlation Studies

Correlation Studies of some soil properties of Iduowina and Uniben are shown in Tables 4.6 and 4.7 respectively. At Idunowina, the correlation study shows 49 pairs of high significance at a level 0.01 significance, of which five have negative correlation. At Uniben the Study Shows 15 pairs of high significance of which two is negatively correlated. The negative correlation at Idunowina are between Sand and WHC (r = -0.940), Clay and PH (r=-0.931), EA and pH (r = -0.991), Fe and pH (r = -0.919) and Cu and pH (r = -0.942). The other foil properties that ps are positively significantly correlated, this shows that as one parameter is rising, the other parameter is also increasing. The significant relationship between these properties shows the importance of these properties in the availability of nutrients. The negative high significant relationship between soil and WHC can be explained on that sand has larger pores. and as such little water can be held in the soil and also the negative relationship (r = -0.991) manifests that EA correlates little to the pH value of the to soil. It is shown that the THBC is positively and highly correlated with the basic cations as well as total organic matter. This explains how bacteria depend on carbon for it's survival.

	SAND	SILT	CLAY	WHC	BD	TOC	TN	EA	PH	SOM	Ca	Mg	K	Na	Fe	Cu	Mn	Zn	THBC	THFC
SAND	1																			
SILT	-0.225	1																		
CLAY	-0.743	-0.485	1																	
WHC	-0.940**	0.255	0.669	1																
BD	0.901*	-0.394	-0.538	-0.885*	1															
TOC	-0.396	-0.222	0.508	0.612	-0.219	1														
TN	-0.417	-0.262	0.554	0.611	-0.214	0.997**	1													
EA	-0.743	-0.419	0.955**	0.694	-0.503	0.637	0.686	1												
PH	0.719	0.415	-0.931**	-0.711	0.468	-0.733	-0.777	-0.991**	1											
SOM	-0.395	-0.222	0.507	0.611	-0.218	1.000**	0.997**	0.636	-0.733	1										
Ca	-0.302	-0.107	0.344	0.570	-0.181	0.966**	0.944**	0.448	-0.562	0.966**	1									
Mg	-0.137	-0.267	0.307	0.418	-0.032	0.942**	0.919**	0.398	-0.514	0.942**	0.976**	1								
K	-0.111	-0.145	0.199	0.408	-0.024	0.918**	0.887*	0.299	-0.422	0.918**	0.980**	0.990**	1							
Na	-0.384	-0.116	0.425	0.635	-0.254	0.968**	0.949**	0.509	-0.617	0.968**	0.994**	0.960**	0.958**	1						
Fe	-0.723	-0.306	0.859	0.600	-0.443	0.484	0.547	0.948**	-0.919**	0.485	0.263	0.189	0.100	0.318	1					
Cu	-0.617	-0.454	0.866	0.656	-0.314	0.814*	0.850*	0.899*	-0.942**	0.814*	0.698	0.659	0.585	0.750	0.788	1				
Mn	-0.256	-0.182	0.355	0.511	-0.097	0.976**	0.961**	0.471	-0.586	0.976**	0.993**	0.981**	0.977**	0.983**	0.301	0.727	1			
Zn	-0.319	-0.125	0.372	0.576	-0.199	0.985	0.968	0.509	-0.616	0.985**	0.986**	0.965**	0.959**	0.976**	0.346	0.705	0.985**	1		
THBC	-0.344	-0.066	0.354	0.614	-0.288	0.957**	0.934**	0.486	-0.587	0.957**	0.966**	0.943**	0.939**	0.956**	0.309	0.642	0.950**	0.987**	1	
THFC	0.220	-0.164	-0.084	-0.467	0.487	-0.360	-0.296	0.008	0.042	-0.358	-0.503	-0.499	-0.521	-0.518	0.281	-0.087	-0.409	-0.450	-0.551	1

Table 4.6 Correlation matrix of some soil properties in Idunowina

* = correlation is significant at the 0.05 level (2-tailed)

* = correlation is significant at the 0.01 level (2-tailed)

	SAND	SILT	CLAY	WHC	BD	TOC	TN	EA	PH	SOM	Ca	Mg	K	Na	Fe	Cu	Mn	Zn	THBC	THFC
SAND	1																			
SILT	-0.606	1																		
CLAY	-0.606	-0.265	1																	
WHC	0.223	-0.243	-0.027	1																
BD	-0.250	-0.216	0.520	0.369	1															
TOC	0.123	0.240	-0.389	-0.824	-0.815	1														
TN	0.291	0.226	-0.579	-0.754	-0.777	0.967**	1													
EA	-0.730	0.303	0.582	-0.686	-0.209	0.439	0.219	1												
PH	0.644	-0.454	-0.326	0.613	0.508	-0.572	-0.361	-0.927*	1											
SOM	0.122	0.241	-0.389	-0.824	-0.816	1.000**	0.967**	0.440	-0.573	1										
Ca	0.414	0.141	-0.643	-0.713	-0.608	0.873	0.962**	0.040	-0.129	0.872	1									
Mg	0.590	-0.191	-0.524	-0.596	-0.295	0.643	0.773	-0.155	0.191	0.642	0.905*	1								
K	0.374	0.181	-0.635	-0.730	-0.578	0.864	0.955*	0.055	-0.134	0.864	0.998**	0.902*	1							
Na	0.387	0.084	-0.554	-0.768	-0.639	0.913*	0.974**	0.137	-0.213	0.913*	0.991**	0.894*	0.985**	1						
Fe	-0.462	-0.139	0.699	0.461	0.169	-0.496	-0.681	0.310	-0.309	-0.495	-0.848	-0.896*	-0.864	-0.782	1					
Cu	-0.591	0.125	0.591	0.152	-0.162	-0.127	-0.352	0.580	-0.657	-0.126	-0.592	-0.798	-0.606	-0.513	0.910*	1				
Mn	0.215	0.298	-0.558	-0.695	-0.890*	0.976**	0.974**	0.288	-0.489	0.976**	0.879*	0.617	0.867	0.899*	-0.522	-0.157	1			
Zn	0.196	0.372	-0.610	-0.674	-0.876	0.959	0.970	0.253	-0.465	0.959	0.883	0.609	0.875	0.891*	-0.558	-0.190	0.995	1		
THBC	0.144	0.328	-0.503	-0.768	-0.842	0.989**	0.980**	0.357	-0.527	0.989**	0.890*	0.635	0.884*	0.913*	-0.543	-0.169	0.994	0.989	1	
THFC	0.240	-0.840	0.550	0.578	0.537	-0.681	-0.710	-0.276	0.452	-0.681	-0.652	-0.332	-0.680	-0.608	0.540	0.187	-0.730	-0.786	-0.756	1

Table 4.7 Correlation matrix of some soil properties in Uniben

* = correlation is significant at the 0.05 level (2-tailed)

* = correlation is significant at the 0.01 level (2-tailed)

At Uniben, the trend in THBC and the basic cations show the same like that of Idunowina. The negative high significant relationship is between Mn and BD (r = -0.890) and EA and pH (r = -0.927). Manganese is important in the metabolic rules on plant cell and provides energy for photosynthesis, therefore it seems that it's adequate amount negate the high value of BD. Also the negative significant relationship of EA Signifies that it's contribution to soil pH is less as in Idunowina. The exchangeable cations have positive correlation with bacteria. It has been established on the humid tropical soils that clay particle migrate from top soil to subsoil and as a result of its large surface area retains basic cations (Brady and Weil, 2002).

4.7 Soil Classifications

The main purpose of soil classification is to remember the purposes of the soils being classified and predict the properties of the soil classified. It also makes us to know the relationship among different types of soil and estimate the productivity of the soil. Based on the USDA soil taxonomy (Soil Survey Staff, 2014) the soils in the study area meet the requirement for placement in the soil order, Inceptisols. Inceptisols are embryonic soils with few diagnostic horizons and have available water for plants in more than half the year. The study areas have soil temperature regimes as Isohyperthermic which implies that the mean annual soil temperature is above 22 ^{0}C and the main temperature is less than 6 ^{0}C at a depth of 50 cm. it has eudic regime and can be placed in soil order of Udept. Soil moisture are closely related to rainfall pattern and hydrology of the area (Kamalu et al., 2002). The soils has been classified as Eutrudept because of their characteristic wetness and have base saturation (by 1 M NH_4OA_C) of more than 50% in the major parts as Alfisols but the base saturation is high >90% and their was no textural jump. In the WRB (World Reference Base for Soil Resources) system it can therefore be correlated with Ruptic-Alfic Eutrudept and can be correlated with our local system which is Orlu clayey (Moss, 1957). This is because it slightly acidic on topsoil and neutral at the subsoil. The difference in value of pH may be attributed to high intensity of rainfall. The range of characteristics of Kulfo and Orlu series looked alike but what distinguishes them is that Kulfo series have heavier texture within 40 cm than the Orlu series, again the colour of the Kulfo series has a hue of 5 while Orlu is less.

The classification of soils of Uniben is the same, Uniben soil is a typical Eutrudept and can be classified as Alagba-clayey in our local classification (Symth and Montgomery, 1962). The Alagba series is located at the upper slopes, the clay content are high. Vine (1956) compared Alagba and Uyo series and observed that they have similar loamy topsoil but Alagba series is much reddish than Uyo in colour. Therefore the soil at Idunowina can be classified as Ruptic-Alfic Eutrudept loamy sandy over clay Isohyperthermic (WRB); Orlu Clayey and that of Uniben is Typic Eutrudept , sandy loam over clay Isohyperthermic (WRB); Alagba series

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

From previous studies, there has been research on the profile distribution of physical properties of soil such as colour in Benin, Edo state but even with that there seem to be lack of study in the profile distribution of the chemical and biological properties of these soils. This is true for soils especially for soils at elevated grounds like the hill summits despite the fact that Edo state is generally on elevated ground. Soil chemical and biological properties play a very important role in determining the usefulness of a soil. These properties can even influence the physical properties of the soils and an example is the presence of Fe in the soil having reddish colour.

5.1 Summary of findings

1. The land area is moderately populated, the soils are deep (>180cm), porous and majorly weak red in colour at Idunowina area, and dark reddish brown at Uniben area. The soil generally is of weak, fine, angular to sub-angular in structure, and widely under the slash-burn traditional system. The soils are generally fine textured and predominantly Kaolinitic in clay origin.

2. The soils are of sedimentary origin, formed in the past with cycles of erosion and deep weathering. The major pedogenic processes are leaching, illuviation and eluviation and transformation of minerals in the endopedon. The bulk density is within the permissible limit and may not therefore pose any problem in crop production. It is highest in topsoil and reduces downward in the subsoil.
3. The project sites can be described as slightly as acidic and alkaline in reaction, having low organic matter content and how exchangeable basic cations. The ECEC was found to be generally low (4.39 – 4.87cmolkg^{-1}).
4. That these soils, exhibit suitable levels of micronutrients which enable them support plant life. Fe may actually be in excess and have adverse effect on the plants.
5. The activities of animals present such as burrowing showed that oxygen and air spaces enough in the soil to support life and other activities.
6. The total heterogeneous bacteria and total heterogeneous counts noticed within the soil, showed a high level of microbial activity. In Ap and Bw_1 horizons there are high level of bacterial and fungal activity, but it reduces as the soil depth increases.
7. The soils at the summit occurred in layers which showed very active transportation and depositing activities over the years, either by wind, water or

man. It also enabled us understand that the soils at the soils at the hill summit can be washed away leading to loss of soil minerals.

8. Significant relationship existed between the soil parameters especially SOM × Ca, Mg, K, Na, Mn, THBC, as well as THBC × Ca, K, Na.
9. Variability studies revealed that soil quality indicators in Idunowina are highly variable than the other parameters.
10. Soil colour is moisture dependent as there is a difference in value and chroma when dry and when moist.

5.2 Conclusion and recommendation

Every soil has its uniqueness which is largely influenced by the properties (biological, physical and chemical) present in it. Understanding these properties that are present in the soil can give rise to proper land use, planning and growing of the right crops that can be optimally cultivated. It can also help understand the local ecosystems present or found at these hill summits and how the soil supports their existence.

It can concluded from the soil properties vary along the soil profile and from one side to another, and that the area shows degradation. The vacation may may be as a result of varied soil forming processes and certainly not the same parent material. The soil in the study area is classified as Ruptic-Alfic Eutrudept (Orlu Clayey) in Idunowina and Typic

Eutrudept (Alagba-Clayey) in Uniben. The soil in the study area is mostly light textured but varying from sand and underlain by clay. Based on the erodability index, it can be concluded that the soil in the topsoil has high erodability an severe weathering, while the subsoils have lower erodability and weathering intensity. Although the level of plants nutrients are low they exhibit suitable levels for plant growth. It is seen that routine soil test should be undertaken in the study areas in order to ensure suitable management practises. Consequently it has necessitated the urgent need for land use planning based on the land characteristics.

Based on the land resources of the area and the secondary data source of the project site, there is the need to suggest the following recommendations:

1. The study areas have soils with very distinct and varied properties with a noteable limitation being fertility, drainage and wetness. Good water control and drainage facility will improve soil productivity.
2. The soils in this areas are fairly fertile enough to cultivate maize, cassava and some other arable crops, the addition of farm yard manure with or fertilizers can improve soil productivity in a larger scale.
3. Planting of some cover crops to avoid direct hit of sunlight should be advised, as the ground around sample site is elevated and enhances contact with sunlight.

4. The slope gradient at the hill summit can actually bring about downward water flow, resulting in erosion and washing away of soil nutrients. To this extent terraces can be built to checkmate this.
5. Clay minerals usually made up by their chemical properties which are present in these soils can be used in geotechnical engineering to stabilize soil and prevent erosion. The apparent high plasticity and swelling properties of these minerals make them effective to improve soil stability and prevent landslides.
6. In order to improve the organic matter content of the area farmers are advised to periodically follow their land as it will also stabilize aggregrate and improve nutrient cycles for sustainable agricultural production.
7. More studies on soils in hill summit areas is encouraged so as to fill the gap in knowledge and ensure adequate land use in the long run.

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