**ASSESSMENT OF SELECTED HYDROLOGICAL PROPERTIES OF SOILS IN NNAMDI AZIKIWE UNIVERSITY IFITE-OGWARI, ANAMBRA STATE, NIGERIA.**

**A RESEARCH PROJECT**

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**IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF AGRICULTURE (B.AGRIC.) DEGREE IN SOIL SCIENCE**

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**CERTIFICATION**

This is to certify that this research work entitled “Assessment of selected hydrological properties of soils in Nnamdi Azikiwe University Ifite-ogwari, Anambra state, Nigeria” was carried out by **Udoidiong, Cyprian Alphonsus** with registration Number: **2016864022,** of Department of Soil Science and land resources, Faculty of Agriculture, Nnamdi Azikiwe University Ifite-ogwari campus, Anambra State, Nigeria.

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**DEDICATION**

This research work is dedicated to God almighty, my lovely parents and siblings.

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**ABSTRACT**

*The study was conducted at Nnamdi Azikiwe University to assess some selected hydrological properties of Ifite-ogwari lowland soil. For the study, two different soil depths (0-15 and 15-30cm) were considered for the sites (upland, midslope and lowland elevation class of soils) and replicated twice. A total of 15 core samples and disturbed samples were collected and carried for laboratory analysis. Particle size distribution was carried out to ascertain the textural class of the soils and the hydrological properties considered were; bulk density, field capacity, hydraulic conductivity, total porosity and wilting point. The results obtained from the study showed no significant differences among the studied soils on its particle size distribution and soil hydrological properties. Although, lowland soils recorded a higher mean value of these parameters. Hence, lowland soils could be recommended for agricultural purposes as it indicates a positive productivity indicator.*

**CHAPTER ONE**

**INTRODUCTION**

**1.1 Background of the Study**

Soil is a natural body comprised of solids (minerals and organic matter), liquid and gases that occurs 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 (Reubens *et al.,* 2007; Williamson *et al.,* 2004).

Soil as an ecosystem of varied organisms, is also a stored house for water for both micro Flora and micro fauna activities. The proportion of water that can be stored in the root zone for crop use is significantly influenced by the soil particle size distribution, organic matter content, and mineralogical composition. Closely related to soil and water retention capacity are the soil water transmission characteristics. These characteristics determines the soil water behaviour in the rooting zone of plants and therefore the supply of water to the plant roots (Reubens *et al.,* 2007). Both Intrinsic (environment) and extrinsic (man-related) factors can significantly influence soil properties, including its hydrological conditions (Reubens *et al.,* 2007). Man-related factors such as; changing land from forest to cultivated land reduced the organic matter, available nitrogen, soil moisture and porosity while bulk density and pH were significantly increasing (Stolte *et al.,* 2006). However, additional factors, such as changes in climate (temperature and precipitation), can further influence the soil hydrological properties (Ziadat and Taimeh, 2013). These factors affect soil hydrological characteristics such as; preferential flow paths, saturated hydraulic conductivity (Ksat), macropore connectivity, root mass and water retention (Hendricks and flury, 2001, Hanson *et al.,* 2004, Williamson *et al.,* 2004). Furthermore, Deforestation and conversion to crop land and pasture in tropical regions, has important effects on hydrological processes including increased flooding and reduced drought flows (Hanson *et al.,* 2004).

Drastic yield reductions of shallow rooted crops can be caused by periodic occurrence of dry spells at critical stages of growth due to low available water holding capacity of many soils (Stolte *et al.,* 2006). Soil hydrological properties, such as soil water retention curve *(SWRC),* soil water diffusivity and soil hydrological conductivity function *(K),* are key elements for determining water retention and water movement in soils and, consequently, its accessibility for plant uptake and growth, (Hall and Olson 1991). Soil and crop properties such as soil texture, porosity (n), bulk density *(p),* vegetation types, and root structures can strongly influence the soils' hydrological properties (Reubens *et al.,* 2007). The knowledge of soil hydrological and physical processes and the associated changes and interactions through soil matrices driven by environmental and/or ecological factors needs to be continuously improved to mitigate potential adverse impacts of future land modifications on soil functioning (Stolte *et al.,* 2006). Soil hydrological properties are among the most important parameters that determine soil quality and its capability to serve the ecosystem. (Ziadat and Taimeh, 2013). Information of soil physical and hydrological characteristics are essential in the development of improved soil, water and crop management, systems. When integrated with improved crop varieties, fertilization, and plant protection, these soil characteristics can aid in the development of economically viable farming systems which can increase and stabilize agricultural production. The purpose of determining the soil physical and hydrological characteristics for the major soils is to facilitate methodological decision - making in planning development strategies and selecting appropriate land use and management practices that are concerned with care and maintenance of soil resources that underpin agricultural productivity (Stolte *et al.,* 2006). In order to develop possible adaptation measures and mitigate any negative effects on the soil, it is important to assess the hydrological properties of soils in Nnamdi Azikiwe university, Ifite Ogwari.

**1.2 Objectives of the Study**

The main objective of this study was;

* To assess some selected hydrological properties of Nnamdi Azikiwe University, Ifite-ogwari, lowland soils.

**CHAPTER TWO**

**LITERATURE REVIEW**

**2.1 Soil as an Ecosystem**

Soils are rich ecosystems, composed of both living and non- living matter with a multitude of interaction between them. Elementarily, soil is defined as the uppermost layer of the earth, on which plant grows, but this the definition is more elaborate. Soil can also be defined as the transformation product of mineral and organic substances on the earth’s surface under the influence of environmental factors operating over a very long time showing defined organization and morphology, and it is also a growing medium for higher plants and basis of life for higher plants and basis of life for animals and mankind (Manici *et al.,* 2019; Bormann and Klaassen, 2008). Definition of the soil varies according to use for which it is put. According to a Pedologist, soil is a natural body, both spatial and temporal, forms at the surface, is a result of complex biogeochemical and physical processes, capable of supporting life, and can be mapped at an appropriate scale (Castellini *et al.,* 2019). Engineers define soil as the unconsolidated material above the bedrock. Geologists define soil as the natural medium for the growth of plants on lands (Castellini *et al.,* 2019). Many a times acronym SOIL is expanded to Soul of Infinite Life (Brady and Weil, 2002; Castellini *et al.,* 2019). Soil microbiologists rightly define soil as a polis (society or community) that is “governed” by soil organisms where fungi are the “governing” organisms in forest soils whereas other microbes are the “governors” or “soil managers” in other ecosystems (Brady and Weil, 2002). According to the FAO, “Soil is a natural body consisting of layers (soil horizons) that are composed of weathered minerals, organic matter, air and water; it is a natural medium for the growth of plants” (FAO, 2016). Thus soil can be viewed as the independent dynamic body of nature that acquires properties in accordance with the forces which act upon it and land is covered with soil (Tapas and Pal, 2016). The soil as an organic material or Loose mineral which is found on the surface of the Earth, basically made up of about 25 Percent of Water, 25 Percent of Air, 45 Percent of Mineral and 5 Percent of Organic Matter (tiny living organisms, humus and sometimes plant residue) (Tapas and Pal, 2016; FAO, 2016). Differences in soils around the globe is based on its factors of formation; climate, parent material, time, relief and organism (Castellini *et al.,* 2019; SSS, 2014). There are different forms of Soils which are basically placed in classes (forms) based on their Profile, Color, Texture, Structure, and Composition (SSS, 2014). Each and Every Soil type is differently formed and they can be found in particular places on the earth’s immediate surface, deep and mid under the surface. Soils which are on the surface (Few millimeters deep) are basically exposed to the environmental factors and direct climatic factors and they are easily blown away by the wind, broken down by temperature modification, washed down by Water, human and animal activity (SSS, 2014; Brady and Weil, 2002). Deep down into the Earth, the soils are often protected from environmental and climatic factors. It is difficult for providing a number of the forms of soils we have on the earth due to the soils formed from a variety of ways and in infinite circumstances (Tapas and Pal, 2016). However, soils can be grouped according to its composition include; Silty, Sandy, Loamy, Peaty and Chalky Soils (Ikemura *et al.,* 2008). Soil ecosystem structure is constituted by dynamic interactive abiotic and biotic compartments, dependent on major key environmental factors like; sunlight and rainfall (Bruinsma, 2003). An ecosystem is a collection of organisms and the local environment with which they interact (Bruinsma, 2003). For the soil scientist studying microbiological processes, ecosystem boundaries may enclose a single soil horizon or a soil profile. When nutrient cycling or the effects of management practices on soils are being considered, the ecosystem may be as large as an entire plant community and soil polypedon system (Castellini *et al.,* 2019). By changing this balanced system, soil functions are also impaired as they are strictly dependent on this structure and biodiversity (Bruinsma, 2003).

**2.2 Soil Properties**

Soils are complex mixtures of minerals, water, air, organic matter, and countless organisms that are the decaying remains of once-living things. It forms at the surface of land – it is the skin of the earth and there are many soil properties that enables soil description and management (Tapas and Pal, 2016).

**2.2.1 Soil Chemical Properties**

Soil is a complex mixture of organic and mineral components (Balasubramanian, 2017). Soil chemical properties indicate biogeochemical processes in soils and their influence on the bioavailability, mobility, distribution, and chemical forms of both plant essential elements and contaminants in the terrestrial environment (Balasubramanian, 2017). Soil chemical properties include; soil pH, electrical conductivity, total organic carbon, cation exchange capacity and heavy metals concentration. Soil pH measures the concentration of hydrogen ion (H+) in the soils and is the major cause of soil acidity which affects the performance of crops and activities of micro-organisms (Francis *et al.,* 2020). Soil pH refers to a soil’s acidity or alkalinity and is the measure of hydrogen ions (H+) in the soil and it is one of the soil chemical properties. A high amount of H+ corresponds to a low pH value and vice versa. The pH scale ranges from approximately 0 to 14 with 7 being neutral, below 7 acidic, and above 7 alkaline (basic) (Francis *et al.,* 2020). Electrical conductivity is the potential of the soil to conduct electricity. This chemical property is anchored in a lot of determinant especially; salt accumulation in the soil (Essien and Hanson, 2013). CEC is the sum total of the acidic and basic cation present in the soil solution (Essien and Hanson (2013). A high basic cation content may imply that the fertility status of the soil may be better than that of surrounding soil. Organic carbon reflects organic matter (the decomposed carbon in a material) (Edem, 2007).

**2.2.2 Soil Physical Properties**

Soil physical properties of soil include; color, texture, structure, porosity and density, consistence. Colors of soils vary widely and indicate such important properties as organic matter, water and redox conditions. Soil texture, structure, porosity, density and consistence are related with types of soil particles and their arrangement. There are two types of soil particle: primary and secondary soil particles (Edem, 2007). Soil is comprised of minerals, soil organic matter (SOM), water, and air. The composition and proportion of these components greatly influence soil physical properties, including texture, structure, and porosity, the fraction of pore space in a soil. In turn, these properties affect air and water movement in the soil, and thus the soil’s ability to function. Soil texture can have a profound effect on many other properties and is considered among the most important physical properties (Tripathi and Misra, 2010). Texture is the proportion of three mineral particles, sand, silt and clay, in a soil (Agunwam, 2010). These particles are distinguished by size, and make up the fine mineral fraction. Particles over 2 mm in diameter (the ‘coarse mineral fraction’) are not considered in texture, though in certain cases they may affect water retention and other properties. The relative amount of various particle sizes in a soil defines its texture, i.e., whether it is a clay, loam, sandy loam or other textural category (Agunwam, 2010). Soil structure is the arrangement and binding together of soil particles into larger clusters, called aggregates or ‘peds.’ Aggregation is important for increasing stability against erosion, for maintaining porosity and soil water movement, and for improving fertility and carbon sequestration in the soil (Nichols *et al.,* 2004). ‘Granular’ structure consists of loosely packed spheroidal peds that are glued together mostly by organic substances (Isirimah, 2000). Soil texture and structure influence porosity by determining the size, number and interconnection of pores (Agunwam, 2010). Coarse-textured soils have many large (macro) pores because of the loose arrangement of larger particles with one another. Fine-textured soils are more tightly arranged and have more small (micro) pores. Unlike texture, porosity and structure are not constant and can be altered by management, water and chemical processes (Edem, 2007).

**2.2.3 Soil Biological Properties**

The soil environment teaming with biological life and is one of the most abundant and diverse ecosystems on earth. Soil biota, including flora (plants), fauna (animals) and microorganisms, perform functions that contribute to the soil’s development, structure and productivity (Isirimah, 2000). Soil Flora are plants that act on the soil environment by aiding in structure and porosity, and in supplying soil organic matter via shoot and root residue. Root channels can remain open for some time after the root decomposes, allowing an avenue for water and air movement. Roots also act to stabilize soil through aggregation and intact root systems can decrease soil loss. The ‘rhizosphere,’ the narrow zone of soil directly surrounding plant roots, is the most biologically active region of the soil (Obasi *et al.,* 2013). It contains sloughed root cells and secreted chemicals (i.e., sugars, organic acids) that provide organisms with food (Suresh, 2008). Soil fauna work as soil engineers, initiating the breakdown of dead plant and animal material, ingesting and processing large amounts of soil, burrowing ‘biopores’ for water and air movement, mixing soil layers, and increasing aggregation (Obasi *et al.,* 2013). Important soil fauna includes; earthworms, insects, nematodes, arthropods and rodents. Earthworms are considered one of the most important soil fauna. Through the process of burrowing, they provide channels that increase a soil’s porosity, water holding capacity, and water infiltration (Lee, 2010). They also increase further biotic activity by breaking down large amounts of SOM through digestion and supplying nutrient-rich secretions in their casts (Savin *et al.,* 2012). Furthermore, earthworms are able to build soil by moving between 1 to 100 tons of subsoil per acre per year to the surface, possibly helping offset losses by erosion (Magdoff and Van, 2000). Soil microorganisms (microbes) are invisible to the naked eye. However, their effect on numerous soil properties are far-ranging (Obasi *et al.,* 2013). Microorganisms represent the largest and most diverse biotic group in soil, with an estimated one million to one billion microorganisms per one gram of agricultural top soil (Tripathi and Misra, 2010). Microbes aid soil structure by physically surrounding particles and ‘gluing’ them together through the secretion of organic compounds, mainly sugars. This contributes to the formation of granular structure in the A horizon where microbial populations are greatest (Essien and Hanson, 2013). Soil microbes include bacteria, protozoa, algae, fungi and actinomycetes. Bacteria are the smallest and most diverse soil microbes. Bacteria are important in soil organic matter decomposition, nutrient transformations and small clay aggregation. Some bacteria carry out very special roles in the soil, such as Rhizobia, the nitrogen-fixing bacteria associated with legume roots. Protozoa (e.g., amoebas, ciliates, flagellates) are mobile organisms that feed on other microbes and soil organic matter (Uzoigwe *et al.,* 2012). Algae, like plants, photosynthesize and are found near the soil surface (Uzoigwe *et al.,* 2012). Fungi are a diverse group of microbes that are extremely important in the breakdown of soil organic matter and large aggregate stability. Many fungi have long ‘hyphae’ or ‘mycelia’ (thin thread-like extensions) that can extend yards to miles underneath the soil surface and physically bind soil particles (Nichols *et al.,* 2004). Actinomycetes are a microbial group that are classified as bacteria, but have hyphae similar to fungi. They are important for soil organic matter breakdown, particularly the more resistant fractions, and give soil much of its ‘earthy’ odor (Nichols *et al.,* 2004).

**2.3 Importance of Soil**

Soils support flora and fauna on which humans and animals depend, soil is part of the larger environment (Agunwam, 2010; Nichols *et al.,* 2004). Soil is, in fact, a link between the air, water, rocks and organisms and is responsible for many different functions in the natural world that we call ecosystem services. These soil functions include: air quality and composition, temperature regulation, nutrient elements recycling (including C), water cycling and purification (filtering), natural waste (decomposition) treatment, and recycling and habitat for most living things and their food (Manici *et al.,* 2019). We cannot survive without soil and the way it is related to environment. The role of soil in ecosystem is manifold. As a matter of fact, soil has a role to play in every sphere of human life as described below.

**2.3.1. Habitat for Food and Other Biomass Production**

Soils provide environment where seeds grow. They provide nutrients, water and other necessary environment which nurture plants for survival (Manici *et al.,* 2019). These plants form together with other plants and organisms to create ecosystems. Soils are part of these ecosystems (Skopp, 1990; Manici *et al.,* 2019). These plants provide valuable habitat and form the main sources of food for animals, microorganisms and human beings. Besides, decomposed organic matter from plants and trees form the biomass in soils (Bormann and Klaassen, 2008).

**2.3.2. Environmental Interaction**

***2.3.2.1. Air Quality***

Well-covered soil can protect erosion. This can restrict wind erosion to control the purity of atmospheric air which in desert area is always contaminated with impounded air particles causing major health problem (Niedda *et al.,* 2014). These particles contain various microorganisms which can cause infection and diseases (Niedda *et al.,* 2014).

***2.3.2.2. Temperature Regulation***

Soil temperature plays an important role in chemical, bio-chemical and biological interaction in the soil environment (Baiamonte *et al.,* 2019) This in turn, influences seed germination, proliferation of microbes making nutrients in form available to plants and microbes and decomposition of organic matter in soil. In soils of cold region, cool temperature can put such reactions at low level causing more organic carbon storage. Most tropical soils are thus poor in organic carbon as they cannot store more organic matter (Brady and Weil, 2002).

***2.3.2.3. Carbon and Nutrient Cycling***

Soils contain large amount of both organic and inorganic carbon. While organic form of carbon is boon for farmers, inorganic carbon is mostly a bane (curse) for them (Manici *et al.,* 2019). Natural processes are all cyclical and so are the processes through which all nutrients and carbon in soil are cycled. On a global level, the total carbon cycle is more complex and involves carbon stored in fossils, soils, oceans and rocks (Bruinsma, 2003). Physical, biological and chemical processes in the soils affect the balance in organic carbon compounds and they are released to the atmosphere as CO2 or are stored in the soil. This same process occurs with nitrogen, phosphorus and all other materials (Manici *et al.,* 2019; Bruinsma, 2003).

**2.3.3. Biological Habitat and Gene Pool**

It is believed that there are more species in existence below the soil surface than above it. Soil is the habitat of organisms which include microbes and higher animals (Nemecek and Poore, 2018). These are extremely beneficial to soil physical and chemical processes that influence soil fertility and productivity. Soils have vertebrates (mice, mile and prairie dogs). These burrowing animals redistribute soil materials from deeper layers to reach the surface. Organic matter is also physically shred into smaller particles for making decomposition easier (Haws *et al.,* 2004). Macroorganisms in soil include earthworms, termites and ants. These animals fill the soil through their burrowing action. Their feces serve as rich sources of soil nutrients. Several species of fungi in soil are important in the decomposition of organic materials to form humus and thus help in the formation of soil aggregates (Manici *et al.,* 2019). Other important microbes include actinomycetes, algae, bacteria, nematodes and protozoa. Actinomycetes give soil its characteristic “earthy” aroma when it rains. Soil has a diverse system of biological characteristics often termed as “soil biodiversity”. This is beneficial for plant growth, including crop production. With increased diversity, the decomposition of organic matter and release of more nutrients are made possible (Nichols *et al.,* 2004).

**2.3.4. Sources of Raw Materials**

Soil is a source of several raw materials for industry. It supplies ores for iron, used for steel industry. Aluminium ore as bauxite is excavated from soils. Several minerals like zinc, manganese etc. are mined from the soil. Many pharmaceutical industries depend largely on soil-mined minerals (Agunwam, 2010; SSS, 2014). Materials of daily needs for us like toothpaste, talcum powder, creams and many such items require clay minerals as fillers. The construction of building requires wood, bricks, metals which are also obtained from soils. Located at the interface between lithosphere, atmosphere, and biosphere, the soil becomes one of the most important components of the environment, performing numerous functions in the terrestrial ecosystems (Manici *et al.,* 2019).

**2.3.5. Physical and Cultural Heritage**

Soil acts as a physical and cultural heritage of the natural and cultural history of the human society, because it reflects on the evolution of natural conditions in an agricultural region and some aspects of human evolution (Rosenzweig and Hillel, 1995). Thus, based on the fossils discovered in the soils, the climate and vegetation characteristics in a certain period of time can be reconstructed (Rosenzweig and Hillel, 1995). Soil is a good indicator of the environmental quality and evolution since it has the ability to permanently adapt to natural or artificial changes and memorize past events. Lot of archeological materials such as coal, ash, pottery, tools, bones, and remains of shells can provide important information on paleontological nature about the past including the soil age (Van, 2002). The soil has been able to relate the evidence of human civilization. Soil has a tremendous memory to keep the information of the past to trace the events of earlier civilizations. Soil protects all the evidences of the past, which are extremely important to understand the evolution of life on the Earth. In terms of cultural function, the soil is a real geological and archeological heritage to look into the culture of human civilization (Mohammadi *et al.,* 2012).

**2.3.6. Platform for Man-made Structures**

Soil acts as a support for houses, industrial buildings, communication ways (road, highways, and airports), sports’ fields, and storage of household and industrial wastes (Mohammadi *et al.,* 2012). It gives an environment for pipelines installation and underground cables. The soil resulted from the excavation of foundation is also used to cover dumps of wastes from metallurgical complexes or to cover the garbage near cities, as a solution for protection against environmental pollution (Mohammadi *et al.,* 2012).

**2.3.7 Soil as a Medium for Plant Growth**

Soil is the stomach of plants. Early human relied on natural fruits, vegetables, and animals that the soil produced directly or indirectly. Our ancestors understood that soils can be used as the best medium for plant growth since soils can supply adequate moisture and nutrients and can also hold the plants for their growth (Lal, 2005). We developed ways to cultivate and manage soils which include fertilization, irrigation and plant protection measures. Life thrives in the biosphere, the zone at the interference of the Earth’s crust and the atmosphere. Here, the sun provides radiant energy, which green plants capture and transform into sugars and other useful chemicals through the process of photosynthesis (Balasubramanian, 2015). Moist soils provide nutrients, water, oxygen and physical support to plants (everything that plants need except the energy from the sun and CO2 from the air). As organisms in the soil decompose dead plants and animals, CO2 is returned to the air, completing the carbon cycle (Tapas and Pal, 2016).

**2.4 Soil Hydrology**

The term hydrology is derived from the Greek words ‘*hudor’* and ‘*logos’*, which mean ‘*water’* and ‘*study’*, respectively (Shukla, 2011). Thus, the simplest definition of hydrology can be that it is a branch of science pertaining to the study of water (Shukla, 2011; UNESCO, 2006). A much more comprehensive definition of hydrology could be that it is a branch of science that encompasses the study of the occurrence, distribution and movement of, and of changes in the quantity, quality and state of atmospheric, surface, soil-borne, plant-borne and subsurface water on earth. Water is one of the most dynamic entities on the earth. It can stay in all three forms, liquid, solid and vapour, at the same time and at room temperature (UNESCO, 2006). The path that water takes through the environment in all these three forms is represented by the hydrological cycle, which describes the continuous movement of liquid, vapour and/or solid (ice) water in the atmosphere, on the soil and on plant surfaces and through the soil and plant surfaces (Shukla *et al.,* 2004). Different components of the hydrological cycle are grouped into precipitation, interception, snow melt, surface runoff, infiltration, percolation, deep percolation, subsurface flow, evaporation, transpiration (or evapotranspiration), condensation, return flow, etc. Sun or solar energy is the driving force for the hydrological cycle, and the overall total mass of water on earth stays fairly constant over time. However, the resident time for water in these different storage components varies from a few days (water vapour) to several thousand years (deep groundwater, ice on the poles) (Shukla *et al.,* 2003). Various components of the hydrological cycle are strongly influenced by human activities – such as changing land use from natural forest to agriculture, from agriculture or forest land to urban land, by the construction of reservoirs and dams, by deforestation and afforestation, and by changing from mechanical tillage to no-tillage or from tillage or no-tillage to conservation tillage, etc. Soil, the interface between the lithosphere and the atmosphere, is the most basic resource that interacts with the biosphere and the hydrosphere to support life on earth. The interaction of the soil with the various components of hydrology is important for the hydrological cycle and is known as soil hydrology (Reynolds *et al.,* 2000). Soil hydrology has a strong influence on the water uptake and release by plants during photosynthesis. Thus, soil hydrology can also be defined as study pertaining to agricultural water management (Shukla *et al.,* 2003). Soil hydrology takes into account all of the components of water related to irrigation and drainage, percolation and recharge to groundwater, capillary rise, root and plant water uptake and release, evaporation from soil and plants, and transpiration (Shukla *et al.,* 2003; Shukla 2011). The fate of the total amount of water applied to the soil as irrigation or natural rainfall is usually determined by taking into account all the different components of the hydrological cycle and conducting a water balance study (Rosenzweig and Hillel, 1995).

**2.5 Roles of Soil Hydrology**

Important soil hydrological processes are: infiltration, drainage, water redistribution within the vadose zone, evaporation, transpiration and deep percolation (Iqbal *et al.,* 2005). All of these processes occur at the microscopic or pore scale within the vadose zone and are primarily governed by the amount, orientation, size, distribution and connectivity of pores, but not just by the total micro- or macroporosities (Ikemura *et al.,* 2008). Soil water storage and transport can also be influenced by the type of vegetation, geology and chemistry of the vadose zone. Thus, soil hydrology is an interdisciplinary field that interacts closely with hydrology, physics, chemistry, engineering, environmental science, pedology, soil science, mathematics, geostatistics and plant science, among others (Lal and Shukla, 2004). Soil hydrological processes are important components of the water budget and directly influence plant growth and sustenance (Iqbal *et al.,* 2005). Soil hydrology addresses practical problems encountered by practitioners, researchers and farmers in real life situations, and in collaboration with other disciplines plays a pivotal role in human endeavour to sustain agri cultural productivity while maintaining soil, water and environmental quality (Haws *et al.,* 2004). With the world population growing at a rapid rate, the importance as well as the role of soil hydrology is becoming critical for not only sustaining or increasing total grain production but also maintaining water and environmental quality, thus maintaining life on earth. An understanding of soil hydrology principles and processes is important for maintaining environmental quality (Haws *et al.,* 2004). Surface soil physical properties control the infiltration of water into the soil and thus are important for causing surface runoff and soil erosion. Runoff water may contain dissolved or suspended sediments as well as chemicals and nutrients (Duffera *et al.,* 2007). These pollutants can be transferred to surface water resources such as lakes, ponds or rivers, so soil hydrology is important for maintaining the water quality of surface water bodies. Vadose zone soil physical properties control the storage and movement of water and dissolved chemicals or nutrients through the profile, and control the migration of contaminants towards the groundwater (Duffera *et al.,* 2007). Thus, knowledge of soil hydrology is important for preventing groundwater contamination. Soil physical properties and surface soil moisture contents also control the migration of fine dust particles into the atmosphere. The high specific surface area associated with these fine dust particles means that they can also carry with them other chemicals that are sorbed on the surface of these particles (Shukla *et al.,* 2003). Consequently, in controlling the concentration of airborne particulate matter, soil hydrological properties are an important component of air quality (Shukla*,* 2011).

**2.6 Hydrological Properties of the Soil**

Water sustains life on Earth and it plays a key role in the energy and matter cycles of the terrestrial system. The status and ﬂuxes of water in the terrestrial system are controlled by hydrological processes, which mainly take place in a thin layer of soil covering the Earth surface. Although the water content of this thin layer is only about 0.05% of the total fresh water on Earth (Shiklomanov, 1993), it plays a decisive role in controlling the major hydrological, biogeochemical, and energy exchange processes that take place at the land surface (Katul *et al.,* 2012). Soil properties especially ρb and infiltration rate are strongly related to soil water movement, porosity, and workability (Friedman *et al.,* 2001). Infiltration rate reflects soil functions of regulating and partitioning water and solute flow and filtering, buffering, degrading, detoxifying organic or inorganic materials in crop‐soil ecosystems (NRCS, 2015). Furthermore, physically based hydrologic models such as Green–Ampt are generally used to fit measured infiltration data (Zaibon *et al.,* 2017) to show soil water infiltration with respect to time via physical parameters like sorptivity (S, mm h‐0.5) and model estimated saturated hydraulic conductivity (Ksat, mm/hr). The estimated Ks represents water‐transmitting capability of soils under hydraulic head gradient and varies with the antecedent soil water content. As S and Ks are influenced by the management, therefore, quantification of these parameters is crucial in order to assess the soil hydrological conditions (Shukla *et al.,* 2003; Shukla*,* 2011).

**2.7 Factors Affecting Soil Hydrological Properties**

Soil hydrological properties show both short- and long-range variability, and are multivariate in nature (Nielsen *et al.,* 1973). Soil hydrological properties are greatly influenced by intrinsic factors of soil formation as well as by extrinsic factors associated with land use and management, and vary both in time and space (Van, 2002). Intrinsic variability is caused by pedogenesis and usually takes place at large timescales. The variability caused by the pedogenetic processes is described as regionalized, with nearby areas considered to be more similar than areas that are further away (Van, 2002). In contrast, the variability caused by extrinsic factors can take effect relatively quickly and cannot be treated as regionalized as soil hydrological properties are greatly influenced by land use and management (Shukla, 2011). For example, intense tillage can cause the breakdown of aggregates, the creation of a plough layer, an increase in soil bulk density with attendant lowering of porosity, reductions in soil water storage and transport through pores, and the exposure of organic matter to degradation, thus causing an overall decline in soil quality which can lead to a decline in agricultural productivity (Shukla*,* 2011). In contrast, no-tillage or conservation tillage can have the exactly opposite outcome, and can improve soil quality and increase agricultural productivity (Bruinsma, 2003). Land management practices can also influence greenhouse gas emissions from agricultural fields. The applications of nitrogenous fertilizers, along with excess water application, can increase N2O emissions from the soil. Similarly, depending upon the quality of biomass and on management practices, CO2 and CH4 emissions can increase and degrade environmental quality (Bates *et al.,* 2008). The preservation of the resource base and of environmental quality is immensely important for sustaining life on earth (Bruinsma, 2003). The degradation or aggradation of groundwater quality, surface water quality, air or environmental quality and soil quality has a profound influence on the productivity and sustainability of agriculture, and on human and animal health, and thus have a profound influence on the overall quality of life on earth (Bates *et al.,* 2008).

**2.7.1 Researches on Hydrological Properties of Soils**

Several studies have been undertaken to investigate the hydrological properties of soils and notably; Hewelke *et al*., (2019) assessed the inﬂuence of the abandoning arable use and the spontaneous aﬀorestation on soil hydraulic properties. This author showed evidence of the occurrence of soil water repellency on the surface layer. Lozano-Baez *et al.,* (2019) investigated the recovery of top-soil saturated soil hydraulic conductivity (Ks), soil physical and hydraulic properties in ﬁve land-use types in the Brazilian Atlantic Forest. The studied land-use types included; a secondary old-growth forest; a forest established through assisted passive restoration 11 years ago; an actively restored forest, with a more intensive land-use history and 11 years of age; a pasture with low-intensity use; and a pasture with high-intensity use. They used the Beerkan method to determine Ks values in the ﬁeld and also measured tree basal area, canopy cover, vegetation height, tree density and species richness in forest covers. These authors reported that Ks estimates decreased when land use was more intense before forest restoration actions.

Castellini *et al.*, (2019) assessed the impact of alternative soil management strategies (conventional tillage and no-tillage) on physical and hydraulic properties of ﬁne-textured soils, applying both ﬁeld and lab procedures and significant results were obtained.

Lozano-Parra *et al.* (2018) investigated the eﬀect of the interactions between soil moisture and vegetation covers on soil temperature. These authors monitored for two and a half hydrological years of soil water content and soil temperature of open grasslands and below tree canopies; significant result was also obtained. Hence it could be concluded that land use could have effect on soil hydrological properties which is anchored on the type of land use. Buytaert *et al.,* (2002) in their study to evaluate the effect of land use on the water retention capacity of Umbric Andosols in south Ecuador. The objective was to acquire a better insight into the hydrological processes of the ecosystem and the role of the soil, in order to assess the impact of changing soil properties due to land use change on the hydrology of the high Andes region. The Umbric Andosols in the Austro Ecuatoriano clearly had an extraordinarily large water retention capacity, making them important in the hydrology of the region. The loss following cultivation of these soils has an obvious impact on its hydrophysical properties. The water retention at wilting point diminishes by an average 16%, after two years of cultivation, which was less than the reduction caused by drying in the laboratory, which reaches an average of 35%. Structural changes affecting water retention stop or stabilize when fields are changed into pasture, however no recovery of the water retention was observed. It seems to be an irreversible event. Also, the water retention loss is much larger at 15cm depth (21%) than the reduction at 40cm, beneath the plough layer which is only 10%.

**CHAPTER THREE**

**MATERIALS AND METHODS**

**3.1 Site Description**

**Field experiment was conducted at Nnamdi Azikiwe University which is located at Ifite-Ogwari, Annex, Anambra state with the coordinate of 06°21’N and 7°61’E (National Bureau of Statistics, 2006).**

**3.2 Climate Description**

**Ifite-Ogwari has 2 climatic seasons, dry season which last from November to march and rainy season which last from April to October with an August break. During the dry period, temperature of the day ranges from 20 – 38°c resulting to increased evapo-transpiration but in rainy season, it ranges from 6 – 28°c with a lower evapo-transpiration. The annual rainfall varies from 1500 to 1650mm (Aghamelu *et al*, 2011). Ifite-Ogwari also has a relative humidity of 80% at dawn (hydrometrology department, Awka).**

**3.3 Ifite-Ogwari Geology**

**The geological formations that underlie Ifite-Ogwari are Imo shale and Bende Ameki formation. In the riverine and low lying areas particularly the plain west of Mamu River as far as to the land beyond the permanent Nnamdi Azikiwe University, the underlying impervious clay shales cause water-logging of the soil during rainy season. The soils of Ifite-Ogwari and Awka are generally Ultisols which are mineral soils having an argillic horizon with a base saturation of <35% when measured at pH of 5.3. The mean annual soil temperature is usually 28°c or higher.**

**3.4 Ifite Ogwari vegetation**

**Ifite-Ogwari lies in the rain forest zone with tall trees which are usually deciduous in nature having thick undergrowth and numerous climbers. The typical trees found in this region are oil palm trees, raffia palm, iroko trees, oil bear and gravelina trees. The oil palm and raffia palm trees are not deciduous in nature.**

**3.5 Sample collection**

Before the start of the field experiment, field survey visits were conducted to generate basic data that are related with hydrological properties for this experiment. **Two different depths (0-15 and 15-30 cm) was considered for the sites (upland, midslope and lowland elevation class of soils) and replicated twice based on information available for each site. Both disturbed and undisturbed samples was collected for analysis. The undisturbed samples were collected with the use of a core sampler while that of the disturbed were collected using a soil Auger. A total of 15 core samples and disturbed samples were collected each and carried to the laboratory for analysis.**

**3.6 Laboratory analysis**

**The undisturbed soil Samples collected were analyzed for some specific parameter such as Particle size distribution, saturated hydraulic conductivity, permanent wilting point, porosity, bulk density, moisture characteristics at various depths.**

* + 1. **Particle size distribution:**

This was determined using Bouyoucous hydrometer method after dispersing the soil samples with sodium hexametaphosphate (calgon) solution. The textural class of the soil was determined using a textural triangle (Klute 1986).

* + 1. **Saturated hydraulic conductivity**

Saturated hydraulic conductivity (Ksat) was determined using the constant head permeameter method (Dane and Topp, 2002). The core sample was placed in a basin of water and allowed to saturate by capillary. The saturated core samples were then placed in a funnel and a cylinder head was being placed on it to a given level which was constantly maintained throughout the experiment. The cylinder head was held to the core cylinder with a masking tape. The water passing through the soil column was collected into a measuring cylinder and the saturated hydraulic conductivity was calculated using the equation.

Ksat =

Where

Ksat = Saturated hydraulic conductivity (cmhr-1)

Q = discharge rate (cm3 min-1)

L = length of soil column (cm)

= Change in hydraulic head (cm)

A = cross sectional area through which the flow takes place (cm2)

t = time (minutes)

**3.6.3 Bulk density**

Bulk density was determined using core samples as described by Dane and Topp (2002). Soil samples was oven-dried at 105°c to a constant mass and bulk density calculated using the equation.

ℓb =

where

ℓb = bulk density (Mgm-3)

Ms = mass of oven dry soil (mg)

Vt = Total volume of soil (m3)

The total volume of the soil was calculated from the internal dimension of the cylinder.

* + 1. **Total porosity**

Total porosity was calculated from particle and bulk density relationship as follows

x 100

1-

ƒ =

Where

ƒ = total porosity (m3m-3)

ℓb = bulk density (Mg m-3)

ℓs = particle density

**3.6.5 Field water capacity**

Field water capacity was determined using Carter (1993) Gravimetric Method. The determination was done with the core cylinder based on the fact that “the content of water, on a mass or volume basis” remaining in a soil two (2) or three (3) days after having been wet and Subtracted from the weight of oven dried core samples and divided by Oven dried core samples weight.

* + 1. **Permanent wilting point (PWP)**

Permanent wilting point was determined using Carter (1993) Gravimetric method. Where a core cylinder based on the fact that “the content of water, on a mass or volume basis” remaining in a soil 10 days and subtracted from the weight of oven dried core samples and divided by Oven dried core samples weight.

**3.7 Statistical analysis**

Statistical analysis of data generated was done using SPSS (Statistical Package for Social Sciences) software package version 21 and significant means were separated using fishers’ least significant differences at 5% level of significant.

**CHAPTER FOUR**

**RESULT AND DISCUSSION**

**4.1 Textural Class**

Texture refers to the relative proportions of particles of various sizes such as sand, silt and clay in the soil (Ajayi *et al.,* 2007). The percentage of sand, silt and clay in the soil determines the textural class of the different soil elevation class examined. No Significant on the percentage of sand was observed among the different elevation classes (upland, mid-slop and lowland) in the study area as shown in Table 4.1. Lowland soils recorded the highest mean value (72.00%) at a soil depth of 15-30cm compared to the mid-slope elevation class which had the lowest mean value (54.2%) at the same soil depth. For silt, lowland elevation class of soil had the highest mean value (32%) at the soil depth of 15-30cm compared to the lowest mean value recorded in the upland soils (18.7%) at a same depth. For clay, the mid-slope soils in the study site had the highest mean value (25.3%) at a depth of 15-30cm compared to the lowland which had the lowest mean value (22.2%) at the same soil depth. The lowland soil was dominated by high sand fractions, very little silt and low clay percent. The soil textural class for the treatments is termed “sandy loam”. The soil type could provide a suitable environment for growth of different crop types under good management practices. The uniqueness of the soils had also been reported by some researchers (Ajayi *et al.,* 2007; Wapa and Kwari, 2004) who identified the soils as characteristically sandy, low in active clay content, low in buffering capacity and high in Kaolinite. Eyankware *et al.,* 2016 reported that higher increase in sand content in the lowland soil could be due to the low contents of organic carbon, organic matter, cation exchange capacity and nitrogenous component in the soil.

**Table 4.1: The result for the particle size distribution and organic matter content in the study area**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Elevation Class of soils** | **Soil Depth (cm)** | **Particle size distribution** | | | | **OMC** |
|  | | **Sand (%)** | **Silt (%)** | **Clay (%)** | **Texture** |  |
| **Upland** | **0-15** | **60.0** | **21.3** | **22.5** | **SL** | **2.36** |
| **15-30** | **58.0** | **18.7** | **23.2** | **SL** | **1.16** |
| **Mid-slope** | **0-15** | **70.0** | **23.6** | **24.7** | **SL** | **2.97** |
| **15-30** | **54.2** | **20.5** | **25.3** | **SL** | **1.26** |
| **Lowland** | **0-15** | **63.5** | **27.8** | **22.4** | **SL** | **2.23** |
| **15-30** | **72.0** | **32.0** | **22.2** | **SL** | **1.61** |
| **F – LSD (p>0.05)** |  | **NS** | **NS** | **NS** |  | **NS** |

**\*SL – Sandy loam; OMC – Organic Matter Content; NS – Non-significant; F-LSD – Fishers Least Significant Differences**

**4.2 Wilting Point**

Permanent wilting point (PWP) or wilting point (WP) is defined as the minimum amount of water in the soil that the plant requires not to wilt (Ajayi *et al.,* 2007). The permanent wilting point is the point when there is no water available to the plant. From the study, there was no significant difference on the permanent wilting point of the studied soils. At soil depth of 15-30cm, the lowland soil had the highest mean value (46.02%) compared to the mid-slope elevation class of soil (38.52%) at a soil depth of 0-15cm. The lowland recorded highest mean value compared to the upland elevation class (42.30%) at a soil depth of 15-130cm. The moisture content at the permanent wilting point varies with soil texture and this finding is also similar to Buytaert *et al.,* (2000). Fine-textured soils retain higher amounts of water (∼26%–32% v/v) than the coarse textured soils (10%–15% v/v) at the permanent wilting point (Buytaert *et al.,* 2002). The higher wilting point of the lowland soil could be attributed to it textural class (sandy loam) and it is an indicator that lowlands in the study area can retain higher amount of water.

**Table 4.2: The result for hydrological properties in the study area**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Elevation Class of soils** | **Soil Depth (cm)** | **FC (%)** | **WP (%)** | **TP (%)** | **Ksat (cm/hr)** | **BD (g/cm3)** |
| **Upland** | **0-15** | **49.90** | **40.63** | **46.90** | **0.34** | **1.35** |
| **15-30** | **52.00** | **42.30** | **47.00** | **0.43** | **1.55** |
| **Mid-slope** | **0-15** | **34.60** | **38.52** | **44.40** | **0.20** | **1.33** |
| **15-30** | **40.00** | **41.12** | **45.40** | **0.30** | **1.35** |
| **Lowland** | **0-15** | **46.70** | **45.68** | **49.80** | **0.41** | **1.20** |
| **15-30** | **42.60** | **46.02** | **51.20** | **0.35** | **1.25** |
| **LSD (p>0.05)** |  | **NS** | **NS** | **NS** | **NS** | **NS** |

**\*FC – Field capacity; WP – Wilting point; TP – Total porosity; ksat – Hydraulic conductivity; BD – Bulk Density**

**4.3 Field Capacity**

Field capacity is the amount of soil moisture or water content held in the soil after excess water has been drained away and the rate of downward movement has decreased (FAO, 2016). The study, highest mean value of field capacity was recorded in the upland soils (52.0%) at a soil depth of 15-30cm, compared to the mid-slope soil (34.60%) with the lowest field capacity mean value at a soil depth of 0-15cm. The mid-slope soil field capacity was lower compared to the lowland soils (46.70%) at the depth of 0-15cm. The reason for the value of lowland soils to record such mean value may be attributed to the organic matter content in the soil, as organic matter is determinant of water retention capacity of the field and also dependent on land use or management as reported by Buytaert *et al.,* 2002.

**4.4 Total Porosity**

Porosity is the fraction of soil that is occupied by pores. From the results, lowland elevation class of the studied soil recorded higher mean value of total porosity (51.20%) at a depth of 15-30cm compared to the mid-slope (44.40%) at the soil depth of 0-15cm. Lowland soils was also higher in total porosity mean value compared to the upland elevation class of soils (47.00%) at a soil depth of 15-30. When increase in total porosity is observed, this could be due to the increase of pores with larger diameter (macropores) associated with better soil structure (Celik *et al.,* 2004; Rós *et al.,* 2013). Soil organic matter influences the degree of aggregation and aggregate stability and can reduce bulk density, increase total porosity and hydraulic conductivity of heavy clay soils (Anikwe, 2000). Increase in total porosity of the lowland soils in the study area could be attributed to an increase in percentage of macro-pores and organic matter content.

**4.5 Hydraulic Conductivity**

Hydraulic conductivity of soil is the measure of the ability of the soil to transmit water.

Upland soil of the study area recorded higher mean value of (0.43cm/hr) at a soil depth of 15-30cm compared to the lower mean value recorded by mid-slope soils (0.20cm/hr) at a soil depth of 0-15cm. The mid-slope soils were significantly lower compared to the lowland soils (0.41%) at a soil depth of 0-15cm. this report is also similar to Buytaert *et al.,* 2002. Organic matter has beneficial effects on hydrological properties of soils such as soil hydraulic conductivity and infiltration rate (Wanas, 2002). Saturated Hydraulic conductivity of the lowland soils could be attributed to the effect of land use, management or organic matter content (Mubarak *et al.,* 2009).

**4.6 Bulk Density**

Bulk density is the mass of the soil per unit volume of soil (volume includes both solid and pores) expressed in gramme per cubic centimeter. From the assessed soils, upland elevation class pf soils had higher mean value (1.55%) at a soil depth of 15-30cm compared to the lowland soil (1.20g/cm3) at a depth of 0-15cm. The lowland soils were significantly lower compared to the midslope soils (1.33%) at a soil depth of 0-15cm and this results coincides with Buytaert *et al.,* 2002; 2000. According to Obi, (2000), Lower bulk density is a positive productivity indicator as it helps in easing root penetration, thereby encouraging downward movement of water through old root channels. The lower value of bulk density in lowlands could be attributed to land management or soil organic matter which influences the degree of aggregation and aggregate stability and can reduce bulk density, increase total porosity and hydraulic conductivity of heavy clay soils (Anikwe, 2000).

**CHAPTER FIVE**

**CONCLUSION AND RECOMMENDATION**

**5.1 Conclusion**

The study was conducted to assess some selected hydrological properties of Ifite-Ogwari lowland soils. The results obtained showed that there were no significant differences among the studied soils on its particle size distribution and soil hydrological properties which includes; Bulk density, total porosity, hydraulic conductivity, field capacity and Permanent wilting point at soil depth of 0-15cm and 15-30cm. Although from the study, lowland soils recorded a higher value of these parameters.

**5.2 Recommendation**

From the results of the study, it could be recommended that lowland soil around the study area can be used for agricultural purpose as lowland indicates a positive productivity indicator.

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