BORON DISTRIBUTION

IN THE SOILS OF A TOPOSEQUENCE IN

A DERIVED SAVANNA AGRO-ECOLOGICAL ZONE OF NIGERIA

BY

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DECLARATION

This is to declare that this research work: "**BORON DISTRIBUTION IN THE SOILS OF A TOPOSEQUENCE IN A DERIVED SAVANNA AGRO-ECOLOGICAL ZONE OF NIGERIA**" was undertaken by me, **MISS OKORO CHIMDINMA IRENE.** A final year student of the Department of Crop and Soil science, College of Agricultural science, Landmark University, under the supervision of **Dr. K. A. Adegbite.** The view of this research work is products of the original research undertaken by **OKORO CHIMDINMA IRENE,** and the views of the research have been dully expressed and acknowledged.

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CERTIFICATION

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EXTERNAL EXAMINER **DATE**

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DEDICATION

I dedicate this work first to God Almighty,

to you:

Bishop David O. Oyedepo

(The Privilege to be a part of the Agricultural Revolution is well appreciated)

Grandma – Mother. Mary O. Okoro,

(for your unending support)

Mum –Ngozi Phidelia Okoro-Okpechi

(Allowing me come forth against all odds has made us soar, we would finish strong)

To my Light

(Leading me on a great path of love has been a great asset)

And you Opeolu Eniola Adeyemi

(A sister of bond better than that of loins)

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God bless you

ABSTRACT

Boron an essential plant nutrient element is one of the few with limited research work and yet is a significant prerequisite for plant growth and development. The study of this research was carried out to determine the distribution of boron in soils of selected profiles along a toposequence in the Landmark University Farm, Eleyin in Isin Local Government Area of Kwara State which is a Derived savanna agro-ecological zone. For this to be done, a reconnaissance study was conducted in which a toposequence was identified. Three profile pits were dug along the toposequence and sited at the upper (EP1), lower (EP2) and bottom (EP3) positions. Soil samples were collected from identifiable genetic horizons down the profiles and were prepared and subjected to laboratory analysis for their physico - chemical properties and boron distribution. Results show that the soils of the area are slightly acidic to moderately acidic (pH in water 4.98-6.66), while soil texture is generally light-textured to medium-textured with texture ranging from sand to loamy sand at the surface and sandy loam, sand, loamy sand to sandy clay loam at sub-surface levels. Total Nitrogen is rated very low to medium (0.02%-1.11%). Available P and Organic matter of the soils are not generally adequate with a range of "very low" to "low" i.e. 4.93-97.23 ppm and 0.40% to 0.44% respectively.

Generally, Boron is found to be inadequate in the soils with a range of 4.00-7.03 mg/kg of soil which is rated low to medium and thus it is recommended that intergrated soil fertility management processes which would as well involve use of boron micronutrient fertilizers should be incorporated into soils of area.

CHAPTER 1

1.0 INTRODUCTION

Soil has been commonly defined as a definite layer of the earth's crust which serves as a medium for plant growth. It also serves for effective plant, organism and environmental interaction. One major attribute of any soil that is of maximum relevance is its fertility rate. In the consideration of soil in its fertility, it is common to mention the presence of soil nutrients which are essentially classified into major or primary and minor or secondary nutrients.

Boron is one of the elements least considered even amongst the minor nutrients.

Therefore it can be thus referred to as a minor in the minors. Chemically, it comes with the symbol B, has the atomic number 5 and belongs to the group 13 (also called IIIa) in the periodic table; it is found in the same family with Aluminum and has similarity with carbon and silicon. It also has a valence of 3.

Biologically, it is not a component of enzymes unlike many essential nutrients. It plays an important role in nucleic acid metabolism, protein metabolism, photosynthesis, carbohydrate biosynthesis and in cell membrane stability (Kumar and Kumar, 2013).

1.1 BORON AND ITS USEFULNESS

Boron, although not much recognized is found in various areas of our everyday life. They can be found in plants, food, soil, water, e.t.c. Boron has been processed industrially as a bleaching agent which is added to most detergent and cleaning agents during its formulations.

1.2 BORON, AS A PLANT NUTRIENT

Boron is a very essential minor element as a plant nutrient as it is important for pollination and seed production. In plants, it helps to ensure uptake of nutrients such as calcium and to create a balance between the interactions of magnesium, calcium and a host of other plant nutrients. It also plays a very active role in plants, despite its availability in seemingly measured quantity; it contributes essentially to plant nutrition. According to (Mineral zone, 2012), the main function of boron in plants is structural. One of the ways boron functions as a plant nutrient is in relation to the cell wall, its development and strength.

As a plant nutrient, boron is not metabolically driven process (i.e. passive response) in its uptake by plants. Through mass flow, it is transported to the roots from the soil solution as it is highly mobile.

1.3 BORON’S ROLE IN PLANTS

The roles of Boron in the plant are numerous and very significant. In Cell wall structure, boron works hand in hand with calcium to ensure structural development of the cell. Just like calcium helps in bone formation and development in humans and animals, the presence of boron helps for unrestricted movement of calcium.

It functions as a translocation for sugar and carbohydrate as well as performs the function of balancing between starch components and sugar.

Various metabolic processes occur through the support which boron renders. This implies that the activity of boron engenders continuity in chain of metabolic processes. Some metabolic processes such as sugar transport, respiration etc. in plants are also affected directly or indirectly by the presence or absence of boron. Boron helps to transfer water and nutrients in plants. Potassium is transported to cells called “guard cells” so as to ensure the control of internal water balance and the presence of boron is an important factor.

1.4 TOPOSEQUENCE

Toposequences are adjacent soils that show differing profile characteristics reflecting the influence of local topography (Jan Glinski, 2011). Most times soils in toposequence regions encounter a lot of nutrient loss or elluviation alongside illuviation and this result in poor maximization of land space in toposequence areas.

It is found associated with major soil groups e.g. oxisols, ultisols, inceptisols, etc.

1.5 BORON IN SOIL

Boron, with a mass 0.0010% of the earth's crust is found in the soil as non-chargeable molecules in soil solution and readily available in concentrated deposits of borate minerals like borax ($Na_2B_4O_7.10H_2O$), inorganic borate complexes of micronutrients, and from mineralization of organic materials. It is also seen as a component of Tourmaline which is an insoluble mineral. It is also present as a non-chargeable molecule in soil solution because at soil pH below 8, non-dissociated boron species are predominant. It is relevant under extremely alkaline conditions. Complex surfaces formed with organic matter helps its retention. This retention is more stable metal hydroxides and clay minerals at pH 9 and 10. Due to its lack of retention as ionic species, it is also easily leached in humid climates, thereby limiting its availability for plant uptake. When boron binds by soil organic matter it is stronger than by minerals due to capability of boric acid to form complexes with polyhydroxylic compounds. Slow release of boron from this organic matter in the course of microbial decomposition appears to be an important source for plant nutrition (Hooda, 2010).

1.6 BORON SOURCE MATERIALS (CAN BE USED AS FERTILIZERS)

The understanding of nutrients in the soil and their rate of availability allows a farmer to adequately manage his land, invariably his soil, so as to ensure high yield of economically feasible crops. Toposequence region soils have been a major concern towards preservation of soil nutrients.

Boron fertilizers are readily available in compounds of boron. Borate is a common form in which boron is utilized. Widely used borates in fertilizer application include:

Borax pentahydrate borax decahydrate though Disodium octaborate tetrahydrate (Etidot-67) because it is more soluble than the former. Sodium borates are used on soil by direct application or used on plants by spraying on the plants which absorb it due to its good soluble nature. Calcium borate (Colemanite) is natural occurring fertilizer materials. They have been known to have low solubility and as such are retained in the soil much longer than sodium borates. Therefore, as such they are more useful in sandy soils (John Emsley, 2011; Spectrum Analysis, 2015).

The Landmark University soils at Eleyin, Kwara State is a newly acquired land and has not been previously studied. It is also observed to be on a toposequence and therefore before major activities commence on the soil, it is essential to explore and understand the basic characteristics of the soil. Since it is aimed at cropping activities, necessity demands that availability and distribution of nutrients are well understood as this will make for proper agronomic practices now and in future.

Therefore this research project is aimed at,

Understanding Boron and its essence in soil and cultivation of crops,

Identification of the soil type present on the toposequence.

Identification of boron present in soils of the Eleyin toposequence.

Understanding the rate of availability and distribution.

Identification of areas of boron abundance and boron level in soil.

Identification of forms of amendment to toposequence soil in "Eleyin" if need arises

CHAPTER 2

LITERATURE REVIEW

2.0 SOIL FERTILITY

Soil fertility is largely determined by the presence, amount and availability of soil essential nutrients. Soil essential nutrients include copper, zinc, iron, manganese, boron, molybdenum, chlorine and others. The quest for sustainable food security in Nigeria through the use of information on nutrient status of soils has long become imperative. The distribution of available micronutrients within the soil profiles has been considered useful for a better understanding of soil's capacity to sustain an adequate amount or supply of these nutrients to plants so as to meet the increasing demand for sustainable food sufficiency.

2.1 MICRONUTRIENTS

Nutrients can be defined as any substance used by an organism as food. They can be divided into two based on their concentration in plant tissue, which are macronutrients and micronutrients. Macronutrients are found in concentration in excess of 1000mg/kg and micronutrients are found in concentration below 1000mg/kg (Ashman and Puri, 2002).

Micronutrients play a vital role in gene expression, biosynthesis of protein, nucleic acids, growth substances, metabolism of carbohydrates and lipids through their involvement in various plant enzymic systems and other physiologically active molecules (Rangel, 2003). Micronutrients are also known as trace elements probably because they are required in a quantity which has to be carefully traced so as to be recognized in the soil as the case of

Boron. Though micronutrients are required in little amounts they are still as important as the macro-nutrients.

The essential micronutrients are Zn, Fe, Mn, Cu, B, Mo, Cl and Ni. Co is also cited as an essential nutrients in some publications; however, essentiality of this element is not yet proved for crop plant (Fageria et.al., 2002;2011).

Generally, studies on micronutrients status of Nigerian soils have been neglected in the past due to non-prevalence of their deficiency symptoms. This has made the information on soil micronutrient status of Nigeria savanna soils scanty. Lombin (1983), Kparmwang et. al.(1995) and Adeboye (2003), reported that limited studies have been conducted on the micronutrients status of soils within the savanna zone of Nigeria. However, the few investigations carried out so far have revealed micronutrient deficiency in some Nigerian savanna soils (Lombin 1983a, 1983b, 1985a).

Influence of macronutrients on crop disease has received considerable attention over the years but very little has been reported on micronutrients. In addition little systematic research has been given to boron (Fageria et.al 2011)

2.2 BORON (ETYMOLOGY)

The name 'boron' has been derived from the mineral borax. It is thought to have come from the Persian name 'burah,' which meant this particular mineral. In 1808, Louis-Josef Gay-Lussac and Louis-Jacques Thénard working in Paris, and Sir Humphry Davy in London, independently extracted boron by heating borax with potassium metal. They discovered that it can be produced by combining boric acid (H_3BO_3) and metallic potassium. In fact, neither had produced the pure element which is almost impossible to obtain. A purer type of boron was isolated in 1892 by Henri Moissan. Eventually, E. Weintraub in the USA produced totally pure boron by sparking a mixture of boron chloride, BCl_3 vapor, and hydrogen. The material so obtained boron was found to have very different properties to those previously reported (Royal Society of Chemistry, 2015).

Boron minerals, especially borax were traded more than thousand years ago. Then, sheep, camel and yak caravans transported borax from desert salt beds in Persia and Tibet to the Arab countries and also to India, mainly for making glass (Mineral zone, 2012). For centuries the only source of borax, $Na_2B_2O_5(OH)_4$, was the crystallized deposits of Lake Yamdok Cho, in Tibet. It was used as a flux used by goldsmiths (Mineral zone, 2012). Boron was first used as fertilizer about 400years ago when Borax (then known as Tincar) was shipped from Asia to Europe. Not until 1915, however, was B suggested as an essential element for plant growth. It was only in 1923 that Boron was confirmed or proofed to be an essential element at the Rothamsted Experimental Station (RES) in England. (Wapa et al., 2014)

2.3 CHEMICAL BORON

Boron belongs to group 13, period 2, block p, with an atomic number 5. At 20℃, Boron is solid and in appearance, pure boron is a dark amorphous powder. Boron is very essential for plant growth and development. Boron (B), the only non–metal among the elements of group III in the periodic table is not uniformly distributed in the earth's crust. Having allotropes; α-rhombohedral B, β-rhombohedral B, γ-B, tetragonal boron, Boron (B) is one of the atoms found in variety of minerals related to Borax ($Na_2B_4O_7.10H_2O$).

It is a relatively a rare element in the earth's crust representing only 0.001%. B exists in many soils largely as Tourmaline (major constituents of Si, Ca, Mg, Al, Fe and B) which is a boroaluminum silicate of great insolubility and resistant to weathering (Wapa et.al. 2014). The primary sources of Boron (B) in most soils are Tourmaline and Volatile emanations of volcanoes. Furthermore, Tourmaline is derived from high temperature rocks and is usually very resistant to chemical breakdown in the weathering zone and thus, accumulates in sediments. When compared with other nutrient elements, the chemistry of Boron (B) in the soil is very simple; it does not undergo oxidation-reduction reactions or volatilization reaction in the soil. Boron containing minerals are either very insoluble (tourmaline) or very soluble (hydrated B minerals) and generally do not control the solubility of B activity in the soil solution (Wapa. et al., 2014).

2.4 BORON IN AGRICULTURE

Boron is an essential plant nutrient and is required in little amounts called trace. This classifies it as a trace element. The plant requirements for boron are lower than the requirements for other nutrients except for Molybdenum and copper (Epstein and Bloom, 2005; Fageria N.K 2009)

It is the only non-metal present amongst the micronutrients and the only one present over a wide pH range as a neutral molecule rather than an ion.

2.4.4 BORON CYCLE IN SOIL-PLANT SYSTEMS

Basic understanding of the cycle of Boron in soil-plant systems is essential for the proper management of this nutrient in crop production. Major soil Boron addition sources are chemical fertilizers, organic matter and parent materials. Boron is removed from soil-plant systems by crop uptake, adsorption on soil colloids, im-mobilization by micro-biomass, and leaching in sandy soils.

Three fractions of B in soil are generally recognized: water soluble, acid soluble and total boron. The water soluble fraction is considered related to plant response and is determined either in soil saturation or in boiling water extract. The latter is always designated as **available B.** The acid-fraction was termed **maximum available B** to indicate its significant in respect to plant nutrition. A variety of soil properties have been identified as affecting the behavior of B in soils. Soil pH, cation exchange capacity, sesquioxides, clay content, type of clay and specific surface, organic matter content and soil salinity have been reported to influence the solubilty and sorption of B in soils (Elrashidi and O'Connor, 1982; Keren and Bingham, 1985; Yerimiyahu et al., 2001; Fageria 2009) of clays, illite is the most reactive with B and kaolinite the least reactive on a weight basis (Keren and Mezuman, 1981)

2.5 GENERAL USES OF BORON

Boron nitride can be used to make materials that are almost as hard as diamond.

Boron has also been reported by literature to suppress diseases through its fertilizers (Gupta and Singh 1995; Kumar and Sharma, 1997; Sarkar et.al., 2000; Stangoulis and Graham, 2007). A significant move in this regard is effect seen in adding B to plant which brought about the reduction of the pathogenic fungus *Plasmodiophora brassicae* i.e. Woronin in *Brassica* species (Dixon, 1996; Stangoulis et.al., 2007).

(Stangoulis et.al., 2007; Fageria et.al., 2011) also reported that B plays a significant role in lignification and phenol metabolism, which are intrinsically associated with plant defense systems.

2.5.1 BORON IN PLANTS

Boron is essential for the cell walls of plants. Its essentiality has been seen the cell division of growing plant tissue; also for pollination, fruit set, and seed development; translocation of sugars and starches; synthesis of amino acids and proteins; nodules' formation in legumes and regulation of carbohydrate metabolism (Heckman, 2009)

Without adequate levels of boron, plants may continue to grow and leaves but fail to produce fruits or seeds. A continuous supply of boron is important for adequate plant growth and optimum yields (Mahler, 2009)

According to Joseph R. Heckman (2009), normal plant growth from germination to maturity requires a continuous supply of Boron. It is not considered poisonous to animals, but in higher doses it can upset the body's metabolism. We take in about 2 milligrams of boron each day from our food and about 60 grams in a lifetime. (Spectrum Analysis, 2015)

2.6 SOIL BORON IN TOPOSEQUENCE

Toposequence is a sequence of related soils that differ, one from the other because of topography as a soil-formation factor, (Jan Glinski, et.al., 2011)

It is often said that well developed or older soils are generally found on protected middle slopes while younger or weakly developed soils are found on lower slope positions.

An interfluve may have the relief positions described above, each relief position carrying different soil series which may have developed from the same parent material but differ in drainage. Such a group of soils is called a "catena". However, it is becoming increasingly clear that the slopes may have been cut in different lithological materials so that the soil series encountered on such slopes do not vary in drainage but in parent material. Such soil-slope sequence is called a "toposequence". The concept of toposequence is more applicable in Nigeria where soils occurring on the same slopes vary in parent material as well as drainage. (Symth & Montgomery, 1962; Esu, 1986; Esu et.al., 1987; 1991)

Farmers are beginning to crop on marginal lands including farming on slopes in many tropical countries. It is important to know that different soils occur at different positions on the landscape (Nuga et.al., 2006). This various positions can have effect on yield of crops. Depending on location on a slope physical and chemical properties of the soil will also vary either minimally or maximally. Soil physical and chemical properties are necessary to define and evaluate soil types, slopes, existing land use or natural cover under given condition of management. Thus, evaluating agricultural land management practices require the knowledge of soil spatial variability and understanding the relationship of soil properties in a topo-sequence. Spatial variability could allow prediction or estimation of values of un-sampled locations within the region (Xuwen et.al., 2001) and can also make a basis for defining different management zones on a field or an area. Appropriate and proper use of an area of land depends upon the characteristic of such a land. There is therefore need to characterize soils and classify them in a manner that will ease communication and transfer of knowledge about such soils to farmers and other stakeholders.

2.7 BORON; ABUNDANCE AND AVAILABILITY

Boron occurs as an orthoboric acid in some volcanic spring waters, and as borates in the minerals borax and colemanite. Extensive borax deposits are found in Turkey. However, by far the most important source of boron is rasorite. This is found in the Mojave Desert in California, USA (Spectrum Analysis, 2015)

High-purity boron is prepared by reducing boron trichloride or tribromide with hydrogen, on electrically heated filaments. Impure, or amorphous, boron can be prepared by heating the trioxide with magnesium powder (Spectrum Analysis, 2015).

The storehouse for most of the soil boron is in soils' organic matter. As a result, most of the available boron is in the plow layer, where organic matter is highest.

Availability of Boron (B) is determined by many factors including pH of the soil, losses by leaching, crop removal, kind of crop and whether the crop is utilized on the farm and returned to the soil as manure. Plants vary in their Boron requirement but, the range between deficient and toxic solution concentration of B is smaller than from any other plant nutrient element. Soil may contain 0.5-2.0 ppm of available B, but this represents only a small part of the total since only 0.5-2.5 % of the total B in the soil is available to plants. The highest concentrations of B are often concentrated in marine evaporates and in marine argillaceous sediments (Erd, 1980; Rego et.al. 2005)

2.7.1 FORMS OF BORON IN SOIL

Boron has been found in a number of minerals, e.g. hydrous borates [borax ($Na_2B_4O_7 \cdot 10H_2O$), kernite ($Na_2B_4O_6(OH)_2.3H_2O$), colemanite ($CaB_3O_4(OH)_3$-H_2O and ulexite ($NaCaB_5O_6(OH)_6.5H_2O$)], anhydrous borates [ludwigite ($Mg_2Fe_3BO_5$) and kotoite ($Mg_3(BO_3)_2$] and complex borosilicate [tourmaline ($NaAl_3Al_6[Si_6O_{18}](BO_3)_3O_3(OH)$ and axenite ($(Ca,Fe,Mn)_3Al_2BO_3Si_4O_{12}OH$)] [Evans and Sparks, 1983].

Tourmaline (3.0 to 4.0% B) is the most well-known B containing mineral (Berger, 1940). Weathering of B containing minerals brings B into solution mainly as boric acid $B(OH)_3$. Boron can rapidly be leached down in acid soils (Gupta, 1979) or it can be accumulated as evaporite deposits in arid climate (Evans and Sparks, 1983). Although, Uptake of Boron is determined by the level of yield obtained.

2.8 SOIL BORON DEFICIENCY AND TOXICITY

Soil may contain 0.5-2.0 parts per million (ppm) of available boron, but this represents only a part of the total since only 0.5-2.5% of the total boron in the soil is available to plants.

There is a very narrow range between boron deficiency and its toxicity as more than 5.0 ppm agronomic crop can be toxic to many agronomic crops. Plants may take up less than 0.5 lb/a boron, yet this nutrient can significantly reduce crop yield. (Kelling K.A. 1999). Soils low in organic matter, are deficient in boron more than often than soils with high organic matter content. (Kelling K.A. 1999)

Organic matter serve as a reservoir of many nutrients amongst which is boron, which is released by the acting on of microorganisms (decomposition) on that organic matter. Thus with little or no microorganisms to readily breakdown organic matter either due to unfavorable conditions or any other factors, B availability can be limited such that it is present but not available or is not present at all. With due correlation, organic matter and moisture content correlate in determining the availability and deficiency of boron, in that, organic matter is found in higher amounts at soil surface and as such plants have the opportunity to feed on soil boron at the surface. This then means that with dry soil surface, unavailability of microorganisms and decomposition processes reduce drastically and as well as organic matter. So we can say that boron content also reduces at surface of soil which is dry, since organic matter has been related to be a major source of soil boron. According to K.A. Kelling 1999, plants cannot feed in the zones most available to boron when soil surface dries up and as such its availability can be recovered by moistening of soil either through rainfall or irrigation.

The loss of available Boron (B) through crop removal, leaching and reversion to unavailable forms, coupled with higher requirements for B through better crop varieties and improved cultural practice, has resulted in an inadequate supply of B available for growth on many agricultural soils. Moreover, the total B content of the soil is not a reliable guide to the adequacy of B for crop growth since less than 5 % of the total may be available for use by plants (Wapa.et al., 2014).

According to Fageria (2009), two types of Boron deficiency are encountered in agricultural soils; The natural deficiency and the induced deficiency. The former is due to lack of boron in soil forming minerals and the latter is resulting from over-liming or other adverse environmental conditions. Boron is seen to be more available in acid soils than in alkaline soils. This is due to the fact that availability of the nutrient element decreases with increase in pH as seen in this table below by Fageria (2009), where an experiment was conducted on boron concentration using dry bean and soybean.

Table 1: Boron concentration (mg kg^{-1}) in shoot of dry bean and soybean as influenced by pH in Brazilian Inceptisol

Soil pH in H_2O	**Dry Bean**	**Soybean**
4.9	33	20
5.9	19	16
6.4	20	11
6.7	17	11
7.0	14	12
R^2	0.90**	0.84**

**** Significant at the 1% probability level.**

Source: Adapted from Fageria N.K (2009)

The reduction of Boron availability from increasing soil pH by liming is caused by B adsorption by Iron and Aluminium hydroxides (sesquioxides). Boron deficiency is largely encountered on low-organic-matter, sandy soils. High rainfall and leaching losses reduce B availability as well as dry weather acting as a trigger to its deficiency (Fageria 2009). Various factors determine and affect the availability of Boron and they include soil solution pH, soil texture, soil moisture, temperature, oxide content, carbonate content, organic matter content and clay mineralogy as well as many others.

Clay content also affect its availability, this is because boron is easily leached out of soils especially when soil aggregates are loosely packed. This is why boron is more deficient in coarse textured soils than in fine textured soils. The finer texture a soil has is very much dependent on the clay content in it. As such the lesser the clay content the more vulnerable the soil is to leaching. According to K.A. Kelling 1999, Boron is not readily held by the soil particles and because less leaching occurs on fine-textured silts and clays, these soils are not boron deficient as often as sands. Joseph R. Heckman 2009, reports that sandy coastal plan soils are typically the most susceptible to Boron deficiency.

Soil boron is found in both organic and inorganic forms that are made available to plants as either or both soil organic matter is decomposed and/or boron-containing minerals dissolve. Boron, as the borate ($BO3^{3-}$) anion, is mobile in the soil and can be easily leached from the surface soil.

Calcium, potassium, and nitrogen concentrations in both the soil and plant can affect boron availability and plant function, the calcium:boron (Ca:B) ratio relationship being the most important. Therefore, soils high in calcium will require more boron than soils low in calcium. The chance for boron toxicity is greater on low calcium-content soils. (Clemson University, 2015)

Boron is routinely included in the fertilizer recommendation for the crops cotton, peanut, alfalfa, apple, root crops, cabbage, broccoli, and cauliflower, and when reseeding clover or where clover seeds are to be harvested. When applied as a part of a soil fertility program, many types of animal manures, superphosphate (0-20-0), and liming materials may contain sufficient boron to meet the boron requirement for some crops. (Clemson University, 2015)

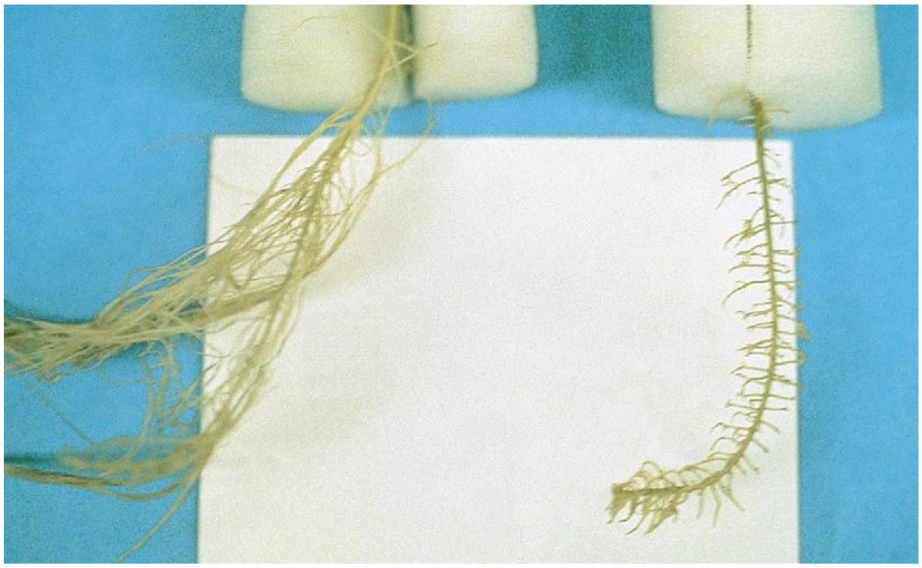

Fig.1. Lack of boron stunts plant vegetative growth and greatly reduces root growth. Decreased root growth reduces the plants' ability to obtain water and nutrients from the soil. (Mahler, 2009)

Fig.2. Boron deficiency results in smaller, deformed, and darker potato tubers. During vegetative growth boron-deficient plants produced 20 percent less biomass—but the real difference becomes apparent at harvest (Mahler, 2009)

Boron is often found in high concentrations in association with saline soils and saline well water (Dhankhar and Dahiya, 1980). Sorption capacity of a given soil is crucial in determining the amount of B in solution. A soil that has high adsorp-tion capacity would be expected to maintain lower soil solution B over a longer period of time than a soil with low adsorption capacity when both soils are irrigated with the same B laden water.

There is a high probability for Boron toxicity to occur via fertilizer application, boron toxicity is detected when plants take up too much boron and excessive levels of boron affect plant growth negatively. One way to avoid this could be to institute a proper management of fertilizer and crop rotation program. Boron should be applied to the soil at low rates only after a demonstrated need has been established through plant tissue and /or soil testing.
As it is known a very narrow range exists between toxicity and deficiency levels in terms of Boron as a nutrient element.

Below is a preview of a range of crops and their boron deficiency symptoms as a response to their soils' boron level:

Table 2: Selected crops and their Boron deficiency symptoms (Heckman, 2009)

PLANTS	DEFICIENCY SYMPTOM
Field Crops	
Alfalfa	Death of terminal bud, rosetting, yellow top, little flowering, and poor seed set.
Clover;	Poor stands, growth and color.
red, white	Reduced flowering and seed set.
Corn	Short, bent cobs, barren ears, blank stalks, poor kernel development.
Soybean	Reduced yield and poor quality.
Vegetables	
Beets	External spotting, cracking, and canker.
Broccoli	Hollow stems or internal discoloration, brown curds.
Cabbage	Hollow stem, watery areas, heads yellow, stunted.
Carrots	Reddening of leaves, splitting of roots.
Cauliflower	Leaves curled, hollow stem, curds dwarfed, brown.
Celery	Stem cracked with brown stripes, heart blackened.
Lettuce	Stunted growth, discoloration of leaves, brittle.
Tomato	Thickened leaves, brittle leaves, fruit fails to set.
Radish	Pale roots, brittle stems, watery flesh, flecked.
Spinach	Roots dry and dark, leaves small and yellowish.
Fruits	
Apple	Pitting, skin discolored, cracking, corking.
Pear	Blossom blast, pitting, internal corking, bark cankers.
Grape	“Hen & Chick” symptom, dead main shoots.
Apricot	Twigs die back, fruit fails to set.
Plum	Fruit cracked, beads of gum internally/on skin.
Walnut	Die back from shoot tips, leafless branches.
Strawberry	Pale chlorotic skin of fruit, cracking, die back.

2.9 THE RESEARCH PROJECT FOR ELEYIN FARMS – (OBJECTIVE)

The uptake of Boron nutrient element by plants is not as high as that of other nutrient elements but its deficiency cannot be ignored and is gradually becoming a subject of keen interest.

In view of the above factors which may lead to plant growth problems, a determination of the available Boron content is one of the most important tests that can be made to diagnose B deficiency and toxicity problems. Boron (B) concentration below 0.15ppm will usually indicate a need for additional supplement. Oyinyola and Chude (2002) reported that B deficiency is widespread in soils of the Nigeria Savanna zones, as response of cotton and some crops to B was discovered. A couple of good work has been done on B in relation to its availability and distribution as a plant nutrient in various agro-ecological zones around the world both on flat and slope inclined topography but these information is strewn across various publication and thus marks the essence of this chapter, which has collectively condensed these materials into available knowledge of recent discoveries in a review. However, it is imperative that this study be carried out to focus on assessing the available B in the soils within the Landmark University farms, Eleyin, Isin LGA, Kwara State, which would provide base material for proper management of the soils in the Landmark University farms. This may provide a Data Base that will serve as the required reference material for future land use planning and management.

CHAPTER 3

METHOD AND METHODOLOGY

3.1 SITE DESCRIPTION

3.1.1 STUDY SITE

This study was conducted in Landmark University Farms which is situated at Eleyin, Isin Local Government Area. A toposequence was selected through a reconnaissance survey. Three Soil profile pits were dug along the toposequence i.e. the upper slope, middle and lower slope. The profile was measured with dimension 1.5m x 1.2m to a depth of 1.5metres. Soil samples were collected based on identified horizons. Profile description was by the use of FAO guidelines for soil description (1976). Laboratory research was carried out to determine the routine nutrient elements and boron in the various soil samples of selected profile along the toposequence at the Soil science department of Landmark University, Omu-Aran, Irepodun LGA.

3.1.2 GEOGRAPHY, SOIL AND CLIMATE OF SITE

The Eleyin farm site is situated in the derived savanna agro-ecological zone of Nigeria (with Latitude 8° 14' 0'' North, Longitude 5° 5' 0'' East according to World map). As situated in Kwara state, its climate regarded as a tropical climate characterized by double rainfall maxima and a tropical wet and dry season which lasts for about 6 months. The mean annual rainfall is about 1,300mm with rainy season from the end of March till early September and dry season from early October to early March. The temperature uniformly ranges between 25℃ and 30℃ in the wet season which is high except in July – August due to prevention of direct insolation by clouding of sky, while the dry season shows 33℃ – 34℃ (Olarenwaju, 2009; Akpenpuun et. al., 2013). The farm area has an undulating topography, making it prone to erosion. The study was conducted in the year 2014.

3.1.3 LAND USE AND VEGETATION

The farm is about 350 hectares of land with 100 hectares cultivated between the years 2014 to date. Cultivated crops around the farm site include Jatropha, maize and cassava. Incursion into the farm by herds of cattle to graze is not uncommon.

3.2 FIELD PROCEDURES

3.2.1 SITE VISIT/ RECONNAISANCE

Information collected on the field includes; site information, general soil information and general profile description.

3.2.2 SOIL SAMPLING

Sampling took place on 30th October, 2014 between morning and mid-day.

Materials used for the sampling process include;

Soil auger, Hand trowel, Polythene bags, Marker pens, Cardboard paper, Soil test kit box, Measuring tape, Camera, Shovel, Cutlass.

3.3 LABORATORY PROCEDURES

Samples were air-dried at room temperature for 3 days, afterwards they were bagged until analysis was to be carried out.

The soil samples were ground using a porcelain pestle and mortar. They were then sieved using a 2mm (mesh 10) separating the gravel from the sample. The gravel was bagged and labeled differently from the 2mm sieved air-dried soil sample and then the routine analysis was carried out.

LABORATORY ANALYSIS

3.3.1 PARTICLE SIZE ANALYSIS (TEXTURAL)

The Hydrometer method was used for this analysis

Procedure:

50g of 2mm sieved air-dried soil sample was weighed into a 250ml beaker. Salt solution, Cargon was prepared and 100ml of it was measured into each soil sample. The samples were left for 30minutes to soak in the salt solution after which the content of each is stirred and turned into cylinders. Water was then added to make up mixture to 1L (1000ml). A plunger was then used to agitate the solution moving it up and down so as to mix the contents thoroughly. Immediately the plunger was removed, the hydrometer was put into the solution and the stop watch was made to start reading. At 40 Seconds (R40sec.), reading was taken at the meniscus line of the hydrometer inside the soil sample solution, as the hydrometer was removed from the suspension; a thermometer was used to take temperature reading for 30 seconds. The suspension was left for 2 hours (R2hrs.), then, another hydrometer and temperature reading was taken.

Calculation

$$\% \text{ silt + clay} = \frac{(R40\ Sec - Ra) + Rc}{\text{Weight of soil}} \times 100$$

$$\% \text{ clay} = \frac{(R2\ hours - Rb) + Rd}{\text{Weight of soil}} \times 100$$

% silt = (silt + clay) – clay

% sand = 100- (silt + clay)

Textural classes of the soil samples were determined using the textural triangle.

3.3.2 SOIL REACTION

Procedure:

The pH was determined using the pH meter with a glass electrode. It was measured both in water and KCl. The soil : water and soil : KCl ratios were 1:2. 10g of 2mm sieved air dried soil sample was weighed into 100ml beaker for each of the 24 soil samples; 20 ml of distilled water was added to each of the samples and 20ml of 1M KCl for the second set of samples. They were subjected to stirring, using a mechanical shaker for 30 minutes interval. Afterwards, the glass electrode of the pH meter is suspended in the solutions while readings were taken.

Note: the pH meter must be calibrated with standard buffer solution of pH 4 and 7 and subsequently rinsed with distilled water and dabbed with a soft tissue paper after analysis of each sample before inserting in the next sample.

3.3.3 ORGANIC MATTER

Organic matter content is based on the organic carbon content. The organic matter was determined using the Walkey-Black wet oxidation method (1934).

Procedure:

1g of 0.5mm sieved soil sample was measured into a 250ml conical flask. 10ml of 0.167M potassium di chromate ($K_2Cr_2O_7$) was added and 20ml concentrated sulphuric acid (H_2SO_4). The flask immediately was gently swirled until the soil and reagents were uniformly mixed for about a minute. It was allowed to stand for 30 minutes, 100ml of distilled water was then added, after adding 3-4 drops of ferroin indicator, and a greenish cast was identified which later turned dark green, samples were titrated with 0.5M ammonium sulphate which was added drop by drop until there was a visible change from green to brownish red (maroon). Readings were taken according the initial point of calibration before the titration and the point of calibration upon which there was a visible color change to maroon. A blank titration was also prepared in the same manner but without soil sample, as a control sample.

The Organic matter was calculated thus:

1ml 0.167M $K_2Cr_2O_7$ = 3mg carbon =0.003g

% Organic carbon = (B-T) x M x 0.003 x 1.33 x 100/wt.

Where:

B = Blank titre value

T = Sample titre value

M = Molarity of $(NH_4)_2\ Fe(SO_4)_2 \cdot 6H_2O$

0.003 = Mass of carbon

1.33 = Factor

Wt. = Sample weight

% Organic matter = % Organic carbon x 1.724

3.3.4 AVAILABLE PHOPHORUS

5g of sample was weighed into a sample beaker. 35 ml of extracting solution was added to it and the mixture was stirred for 5 minute and then filtered. 5 ml of the extract was pippeted into 25 ml measuring cylinder and 4ml of developing solution (reagent B) was added. This was then made up to mark with distilled water and allowed to stand for 15minutes. The absorbance was read at 660nm wavelength using spectrophotometer. The same procedure was carried out on the blank expect that of the extractant was not added.

Calculation: ppm of soil = ppm of P in solution × 35

3.3.5 TOTAL NITROGEN

This was determined using the kjeldahl digestion method.

The amount of Nitrogen is calculated thus:

$$\% N = \frac{Mass\ of\ N}{wt.} X\ 100$$

$$= M\ x\ T\ x\ 0.014\ x\ \frac{V1}{V2}\ x\ \frac{100}{wt.}$$

Where:

T = Control titre

M = Molarity of acid

V_2 = Volume of digest used in the digest

V_1 = Final volume of digest

W = Weight of soil used for digestion

3.3.6 EXCHANGE ACIDITY

5g of dried soil was weighed into a sample bottle and 50mls of 1N KCL was added to it. The mixture was shaken for 1 hour and the suspension was filtered using filter paper to obtain filtrate. 25mls of the extract was pippeted into 100mls conical flask and 4 drops of phenolphthalein indicator was added. The mixture was titrated against 0.01N NaOH. The colour changed from colourless to pink colour at the end point.

Calculation

Total acidity = Titer x volume of extraction ÷25 x strength of NaOH x 100 ÷ weight of soil

3.3.7 EXCHANGEABLE BASES

Exchangeable cations were extracted with 1N NH4OAC (pH 7.0). The cations (K and Na) in the filtered extracts were determined with a flame photometer while Ca and Mg were determined by titration method using 0.02N EDTA. 10g of the soil samples were weighed into a 250ml beaker and 100ml of NH_4OAc was added and the mixtures were allowed to shake for 1 hour using mechanical shaker after which the samples were filtered using filter papers and volumetric flask to obtain the extracts.

3.3.7.1 Ca AND Mg determination

5ml of the extract was pippeted into a conical flask, then 5ml of concentrated NH_4OH, 5 drops of 2% sodium cyanide and 3 drops of erychrome black T indicator were added and finally titrated with 0.02N EDTA. Colour change was observed from colourless to blue at the end point.

For Ca, 5ml of the extract was pippeted into a conical flask and 5mls of KOH was added with, 5drops of 10% hydroxylamine hydrochloride, 5 drops of 2% sodium cyanide and 3 drops of calon as indicators. 0.02N EDTA solution was used for the titration. Colour change was observed at the end point.

Calculation

Ca + Mg = Titer x 0.02 x 50 ÷ 5 x 100 ÷5

Ca = Titer x 0.02 x 50 ÷5 x 100 ÷ 5

3.3.7.2 Na and K determination

The exchangeable sodium and potassium in the soil extracts was determined using flame photometer. The standard of sodium and potassium were prepared with concentration in part per million (ppm). A blank of ammonium acetate extract was also prepared which has no soil sample. This was used to neutralized the flame photometer electrode

Potassium standard ppm	Sodium standard ppm
4 8 12 16 20	2 4 6 8 10

The percentage of flame emission for each of the soil extract was recorded. Sodium and potassium standard were plotted against their various concentration and the extracts were determined using their percentage emission.

3.3.8 CATION EXCHANGE CAPACITY

The CEC in this research was determined by the summation method. i.e. the sum of the Exchangeable bases and Exchangeable acidity.

3.4 DETERMINATION OF BORON

Available Boron was determined using curcumin method. Where 10g of light colored soil was added to 25ml of near boiling distilled water for five minutes after which it was removed from heat and 2 drops of CaCl2 solution was added, it was then allowed to cool and filtered through a boron-free filter paper. The 0.5ml of the soil extract liquor was placed in a polypropylene beater and 2ml of curcumin reagent was included. It was mixed thoroughly and allowed to evaporate into dryness in a 55.43℃ water bath or oven. After all visible liquid has disappeared, it is then mix dissolved in 10ml of ethyl alcohol and transferred to a colorimeter tube. Any turbidity present is allowed to settle out and when solution is clear, it is read on a colorimeter within 2 hours. A set of standards is prepared (0.2, 0.4, 0.6, 0.8 and 1.0 ppm) and it is read at 540mm wavelength.

3.5 DATA/STATISCAL ANALYSIS

Duncan Multiple Range Test was used to determine the significance in boron distribution with depth of horizons.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.0 PARTICLE SIZE DISTRIBUTION

The textural analysis of the three profile pits in the project area shows very high sand composition. The upper slope exhibits sand composition of between 79.12% in the lowest horizon to 87.12% in the surface horizon giving sandy to sandy loam textures. For the middle slope position, sand composition varies from 78.12% in Ep_2C_1 to 90.12% in EP_2A_2 again giving sandy to sandy loam and loamy sand texture. The bottom slope however has less sandy composition varying from 58.12% in EP_3C_2 to 84.12% in EP_3A_1. In this bottom slope, the trend is a clear decrease in sand composition down the lower horizons.

Generally, it can be seen that while sand composition decreases down the horizons in all the slopes, clay composition increases with depth of horizon which agrees with Jacob M. Wapa et.al. (2014)

Textural class was mainly sand and loamy sand in the surface horizons across the slope but down the profiles of each slope, it ranges from sand, loamy sand, sandy loam to sandy clay loam which is very efficient for root growth and development.

Clearly sand composition defines the textural classification of soils in the area. In the upper and bottom profiles, sand composition decreases down the lower horizons while in the middle slope, there is no pattern.

Table 3: Particle size and soil textural distribution of the Eleyin toposequence

Pedon	Horizon Depth	Horizon Designation	% Clay	% Silt	% Sand	Textural Class
EP1	0-16	A1	3.88	9.00	87.12	Sand
	16-25	A2	5.88	14.28	79.84	Loamy sand
	25-36	B	11.88	9.00	79.12	Sandy loam
EP2	0-11	A1	3.88	7.00	89.12	Sand
	11-24	A2	3.88	6.00	90.12	Sand
	24-37	B1	9.88	5.00	85.12	Loamy sand
	37-65	B2	16.88	5.00	78.12	Sandy loam
	65-128	C1	10.88	6.00	83.12	Loamy sand
	128-144	C2	12.88	8.00	79.12	Sandy Loam
EP3	0-10	A1	3.88	12.00	84.12	Loamy sand
	10-25	A2	10.88	11.00	78.12	Sandy loam
	25-43	B1	20.88	9.00	70.12	Sandy clay loam
	43-61	B2	26.88	10.00	63.12	Sandy clay loam
	61-92	C1	30.88	10.00	59.12	Sandy clay loam
	92-150	C2	30.88	11.00	58.12	Sandy clay loam

Table 4: Morphological properties of soil formed along a toposequence (Eleyin)

Pedon	Horizon Depth (cm)	Horizon Designation	Color Code	Color Description	Boundary	Root	Consistency
EP1	0-16	A1	7.5 YR 2/2	Brownish black	sh.sm	c.fn.fb	ns.sp
	16-25	A2	7.5 YR 4/6	Brown	sh.sm	c.m.fb	ms.sp
	25-36	B	5 YR 5/6	Bright Reddish Brown	cl.sm	c.fb.f.wd	ms.np
EP2	0-11	A1	7.5 YR 3/3	Dark Brown	sh.sm	c.fn.fb	ms.sp
	11-24	A2	7.5 YR 4/6	Brown	sh.wv	c.fn.fb	ms.mp
	24-37	B1	7.5YR 5/8		cl.wv	f.vfn.fb	ms.mp
	37-65	B2	5 YR 5/8	Bright Reddish Brown	cl.wv		ss.sp
	65-128	C1	2.5YR 3/6	Dark reddish brown	cl.sm		ss.sp
	128-144	C2	7.5YR 6/8	Orange	cl.sm		ms.mp
Ep3	0-10	A1	7.5 YR 4/3	Brown		mn.fn.fb	ms.mp
	10-25	A2	7.5 YR 5/4	Dull brown		fn.fb	ss.sp
	25-43	B1	7.5 YR 4/6	Brown		fn.fb	ss.vp
	43-61	B2	7.5YR 6/6	Orange		-	ss.vp
	61-92	C1	7.5YR 5/6	Bright brown		-	vs.vp
	92-150	C2	7.5YR 7/8	Yellow orange		-	vs.vp

Symbols representation:

c- common f- few vf- very few mn- many fn- fine vfn- very fine m- medium
fb- fibrous wd- woody np- non plastic sp- slightly plastic vp- very plastic
ns- non sticky ss- slightly sticky ms- moderately sticky vs- very sticky
sh- sharp sm- smooth cl- clear wv- wavy ab- abrupt

4.1 SOIL REACTION

The reaction of the soils of the area is generally adequate for all the slope positions varying from 5.54 to 6.66 (moderately acid to strongly acid) in the upper slope, 5.51 to 6.4 (relatively strongly acid to slightly acid) in the middle position and from 4.98 to 6.49 (strongly acid to slightly acid) in the bottom slope.

There is no trend of variation between the horizons in the slopes and along the slopes of the toposequence. According to Agbede (2009), soil reaction has a direct influence on essential nutrients availability in the soil showing a decline of soil micronutrient availability as soil pH increases.

As expected, the pH as determined in 1N KCl was lower than pH determined in water which can be related to acidic soils. In crop production practices where acidic soils are not necessarily needed, this is a clear indication for liming requirement.

4.2 AVAILABLE PHOSPHORUS

The available phosphorus varies from 6.34 to 79.44 ppm P in the upper slope showing low to moderate to very high rating. In the middle slope, the variation is from 4.93 to 90.01 ppm P again exhibiting low to moderate and very high. For the bottom slope, the variation is from 8.46 ppm P to 97.23 ppm P showing moderate to very high. In all the surface horizons, there is relatively adequacy of available phosphorus as the trend is from moderate to very high.

This can be attributed to the use of mineral fertilizer at some points on the toposequence as some parts have been under cultivation. This study agrees with Wapa.et.al. (2014). According to Wapa.et.al, “low” to “moderate” levels of available P indicate that Phosphorus may be chemically bound as phosphates of Fe and Al owing to the observed acidity of the soil and as well the high abundance of Fe in soil. Agbede (2009) agrees that a significant correlation exist between available P, soil pH and Fe and Al in the soil.

4.3 ORGANIC MATTER

Organic matter of the soils in the area is generally not adequate. A range can be seen from low to very low across the slope. The upper slope has its Organic matter level between very low (0.4%) to low (0.44%) down the horizons while the middle slope shows a range of very low (0.40%) to low (0.41%) level of organic matter as well. The bottom slope has the same but with the value range of 0.40% to 0.43%. The trend within the profiles show a consistent decrease down the horizon in the upper and middle slope but in the lower slopes there is a slight increase from the surface horizon to the B-horizon and then following no particular pattern.

In all the surface horizons Organic matter is inadequate as it varies from very low (0.40) to low (0.44)

4.4 TOTAL NITROGEN

From the upper slope, Total N is seen to be on a range of 0.1% - 0.15% varying from very low to moderate low. There is a slight increase from EP_1A_1 to EP_1A_2 (which could be as a result of surface runoff) and then a decrease from EP_1A_2 to the last horizon on that slope. The middle slope has a trend of very low to moderately low to medium on a value range of 0.02% -0.198% with Total N at its highest at the surface of this slope and a significant trend of decrease down the horizons of this slope. The bottom slope EP_3 reveals a clear reduction of Total N down the toposequence, with a range of 0.063% - 0.171% which keeps Total N between medium to very low from surface to the lowest horizon of the bottom slope profile.

All the surfaces of the toposequence fall in the range of "moderate low" to "medium" with higher concentrations of Total N at the surfaces.

The "low" range of Total N across the slopes can be partly attributed to the predominant sandy texture of the soil (sand, sandy loam, sandy clay loam) which enhances susceptibility of soil to high leaching as ascertained by Wapa et.al. (2014) Also, N is a very mobile nutrient element and prone to leaching, percolation and volatilization (Ogbodo, 2012; Wapa et.al, 2014). This accounts for the "moderate low" to "low" availability of Nitrogen in the soils.

4.5 EXCHANGEABLE BASES

Exchangeable bases in soil comprise of Ca, Mg, K, Na and H+Al and the order of abundance in the soils of the research study area in increasing order is Ca>Mg>Na>K

4.5.1 EXCHANGEABLE SODIUM

Na is generally very inadequate in the Eleyin soils as all the slopes are shown to be within the very low level of sodium availability. The trend generally shows near unavailability of Na in the toposequence with no particular pattern down the horizons. For instance, the upper slope reveals an increase from EP_1A_1 (0.02 cmol/kg of soil) to EP_1A_2 (0.06 cmol/kg of soil) and a decrease from EP_1A_2 to EP_1B (0.04 cmol/kg of soil). This indicates absence of salinity as abundance of Na shows presence of potential salinity.

4.5.2 EXCHANGEABLE POTASSIUM

Potassium is generally “low” (0.2 to 3.0 cmol/kg of soil) in all the horizons in all the profiles which the exception of EP_1A_1 which posted moderate (0.46 cmol/kg of soil). There is therefore the possibility of potassium deficiency and the need for supplementation. There is consistent trend in K distribution within profiles in the upper and middle slopes with K decreasing down the profile, also all surface horizons show an increasing trend of K along the slopes (upper to middle to bottom). This trend of distribution can be attributed to forces of erosion that washes nutrient from upper slopes and deposit same on the lower slopes as reported by Jacob et.al. (2014)

4.5.3 EXCHANGEABLE CALCIUM

Calcium values in all the horizons in all the profiles posted “low” values (2-5 cmol/kg of soil), although calcium is the dominant cation.

4.5.4 MAGNESIUM

Magnesium values are also similar to calcium trend as the values are all “low” (1-3 cmol/kg of soil) in all the horizons in all the profiles across the toposequence. Even the low values does not seem to follow a particular pattern

4.6 CEC

The cation exchange capacity (CEC) for all the horizons of all the profiles across the toposequence as shown in Table varies from “very low” (< 6cmol/kg of soil) to “low” (6-12 cmol/kg of soil). In the upper slope and lower slope positions the values are “very low” and “low” in the middle slope positions. This is an indication that the soils of the area are very poor in their ability to exchange cations –an indication that the fertility of the soils of the area across the toposequence is poor. The soils of area will therefore benefit greatly from fertilizer supplemention- both inorganic and organic. The “low” to “very low” CEC values of the soil and other exchangeable bases in the soil can be attributed to high weathering and leaching rate of basic cations which could result from high temperature and rainfall associated with humid tropical climates. Low CEC value also suggests that clay type is low activity clay (LAC) which are often low in the nutrient retention and fertility status.

4.7 BORON DISTRIBUTION

Boron distribution as shown in the table reveals that in the upper slope position in Boron content down the horizons. For example, in the surface horizon, it is 1.10 mg/kg and 0.77 mg/kg in the next horizon and 0.06 mg/kg in the last horizon. While boron is medium in Ep_1A_1 and Ep_1A_2, it is very low (0.06 mg/kg) in Ep_1B. Middle slope also shows decrease down the horizons but with a decrease from the surface horizon (Ep_2A_1: 1.16 mg/kg) to the next (Ep_2A_2: 0.22 mg/kg).

From Table 2, it is observed that Upper slope of the toposequence shows that boron is medium in all other horizons except the lowest where it is low while the middle slope from data correlated reflects that boron is medium at the surface horizon while the rest of the horizons have low boron content thus showing a trend of decrease down the horizon. The bottom slope with a variation of low to medium boron content has boron low at the surface with Ep_3B_2 and Ep_3C_2 horizons showing that boron is medium.

From the Duncan Multiple Range Test (DMRT), mean values reveal no significant difference in the distribution of boron with depth of horizons in the profiles along the slopes.

Soils in this area have not undergone boron research thus consistent literatures from which comparisons can be made are unavailable. Although, this finding has shown that boron is relatively not abundant in the soils of this study area which can be agreed upon by the ratings observed in the various physico - chemical properties of the soil as discussed earlier

Table 5: Boron distribution of the Eleyin toposequence

Pedon	Horizon Designation	Horizon Depth	Available Boron (mg/kg)	Boron Rating
EP1	A1	0-16	1.10	Medium
	A2	16-25	0.77	Medium
	B	25-36	0.06	Low
EP2	A1	0-11	1.16	Medium
	A2	11-24	0.22	Low
	B1	24-37	0.33	Low
	B2	37-65	0.11	Low
	C1	65-128	0.06	Low
	C2	128-144	0.06	Low
EP3	A1	0-10	0.17	Low
	A2	10-25	0.39	Low
	B1	25-43	0.00	Low
	B2	43-61	0.88	Medium
	C1	61-92	0.00	Low
	C2	92-150	0.72	Medium

Boron Rating: < 0.50 – low 0.50-2.0 –medium > 2.0 –high

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The soils of selected profiles of the Landmark University farms Eleyin are generally Sand, sandy loam, loamy sand and sandy clay loam in texture, they are therefore light-textured to medium-textured. They are acidic in soil reaction and have very low to medium Total Nitrogen content. They have relative availability of available P and Organic matter of the soils is not generally adequate with a range of "very low" to "low". The exchangeable bases and CEC in the soil are inadequate as well.

Boron as a very essential micronutrient required for growth and development of crops. It is also a very delicate nutrient element which has a thin range between its toxicity and deficiency (easily expressed on plant parts and morphology) and also is easily removed from the soil by various factors such as pH, soil water holding capacity, soil texture and structure etc. it is therefore very essential to manage soils properly so as to ensure that boron deficiency in soils is minimized as well as plant uptake of boron is maximized.

5.2 RECOMMENDATIONS

The Eleyin soil is deficient in boron which may be due to numerous deficiencies in the soil's physico -chemical properties and can be corrected. Considering the results obtained and the objectives of the study, some suggestions for correction include:

a. A Comprehensive and detailed survey of the soils in the study area is needed in order to determine the management design to be implemented
b. The use of integrated soil fertility management approach is advisable for soils of slopes in this area. In essence inorganic and organic nutrient sources should be incorporated in a cost effective but soil productive way. Such as:
   - Selection of cultivars with low requirement for boron and adoption of improved variety of cultivars for crop production during the period of boron reclaimation
   - Erosion control methods such as contour strip, contour bunds, earth banks as well as adequate mulching should be introduced to the slopes of this area i.e. the toposequence, as this would help to increase organic matter especially at the surface horizons which would in turn increase and ensure nutrient availability and uptake for plants. It would also help to reduce nutrient loss via surface runoff.
   - There is a need for nitrogenous fertilizers in the soils especially on the upper slope.
   - There is a need for application of boron fertilizer.

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