FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA

LABOUR IS FOR THE FARMER, SOIL FERTILITY AND CROP NUTRITION PRODUCE CROP YIELDS

By

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Introduction

All thanks to Almighty Allah for making this day a reality by sparing my life and yours and bringing you all here safely. This is the 74th inaugural lecture of this great citadel of technological learning and the fourth in the recently rechristened Department of Soil Science and Land Management.

Derivation of the Title of the Lecture

The title of the lecture was derived from paraphrasing the Yoruba proverb which says, "***wahala ni tagbe, olorun ni mu isu ta"***. The literal translation in English is, ***'labour is for the farmer, God forms yam tuber'***. The proverb is used to remind somebody who works unusually hard at an endeavour compared to his peers, to take it easy as only God can crown his effort with success, no matter how hard he exerts himself. The title is analogous to this proverb in the sense that, no matter what a farmer does in terms of excellent agronomic practices, it is soil fertility and nutritional status of the plant that will ultimately bring desirable yields of crop.

The Soil

From the beginning of the world, to the present, soils can be classified into two broad types. The first type is the soil that not only antedates human beings, but that we know very little about, that was used to form or mould our forefather, Adam, as stated in the two Holy books, the Quran and the Bible. This soil was specifically referred to as clay with a sticky property in the Quran and dust in the Bible.

"Behold, thy Lord said to the angels, "I am about to create man from clay"(Surat Sad, 38:71).

"Just ask their opinion, are they the most difficult to create, or the (other) beings, We have created? Them have We created out of a sticky clay" (Surat As-Saffat, 37:11).

"And the Lord God formed man of the dust of the ground, and breathed into his nostrils the breath of life; and man became a living soul" (Genesis 2:7).

Based on our temporal knowledge, clay particles are part of the components of the mineral or inorganic matter of the soil and smaller than 0.002 mm diameter in size. They have large specific surface area per unit mass and colloidal in nature, with negative charges on their surface. These make them to have tremendous capacity to adsorb water and cataionic plant nutrient elements, such as calcium (Ca), magnesium (Mg), and potassium (K). Soils that are dominated by or have a proportion of these clay particles are in clayey textural class of soils including sandy clay, silty clay, loamy clay and the typical clay soils. Clay soils are dominated by micropores which are convoluted making these soils to have poor drainage and be waterlogged after heavy rain. These properties of clay particles are conferred on the clay textural class of soils making them to be inherently fertile for crop production. Probably, this is one of the reasons why God in his infinite wisdom formed or moulded Adam from clay, so that we can be fertile for procreation.

The second type of soil is the one we know now. It is defined as **"the unconsolidated material on the surface of the earth consisting primarily of mineral or inorganic and organic**

matter and containing pore space occupied by air and water, which has been subjected to and influenced by genetic and environmental factors of parent material, climate, living organisms, and topography. These factors interact over time to develop soil that differs from the material from which it was derived in many physical, chemical, biological, and morphological properties and characteristics (USBR, 2003). The genesis of the soil is the rock, which is a mixture of minerals. The weathering of the rock and minerals contained in them initiates the process of soil formation and the release of plant nutrients. Minerals are therefore the primary source of plant nutrient elements. For example, the hydrolysis chemical weathering of the mineral, orthoclase feldspars results in the formation of aluminosilicate and release of plant available K. The equation of the reaction is:

$$KAlSi_3O_8 + HOH \rightarrow HAlSi_3O_8 + KOH$$

Thus, soils that have been subjected to intense weathering with only non-weatherable minerals such as quartz (SiO_2), exemplified by tropical and subtropical soils, and regarded as 'old,' are inherently infertile. This low inherent soil fertility in the highly weathered and leached soils of tropical soils largely account for low and unsustained crop yields in most African countries (Okalebo, *et al.*, 2006). On the other hand, soils that have not been subjected to intense weathering and still contain weatherable minerals, such as temperate and arctic soils are regarded as 'young' soils and inherently fertile.

Importance of Soil

The essentiality of soil to the survival and well being of humans on earth was aptly captured by the following writings several years ago.

"Upon this handful of soil our survival depends. Husband it and it will grow food, our fuel, and our shelter and surround us with beauty. Abuse it and the soil will collapse and die, taking humanity with it"

- Vedas Sanskrit Scripture, 1500 BC.

"There is nothing in the whole of nature which is more important or deserves much attention as the soil. Truly it is the soil which nourishes and provides for the whole nature, the whole of creation depends on the soil, which is the ultimate foundation of our existence"

- Fredrich Albert Fallon, 1862.

Soil is a major component of the land and the ecosystem. It is a non-renewable natural resource on a human time-scale that harbours the wealth of a nation. Soil is the ultimate foundation of human existence on earth and invaluable to mankind as it provides food, fibre, feed, fuel, numerous other goods and ecosystem services. Historically, soil was responsible for the rise and fall of the civilisation of Mesopotamia, situated between rivers Tigris and Euphrates in the present day Iraq. The Greek historian, Herotodus, dating back to 50 BC. reported the phenomenal yields obtained, due to the very high fertility of the soil. Numerous people with different skills migrated to the area to settle and constructed a well-developed irrigation system. The same soil when it was poorly managed became saline with high salt concentration resulting in production of unsatisfactory poor yields. The consequence was the emigration of people from the area and thus, the downfall of the civilization.

Soil Fertility and Plant Nutrition

The fertility of soil can be defined as '**the capacity of a specific soil to sustain plant and animal productivity within natural and managed ecosystems by supplying essential nutrients**

and water in adequate and available forms (Karlen *et al.*, 2008). Soil fertility status is usually estimated in terms of nutrients reserves, and its indices include acidity, organic matter content, macro and micro nutrients content, base saturation and cation exchange capacity (Sharma *et al.*, 2011). It is central to the productivity of agricultural ecosystems, because it is the medium from which agricultural production emanates. The improper management of soil fertility with attendant soil fertility depletion in sub-Saharan Africa (SSA) is responsible for the food crisis in the region. In smallholder farms, it is the fundamental biophysical root cause of declining per capital food production (Sanchez *et al.*, 1997). The average nutrient loss in SSA was estimated to be equivalent to 100 kg fertilizer ha^{-1} yr^{-1} in 2000 (FAO, 2000). Using the degree of soil nutrient in a grouping of SSA countries, Nigeria was placed in the 'High', 21 – 40 kg yr^{-1} group (Stoorvogel & Smaling, 1990).

Certain substances are taken from the environment, which all living cells of both plants and animals use for the synthesis of their own cellular components or as energy source. The supply and absorption of chemical compounds needed for growth and metabolism are referred to as nutrition and the chemical compounds as nutrients. Metabolic processes are thus the mechanism by which these nutrients are converted to cellular materials or used for energetic purposes. Plant nutrition deals with the acquisition of inorganic nutrients which they use as raw materials to form living matter. In this respect, they differ from human beings, animals, and some microorganisms, which additionally need organic compounds as foodstuff.

Importance of Soil Fertility and Plant Nutrition

The importance of soil fertility and plant nutrition for food production had been recognised since the beginning of agriculture. Over time, the ancient people observed that continuous cropping of some soils resulted in poor crop yields and this probably was what led to their practice of adding manure to the soil to restore fertility. Documented evidence reported that in Greece, long before the birth of Christ, manuring was an agricultural practice and the manures were systematically collected and stored. The various manures applied include city sewage, human, swine, goat, sheep, cow, horse, excrements, animal blood and dead bodies of man and animals. Green manure crops, particularly legumes were also applied. In the same vein, application of mineral fertilizers to restore soil fertility and productivity was not entirely unknown to the ancient people. Liming, wood ash, saltpetre or potassium nitrates were all used as soil amendments by the Greeks, Romans, Persians, and Jews.

Soil fertility and plant nutrition are essential to the health and survival of all life on earth. The world population is growing at about two percent a year and expected to reach 11 billion in 2050 (FAO, 2008). This increase in human population resulting in greater human disturbance of earth's ecosystem to produce food and fibre will exert greater demand on soils all over the world to supply essential nutrients to plants. The soils' inherent ability to furnish plants with sufficient nutrients for their growth and development has been decreasing with breeding of crop varieties with high potential yields to satisfy the increased teeming population and ultimately increased demand for food and fibre. Soil fertility and plant nutrition are crucial to production of food and fibre to meet the demand of the teeming population.

Essential Plant Nutrient Elements

The term essential mineral nutrient elements for plants was first proposed by Arnon and Stout in 1939, as the elements which are required for the normal life cycle of the plant, and whose function cannot be substituted by other chemical compounds, and must be directly involved in metabolism or nutrition in plants. There are eighteen of them, with the latest inclusion being nickel (Ni) in

1987 (Brown *et a*l., 1987), which is a key component of selected enzymes involved in N metabolism and biological N_2 fixation (Liu, 2001). Carbon (C), hydrogen (H), and oxygen (O) are the most abundant in plants and are derived from air and water and not considered as mineral elements. They are converted by photosynthesis into simple carbohydrates from which sugars, proteins, nucleic acid and other organic compounds are synthesised.

The remaining fifteen elements are grouped into macronutrients and micronutrients, based on the relative amount taken up from the soil and the relative abundance in plants. The relative and average nutrient concentrations in plants are shown in Table 1.

Table 1: Relative and Average Plant Nutrient Concentrations

Plant Nutrient	Relative Concentration	Average Concentration*
H	60,000,000	6.0 %
O	30,000,000	45.0 %
C	30,000,000	45.0 %
N	1,000,000	1.5 %
K	400,000	1.0 %
Ca	200,000	0.5 %
Mg	100,000	0.2 %
P	30,000	0.2 %
S	30,000	0.1 %
Cl	3,000	100 ppm (0.01 %)
Fe	2,000	100 ppm
B	2,000	20 ppm
Mn	1,000	50 ppm
Zn	300	20 ppm
Cu	100	6 ppm
Mo	1	0.1 ppm

* Concentration expressed by weight on a dry matter basis.

Source: *Soil Fertility and Fertilizers (Tisdale et al., 2003)*

The macronutrients, N, phosphorus (P), K, Ca, Mg, and sulphur (S), have relatively high concentration in plants, compared to the micronutrients, iron (Fe), manganese (Mn), boron (B), copper (Cu), cobalt (Co), molybdenum (Mo), zinc (Zn), chlorine (Cl) and Ni, with very small concentration in plants.

Some other elements which are essential micronutrients for some certain plants species under specific conditions are usually defined as beneficial elements. They include sodium (Na), silicon (Si), and vanadium (Va). These elements can stimulate growth, compensate for the toxic effects of other elements, and replace essential nutrients in their less specific functions such as osmotic pressure. Silicon is essential micronutrients for rice and improves erectness of rice leaves, increases photosynthesis because of better light interception, and provides greater resistance to diseases and insect pests (Romheld & Marchner, 1991).

Metabolic Roles and Deficiency Symptoms of Essential Macronutrients

The metabolic role of the different nutrients and their physiological mobility within the plant determine their deficiency symptoms and which leaves will exhibit the symptom. Albeit, the deficiency symptoms may vary between plants, general symptoms are usually common to most crops.

Nitrogen

Nitrogen is the most frequently deficient of all essential nutrients. It is absorbed by most plants as nitrate (NO_3^-) and ammonium (NH_3^+) ions by some crops such as rice. In the plants, the NO_3^- is reduced to NH_3^+ which is then assimilated into numerous amino acids that are subsequently incorporated into proteins, and nucleic acids. Nitrogen provides the framework for chloroplast and a major component of chlorophyll. Its deficiency symptom is chlorosis of lower leaves due to its mobility in the plant. Cereal crops have the most affinity for N. Various deficiency symptoms of N are shown in Plates 1 to 6.

Plate 1: Nitrogen deficiency in maize

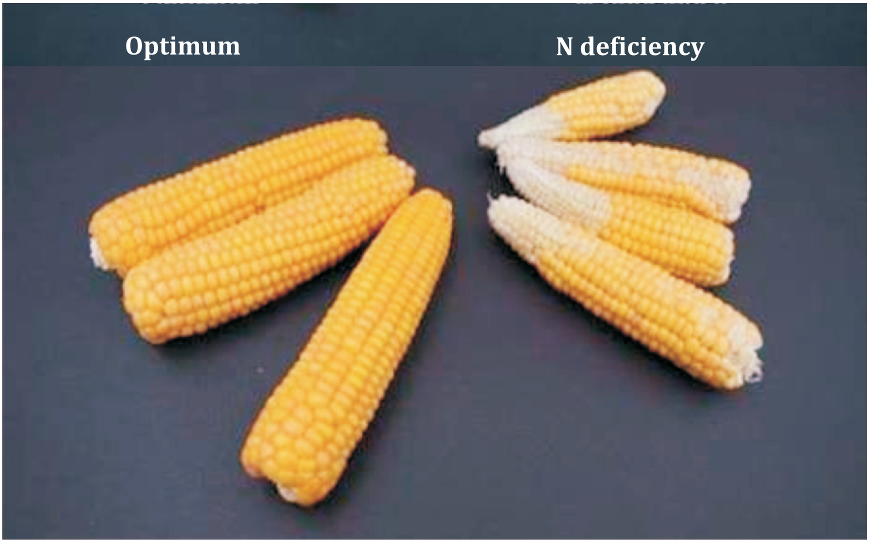


Plate 2: Nitrogen deficiency symptoms in maize cob

Phosphorus

Phosphorus is next in importance to N in terms of deficiency. It is absorbed either in the form of orthophosphate ions, $H_2PO_4^-$ at low soil pH values and HPO_4^{2-} at higher values of pH. The most vital roles of P is in energy storage and transfer as a component of Adenosine di – and triphosphates (ADP and ATP) which act as "energy currency" within plants. Other functions include electron transport and nucleic acid synthesis. It is a component of every living plant and animal cells and a vital element for metabolic processes. Phosphorus in plants improves flower formation and seed production, increases stalk and stem strength, and stimulates root development. In terms of human health, P can increase flavonoids and other antioxidants in fruits and vegetables, such as apples and tomatoes, resulting in an increase in disease-fighting health benefits for humans. Common deficiency symptom is purple-coloured lower leaves due to its mobility in plants (Plates 7 and 8). Legumes have the most affinity for P.

Plate 3: Phosphorus deficiency in young maize plants

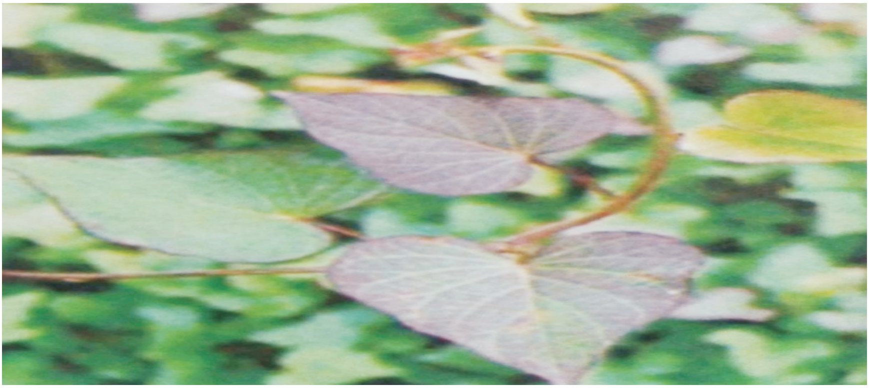


Plate 4: Phosphorus deficiency in sweet potato plant

Potassium

Potassium unlike N, P, and a host of other nutrients forms no coordinated compounds in the plant, but exists solely as K^+ and absorb by plants in this form. It is involved in osmotic regulation of cells, transport of photosynthetate and enzyme activation. Due to the ionic nature, K has functions that are particularly related to the ionic strength of solutions within plant cells. As a result of its mobility within the plant, deficiency symptoms are shown on lower leaves as marginal and interveinal chlorosis and necrosis (Plate 9). Root and tuber crops have the most affinity for K.

Calcium, Magnesium and Sulphur

Calcium is absorbed as Ca^{2+} and essential in the structure, permeability of cell membranes and cell wall formation. It is important in cell elongation and division and thus, deficiency symptoms manifest as failure of terminal buds of shoot and apical tips of roots to develop, which causes plant growth to cease. Similar to Ca, Mg is also absorbed as Mg^{2+} and an ionic component of chlorophyll. It is involved in many physiological and biochemical functions in plant especially those involving phosphate transfer from ATP requiring Mg^{2+}, including photosynthesis, and respiration. Deficiency symptoms of Mg include interveinal chlorosis and necrotic areas along the veins of the lower leaves (Plate 10).

Plate 5: Potassium deficiency in maize

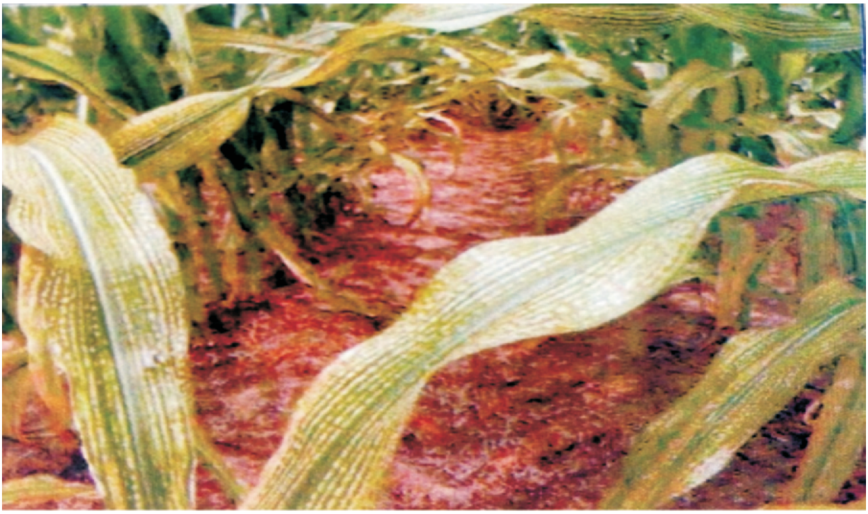


Plate 6: Magnesium deficiency in maize

Sulphur is absorbed almost exclusively as sulphate ion (SO_4^{2-}) with small quantities absorbed as sulphur dioxide (SO_2). The principal metabolic role of S is protein synthesis as it is a constituent of some amino acids such as cysteine. Deficiency symptoms of S resemble the chlorosis of N deficiency, but yellowing is more generalized over the entire plant and starts first on young leaves, because it is not easily translocated in the plant. Oil crops including cotton, soybean, and groundnut have strong affinity for S.

Metabolic Roles and Deficiency Symptoms of Essential Micronutrients

Iron

Iron is absorbed by plants mainly in the form of Fe^{2+} and as Fe^{3+} and as organically complexed or chelated Fe, although the Fe2+ is utilized in metabolic processes in the plant. The chemical properties of Fe make it to be important in oxidation-reduction reactions including respiration and photosynthesis and provision of the potential for many of the enzymatic transformation. Its deficiency first appears on the young leaves because, it is not translocated from older leaves, as interveinal chlorosis which progresses over the entire leaf (Tisdale *et al.*, 2003).

Iron Toxicity

Iron toxicity is as a result of reducing conditions in the soil that promotes the accumulation of soluble Fe^{2+} in the soil solution which is then absorbed by roots and then accumulates in leaves. Yield losses will occur when the Fe content in leaves is above 500 mg Fe kg^{-1} (Marschner, 1995; Mengel & Kirkby, 1987). Iron toxicity causes nutritional disorders in lowland or fadama rice referred to as bronzing. The symptoms in rice, yellowing and bronzing, are because of excessive Fe absorption accumulation in the plants (Audbert & Fofana, 2009). Soil and water conditions that prevail in inland valley swamps and other welland swamps lead to the development of Fe toxicity in rice (Becker & Asch, 2005; Virmani, 1979). Soils with levels of Fe high enough to cause toxicity occur in many inland valleys and irrigated fields of Africa

(Narteh & Sahrawat, 1999; Virmani, 1979). It is a major constraint to rice production in the lowlands of West Africa (Abifarin, 1988, 1989; Becker & Asch, 2005).

The specific symptoms of rice toxicity include brown spots, starting from the tip of the leaf and develop into purple, reddish-brown or yellow discolouration of leaves, at the early growth stage of the plant. Over time, ultimately leaves dry up and plants have a scorched appearance. Roots are poorly developed and have dark brown colouration. The plants have stunted growth with reduced tillering and spikelet fertility (Audebert & Fofana, 2009; Bode *et al*., 1995).

There are several ways by which Fe toxicity can be controlled. But, the most cost-effective way is to plant tolerant cultivars or rice (Abifarin, 1989). Iron toxicity increases plant requirements for nutrients including P, K, Ca, Mg, and Zn, therefore, the application of these nutrients will enhance plant tolerance by mitigating Fe toxicity (Olaleye & Ogunkunle, 2008; Sahrawat, 1998; Sahrawat *et al*., 1996). Under very high Fe toxicity, a combination of planting of tolerant cultivars and improved soil and nutrients management coupled with improved water management through irrigation may be the best results in terms of desirable crop yield (Diatta *et al*., 1998; Sahrawat *et al*., 1996).

Manganese and Copper

Manganese is absorbed by plants in cataionic form as Mn^{2+}. It is involved in photosynthesis, protein synthesis and oxidation-reduction processes in decarboxylation and hydrolysis reactions. Due to its relative immobility in plant, deficiencies show up first on young leaves as interveinal chlorosis and in severe cases, brown necrotic spots, and in cereals as white grayish spots. Similar to Mn, Cu is also absorbed by plants in cataionic form as Cu^{2+}. It plays a major role in osmotic regulation, protein synthesis and as catalyst in photosynthesis. Copper is dominant in many enzymes and cannot be substituted by any other elements. The deficiency is expressed as a light overall chlorosis with permanent loss of turgor in young leaves, with some leaves developing sunken necrotic spots and a tendency to bend backwards.

Zinc, Cobalt and Nickel

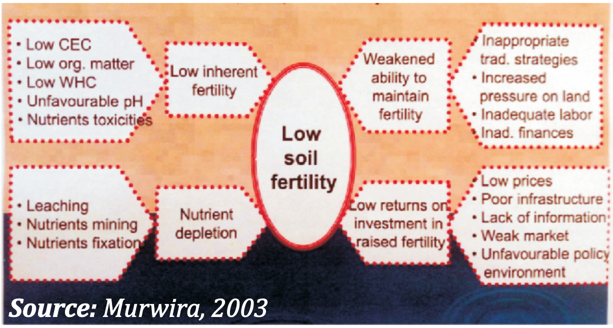
Plant roots absorb Zn in cataionic forms as Zn^{2+} and soluble Zn salts and Zn complexes can also enter the plant through the leaves. The principal metabolic roles of Zn are protein synthesis, and regulation of enzyme systems for energy production. Zinc is needed in the production of auxins (growth hormones) such as indole acetic acid (IAA). The deficiency symptoms of Zn even though, appear most frequently on leaves, sometimes they can also appear on branches or fruits. The symptoms appear as light green, yellow, or white areas between the veins of leaves starting with the young leaves and spreading as it progresses to the lower leaves. In trees especially, the leaves become very small and resetting or clustering of the leaves at the top of tree branches. In maize and sorghum, Zn deficiency is called white bud and in cotton, little leaf (Tisdale *et al*., 2003).

Cobalt is taken up by plants in the cataionic form as Co^{2+} like Zn. It is associated with vitamin B12 synthesis and needed by rhizobia bacteria in legume root nodules. Its deficiency symptoms include poor nodulation by symbiotic legumes and premature dropping of fruits. Nickel is also absorbed by most plants in cataionic form as Ni^{2+}. It is an irreplaceable constituent of the urease enzyme which has a Ni metallo-center, making it essential for urease enzyme activity. The urease enzyme assists in the hydrolysis of urea to ammoniacal-N, which plants can utilize. The deficiency symptom of Ni is necrosis of tips of plant (Wood, 2015). Nickel nutrition plays an important role in protecting plants from certain pant diseases by the synthesis of phytoalexins that the plant produces to defend itself against pathogens (IPNI, 2016). The application of Ni to the root of cowpea effectively reduces leaf fungal infection (Graham *et al.*, 1985).

Boron, Molybdenum and Chlorine

Boron is absorbed by plants as undissociated boric acid (HBO_3). It aids in cell development and division and is required in a number of growth processes especially translocation of sugars, starches, N, and P, synthesis of proteins, nodule formulation in legumes and pollen development. Amongst the micronutrients, B deficiency is the most widespread. Deficiency symptoms include thickened, wilted or curled leaves, and rotting of tubers, fruits, or roots referred to as brown heart (Tisdale *et al.*, 2008).

Molybdenum is a non-metal absorbed by plants as molybdate ion (MoO_4^{2-}). It is essential in nitrate reduction, symbiotic nitrogen fixation, and Fe absorption and translocation in plants. The deficiency of Mo is very rarely observed visually in plants. Chlorine is absorbed by plants as Cl^- through boot roots and aerial parts, especially the leaves. One of the most important functions of Cl^- is aiding turgor of leaves and other parts. Thus, deficiency symptoms include partial wilting and loss of leaf turgor. Diseases of plants such as stalk rot of maize, hollow heart of potatoes and leaf rust of wheat have been found to be suppressed by application of Cl^- fertilizers (Tisdale *et al.*, 2003).



***Source:** Murwira, 2003*

Figure 1: Biophysical, chemical and socio-economic factors contributing to low soil fertility and poor productivity in sub-Sahara Africa

The chemical factors include low cation exchange capacity (CEC) as a result of the dominance of the soils by low activity clays (LAC) minerals such as amorphous clay minerals, oxides of Fe and Al and kaolinite, which makes the soil to retain low amount of cataionic nutrients, Ca, Mg, K and even some micronutrients, Zn and Cu. The soils are also very low in soil organic matter due to optimum condition of rainfall and temperature for its mineralization and the practice by farmers of not retaining crop residues in the soil after harvest, clearing of vegetation by burning and overgrazing by animals. The low soil organic matter content results in structural instability of the soil, since it is a major binding agent (Mikha & Rice, 2004) with consequent low water-holding capacity. Humus, stabilized C, which is the end product of soil organic matter and final stage in the conversion of soil organic materials to organic matter, has much greater capacity to hold water and nutrient ions than other soil components (Esu, 1999). Each tonne of humus has been estimated to have within it 80 kg N, 20 kg P and 14 kg S that is “locked up” and are released as the humus-C is mineralized (Norton, 2017).

Majority of the soils of sub-Saharan Africa are acidic in nature. In Nigeria for example, over 70 % of arable soils are acidic, due to rainfall exceeding evapotraspiration and high levels of leaching of soil exchangeable bases. The soils are acidic because of the inherently acidic nature of the parent materials, sedimentary and basement complex rocks from which they are derived. This acidic nature of the soils increases Fe, Mn and Al toxicities, inhibition of biological processes, especially those carried out by bacteria that cannot survive or thrive in acidic soils, reduced CEC of the soil, P reserves, and diminished solubility of Mo and B. acidic soils are also stripped of cataionic nutrients, Ca, Mg, and K (Ogunkunle, 2016). Based on all these, the soils are therefore inherently low in fertility.

The biophysical factors that contribute to soil nutrient depletion and ultimately low soil fertility include leaching, nutrients mining and nutrients fixation. In addition to loss of cataionic nutrients by leaching, NO_3^- is also subjected to intense leaching from the soil due to its mobility in the soil. Intensification of cropping leads to removal or mining of a lot of nutrients from the soils which are not usually replenished. Nutrient losses also occur by water or wind erosion of the topsoil rich in nutrients and organic matter. Nutrient fixation is the process by which some nutrients such as P and K are converted to unavailable forms in the soil. Phosphorus is fixed in the soil by being immobilized by soil microorganisms to become soil microbial biomass P or adsorbed to surfaces of clay minerals and Fe/Al oxides or precipitated as secondary P compounds of Fe, Al and Mn phosphates in acid soils and Ca, Mg phosphates in alkaline soils. The acidic nature and high amounts of Fe, Al and Mn in majority of soils of SSA make them to have high P fixation. Fixation of K occurs in some soils with high non-expanding clay minerals such as illite and vermiculite in which K^+ is entrapped in the interlattice space or space between two unit cells of the minerals. The K^+ is small enough to fit smugly into the space and is held very firmly by electrostatic forces, thereby preventing the expansion and contraction of the minerals and making the K^+ unavailable for uptake of plants. As a result of this fixation, the surface area of the mineral is also reduced.

The socio-economic factor of inappropriate trading strategies weakens the ability of the farmers to improve the fertility of the soil by not allowing the farmers to obtain good prices for their produce. This makes them to have inadequate finances to invest in inputs that will enable the improvement of soil fertility. The cultivation of marginal lands due to shortage of arable land, that require a lot of investment to improve its fertility coupled with shortage of labour to carry soil fertility maintenance are also contributory factors to the weakness of the ability of the farmers to improve and maintain the fertility of the soil.

Most of the farmers do not usually get good prices for their produce especially at the peak of the harvest season when there is glut or surplus produce in the market. Based on the law of demand and supply, there is fall in the price of farm produce. Majority of our farmers live in rural areas where they have little or no access to relevant information that will aid their activities. Newly developed farming technological packages, Nigerian Meteorological Services (NIMET) planting windows for different areas and other relevant information are not available for the farmers. There is dire shortage of extension agents that will to disseminate information on newly developed technological packages in most of the countries including Nigeria. The marketing structure for agricultural produce with the exception of some cash crops is not well developed and very weak to the detriment of the farmers. The middlemen in most cases earn more than the farmers that laboured hard to produce the crops. In most countries of SSA, farming-friendly government policies including custom duties and subsidy on imported agricultural equipment and inputs, importation of agricultural produce, for example rice in Nigeria, do not allow farmers to earn a decent income from their produce. All these result in farmers not being able to recoup the little investments expended in improving the fertility of the soil from the sale of their produce. The low returns on investments will therefore dampened and probably cessation of maintenance of soil fertility with consequent low fertility of soils.

Maintenance of Soil Fertility

The maintenance of soil fertility is an imperative for farmers in sub-Saharan Africa. The intensification of agriculture, improvement in crop production and seed systems, elimination of crop diseases and pests, and lack of access to enough fertilizers have made maintenance of soil fertility critical to sustainable agricultural management systems, that balance the needs and priorities for agricultural production with those for a safe and clean environment. In recent times, the advent of large scale commercial farms in the country has led to increased use of fertilizers to maintain soil fertility. Among the smallholder farmers, some decades ago, the introduction of hybrid varieties of crops, for example maize, requiring fertilizer among other inputs, to attain their potential yields, increased the application of fertilizer. However, the application of fertilizers is characterized by inadequate fertilization, and unbalanced fertilizer use resulting in low response to the fertilizer with consequent adverse effect on crop yield and quality. Specifically, studies have confirmed that application of N alone reduced the quality, while a combination of N: P: K – Mg improved the general acceptability of yam tubers when pounded or fried (Adeniji *et al*., 1998). The application of fertilizers to maintain soil fertility and ensure improved and sustainable crop productivity without adding to environmental concerns will require concepts derived from proven scientific principles. Some of the concepts that have been developed include Integrated Soil Fertility Management (ISFM) and 4R Nutrient Stewardship.

Integrated Soil Fertility Management

The approach developed to not only improve but maintain soil fertility in sub-Saharan Africa is Integrated Soil Fertility Management (ISFM) which has been defined as **the application of soil fertility management practices, and the knowledge to adopt these to local conditions, which maximize fertilizer and organic resource use efficiency and crop productivity**. These necessarily include appropriate fertilizer and organic input management in combination with the utilization of improved germplasm (Vanlauwe *et al*., 2015). One of the salient aspects of ISFM is the need to combine inorganic and organic inputs to maintain the fertility of the soil sustainably. Continuous application of either of these inputs alone tends to create soil related constraints to crop productivity in sub-Saharan Africa (Vanlauwe *et al*., 2010). In long-term trials, crop yields decrease after several years despite inorganic fertilizer application (Greenland, 1994). The limiting factors might be other nutrients not contained in the fertilizers, especially the micronutrients, soil acidity and soil physical conditions. When several of these factors appear successively, application of organic manure can be a practical solution (Pieri, 1989). The combination of the inputs results in a general improvement in soil fertility status (Okalebo *et al*., 2003). The organic input is a precursor of soil organic matter, which is a good proxy for soil fertility statue and maintains the soil physical and chemical properties contributing to such as cation exchange capacity (CEC), and soil structure which are suboptimal in most soils of sub-Saharan Africa which are sandy in nature with low activity clay minerals (Vanlauwe *et al*., 2002). The increased soil organic matter content enables improved nutrient retention, turnover and availability. The organic input counteracts soil acidity and aluminium toxicity (Pypers *et a*l., 2005). In tropical farming systems where highly weathered soils are commonly found, together with a lack of means by the poor resource farmers to acquire inorganic fertilizer inputs, organic inputs are essential in providing nutrients for crop growth and maintaining soil organic carbon content (Woomer *et al*., 1994).

The combined application of mineral fertilizer with organic inputs substantially improve the agronomic efficiency of the nutrient use compared to the same amount of nutrients applied through either source alone (Vanlauwe *et al*., 2001). A positive interaction is obtained when the combined application results in a grater yield benefit compared to the sum of crop yield when equivalent amounts of inorganic and organic inputs are applied separately. The improved agronomic efficiency is due to common inorganic fertilizers lacking the micronutrients essential for crop growth, which the organic inputs contain. The organic input on the other hand, contain low amounts of N, P, and K, which will necessitate their excessive application rates of sometimes more than ten tons per hectare, to meet the crop needs, if they are applied alone and efficiency of nutrients applied through them alone is often low (Cadish & Giller, 1997 ; Vanlauwe & Sanginga, 1995). Thus, combining both of them enables supply of all nutrients in suitable quantities and proportion and has been advocated as a sound crop production management principle for smallholder farming in SSA because neither of the two inputs is usually available in sufficient quantities and because both inputs are needed in the long-term to sustain soil fertility and optimize crop production. Generally, crop growth and yields are better with ISFM (Plate 5).

Plate 7: Maize on the left under ISFM and those on the right with only mineral fertilizers

4R Nutrient Stewardship

The concept of 4R Nutrient Stewardship is defined as 'applying the right source of plant nutrients at the right rate, at the right time, and at the right place, for sustainably managing plant nutrients and increasing crop productivity (Fig. 2). The concept is derived from the scientific principles of Fertilizer Best Management Practices (FMBPs), which are agricultural

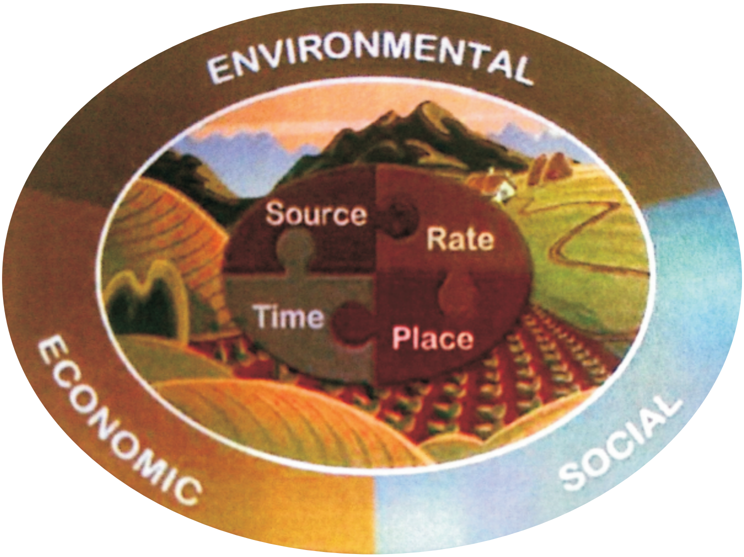


Figure 2: The 4R Nutrient Stewardship Concept

production techniques and principles developed through scientific research and verified on farmers fields to maximize economic, social, and environmental benefits (IFA, 2009). This is with the aim of managing flow of nutrients in the course of producing affordable and healthy food in a sustainable manner that protect the environment, conserve natural resources, and at the same time become profitable to producers. The concept also aligned with balanced nutrition for crops which considers the plant requirement for all essential nutrients in the correct proportion. Farmers need science-oriented information on the role of balanced plant nutrition to optimize profitability and minimize environmental impact. The 4R concept is thus an approach for fertilizer best management practices adopted by the world's fertilizer industry in 2007, as an essential tool towards sustainable agricultural systems. The over or under use of nutrients or applying them in an imbalanced manner at an inappropriate time or by wrong methods, results in low crop productivity, and economic returns or farm profitability and often leads to a large environmental footprint of fertilizer use (Satyanarayana *et a*l., 2016). The blanket fertilizer recommendations which are the common practice in sub-Saharan Africa results in inefficient use of fertilizer with resultant low crop productivity. The 4R Nutrient Stewardship framework has been reported to promote application of nutrients to ensure high crop yields, better nutrient use efficiency, and profitability of smallholder farmers through the four 'rights' of nutrient management (Majunder *et al*., 2014).

Soil Fertility, Plant Nutrition, Human Health and Food Security

The fertility of the soil indirectly affects human health through the type and quantity of plant nutrients that are available for absorption by food crops. This is because the quality and nutritional quality of food crops underpins human health (Oliver & Gregory, 2015). Human health has been defined as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity by World Health Organisation (WHO) in 1948. With this definition, responsibility for human health does not only lie within the domain of medical sciences, but extend beyond to many other disciplines including agricultural science. Agriculture plays a central role in both food availability and food quality, and is also the main source of income and livelihood for 70 to 80 % of people who currently suffer from hunger in developing countries (Oliver & Gregory, 2015). Soil fertility and plant nutrition determine the quantity and quality of food that can be obtained on a given piece of land, with effect on human health.

The maintenance of soil fertility by the use of fertilizers in crop production has boosted crop production per unit area, increasing the quantity and quality of crop yields especially in terms of essential trace elements for humans including Zn, selenium (Se) and iodine (I). The world's population grew from 3.1 to 6.8 billion between 1961 and 2008 and in the same period, global cereal production grew from 900 to 2,500 Mt, with much of the growth associated with increase in world fertilizer use from 30 to over 150 Mt (FAO, 2012; IFA, 2012). World cereal production will not be up to half of the current level without fertilizer use (Erisman *et al*., 2008). As there can be no human health without food, crop production entails producing crops that nourishes human health. Fertilizer use can help to achieve this objective towards the goal of healthy and productive lives for all in the context of a burgeoning world population (Bruulesma *et al*., 2012).

Agronomic biofortification is the fertilization of staple food crops with micronutrients to increase their concentration in edible parts of the crop. It can be an important part and effective strategy to address micronutrients dietary deficiencies especially in the developing countries including Nigeria, whose daily diet is dominated by cereal-based foods. The most sustainable solution for micronutrients deficiency is to increase the consumption of diversified diet of meat, poultry, fish, fruits, legumes and vegetables among the urban poor and people in rural areas, which is a long-term solution, with short-term measures as food fortification and supplementation. However, all these measures may not reduce micronutrient deficiencies in people who have very poor access to formal markets and health care systems and who often rely on household-produced staple food crops for a large share of their dietary intake (Oritz-Mannasero *et al*., 2007). Agronomic biofortification can be a short-term and cost effective solution to alleviate micronutrient deficiencies until the longer-term most sustainable solution, diet diversification is achieved. It can be highly effective for Zn and Se and to a certain, iodine (I) and Co. Agronomic biofortification can only increase I concentration in leaves, while Co can only reach humans via the ruminant route in order to be useful in terms of vitamin B12 (Lyons & Cakmak, 2012).

Zinc is essential for human health and the effect of its deficiency in humans was only defined in the early 1900s as a condition characterised by short stature, underdeveloped secondary sexual characteristics and a body with long legs, impaired immune functions, skin disorders, and a low appetite (Prassad, 1991). For crops growing in low Zn soils, agronomic biofortification will not only increase Zn concentration in grains, but there is added benefit of increase in yield due to increase in soil Zn. A combination of soil and foliar application or foliar application twice at late growth stage appears to be the most effective agronomic biofortification method for Zn with zinc sulphate ($ZnSO_4$), the cheapest and most effective source of Zn to use. The maximisation of agronomic biofortification of food crops with Zn is highly dependent on the N nutritional status of the crop. The enrichment of the grain with Zn is maximized when the N nutrition regime of the plant is improved by application of N fertilizers (Kutman *et al*., 2010). Symptoms of Zn deficiency in pregnant women may include high rates of infectious diseases and complications during pregnancy or at birth (Ruel & Bruis, 1998; Welch, 2002). Zinc deficiency in humans is widespread worldwide and estimated to affect more than 25 % of the world's population (Mavet & Sandstead, 2006). It is estimated to be responsible for about 800,000 deaths annually from diarrhoea, pneumonia, and malaria in children under the age of five (Caulfield & Black, 2004). Zinc ranks fifth amongst the most important health risk factors in developing countries and eleventh worldwide according to a WHO 1992 report.

Similar to Zn, Se is also an essential element for humans and its intake is primarily from dietary sources (Fairweather, *et al*., 2011). Selenium is important in terms of being antioxidant, anti-inflammatory, anti-cancer, anti-viral, and anti-aging activity, along with key roles in the thyroid gland, brain, heart, and gonads (Lyons & Cakmak, 2012). Regular suboptimal intake of Se leading to its deficiency results in adverse health conditions including cardiovascular disorders, impaired immune function, and some form of cancer (Chilimba *et al*., 2012). Selenium seems to be a crucial micronutrient for people infected with HIV (Baum *et al.,* 1997) and it has been suggested that adequate Se can be expected to reduce the rates of cancer worldwide (Coombs, 2001). Selenium alongside Zn is well suited to agronomic biofortification of food crops. Soil or foliar application can be a highly effective method for biofortification whether foliar application around mid-booting stage of the crop or soil application at seedling growth stage. Selenate (SeO_4^{2-}) is the most effective form of Se for biofortification as it is readily taken up by plants growing on most soils , transported easily throughout the plant, and accumulates in edible parts of crop (Lyons *et al*., 2003).

In a public health setting, biofortification of food crops with Se has already been adopted at a national scale in Finland since 1984, following primary legislation with an immediate increase in the Se concentrations of Finnish foods and dietary intake (Broadley *et al*., 2006; Chilamba, *et al*., 2012). In the 1960s and 1970s, there was the understanding that low dietary Se intake may be a risk factor in the high rate of occurrence of cardiovascular disease. In response, the government mandated the addition of Se as selenate to all multi-nutrient fertilizer sold in the country from 1984. By 1987, Se in wheat grain increased, human dietary intake of Se trebled, human blood plasma Se level doubled and heart disease continue to decline, with continued addition of 10 mg kg^{-1} of Se to all crops (Broadley *et al* ., 2006; Hartikainen, 2005; Makela *et al*., 2005). This programme adopted by the Finnish government is an authentic food system strategy which is safe, effective, and cost-efficient, that improved Se nutritional status of the entire population.

Food security is said to exist when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food, while nutrition security means access to adequate utilization and absorption of nutrients in food, in order to be able to live a healthy and active life (FAO, 2009). Plant nutrition in addition to increasing crop yields, determines human nutritional needs, including the amount and types of carbohydrates, proteins, oils, vitamins, and minerals in food crops. Adequate nutrition of food crops boosts the healthy components, such that they can meet the dietary requirements of these components when they are consumed by humans. Cereal crops with adequate N nutrition status have high and quality protein content. In maize and wheat, protein may increase with N rates higher than needed for optimum yield. In potatoes, N fertilization increases starch and protein concentrations, while P, K, and S enhance protein biological value. Foliar application of K and S enhanced sweetness, beta-carotene, vitamin C and folic acid contents of melons. In banana, K nutrition enhances fruit quality parameters such as sugars and ascorbic acid and decreases fruit acidity. Liming of acid soils of limited fertility can increase the Ca and Mg contents of soybean. The improvement in the K nutrition of tomatoes promotes the concentrations of lycopene in their fruits (Bruulesma *et al*., 2012).

My Contributions

In over three decades of my sojourn in the academic world, I have made modest contributions to knowledge in the field of Soil Fertility and its cognate fields with my teachers, colleagues and students. My contributions also included academic development in the field of Soil Science as a whole.

Soil Fertility Maintenance using Grain and Herbaceous Legumes

Nitrogen is an important constraint to maize production in the soils of the Guinea savanna of Nigeria. The integration by crop rotation of legumes, both grain and herbaceous into the cropping systems can be an option in eliminating N constraints, improve N use efficiency (NUE) and ultimately the yields of the succeeding cereal crop. A study was carried out to determine the effects of preceding grain, soybean and cowpea, herbaceous, *Centrosema pascuorum* legumes and fallow when their residues are incorporated, on soil N, NUE and yield of the succeeding maize crop in Zaria, northern Guinea Savanna of Nigeria. Results showed that the incorporation of legume residues significantly increased the soil inorganic or mineral N (Table 2). The NUE which is the grain yield per unit of available soil N was higher in maize that succeeded the legumes (Table 3). The grain yield response of maize following the legumes was significantly higher than that of maize after fallow (Fig. 2). The conclusion was that there was higher grain yield of maize when it is rotated with a legume and the residues of the legume are incorporated (Adeboye *et al*., 2005).

Table 2: Effects of incorporation of legumes and fallow residue on soil inorganic N

	Before management practices	**Plant residue**	**Residue management practice**	
			Incorporation	**Removal**
Inorganic N (g kg^{-1})	0.400	Soybean	0.100 (0.00)[a]	0.050 (0.016)
	0.045	Cowpea	0.050 (0.00)[a]	0.040 (0.006)
	0.040	Centro	0.100 (0.006)[a]	0.060 (0.010)
	0.040	Fallow	0.040 (0.00)	0.040 (0.000)

[a] By t-test between before management practice and after residue management indicates significant difference at $P<0.05$ Standard Error of means in parenthesis.

Table 3: Nitrogen use efficiency of maize rotated with legume and fallow with combined N fertilizer rate and residue management

Previous Legumes and Fallow	N use efficiency (kg grain kg soil-N^{-1})
Soybean	24.03
Cowpea	24.68
Centro	24.03
Fallow	19.96

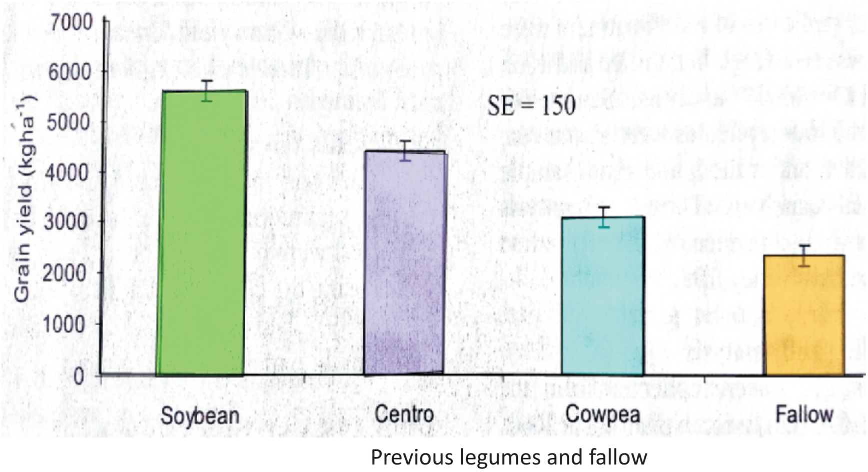


Figure 3: Maize grain yield response to previous legumes and fallow

The availability of N for the succeeding crop in rotation usually accounts for the greatest proportion of beneficial effect of rotation. The N fixed by the legume apart from being utilised by the legume is also contributed to the succeeding crop. One of the commonly used methods for determining or estimating N contribution from legume in rotation is the N Fertilizer Replacement Value (NFRV). The NFRV of a legume is the amount of fertilizer N required by a non-legume when not rotated with legume, to obtain grain yields equivalent to those obtained when the non-legume followed legume in rotation. The NFRV is estimated by the method described by Carsky *et al.*, (2001).

$$\text{NFRV} = \frac{\text{Yield after legume without N fertilizer} - \text{Intercept}}{\text{Slope}}$$

The response of the succeeding cereal crop to urea N in the fallow plot is fitted to a linear model. The intercept is the grain yield after fallow or a non-legume with no N fertilizer and the slope is the response of maize to fertilizer N. In the same study described above, the NFRV of the legumes was determined. The response of maize grain yield after fallow is shown in Fig. 3. The estimated NFRV of the legumes with their residue incorporated were 55, 10 and 34 kg N ha^{-1} for soybean, cowpea and *Centrosema pascuorum* respectively. Therefore, the N fertilizer need of maize is reduced, that is, the amount of N fertilizer to apply to maize for optimum grain yield is reduced when it is rotated with these legumes with their residues incorporated (Adeboye, 2008).

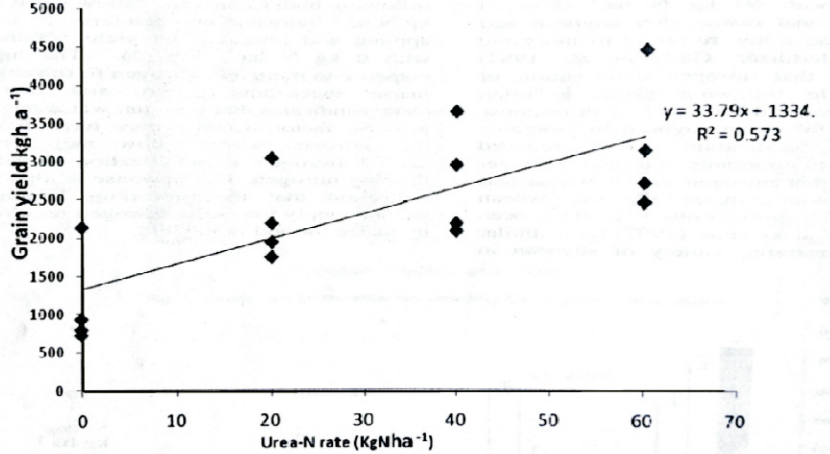


Figure 4: Maize grain yield after fallow as a function of urea - N rate

A similar study was also conducted at Minna in the southern Guinea Savanna of Nigeria to determine the effects of natural and *Aescynomene histrix* fallows on soil organic carbon (SOC), soil N and grain yield of the following maize. Results showed that both fallows increased SOC content, while only *Aeschynomene* fallow increased the soil N (Table 4). The two fallows and inorganic N fertilization had comparable grain yield (Table 5). The conclusion was that both fallows can be used to improve soil fertility, and maize grain yield and 60 kg N ha^{-1} seem to be optimum for maize grain production in the area (Lawal *et al.*, 2015).

Table 4: Effect of phosphorous fertilization on the growth, biomass production and nodulation of green manure legumes in the greenhouse

S/No	Treatments	Plant height (cm)	Fresh biomass weight (g pot^{-1})	Nodule number (nr. Pot^{-1})
1	AI Only	85c	44.46b	24b
2	AI with 15 kg P ha^{-1}	81c	38.5b	22b
3	AI with 30 kg P ha^{-1}	72c	40.9b	17b
4	AI with 45 kg P ha^{-1}	70c	38.4b	17b
5	AI with 60 kg P ha^{-1}	65c	36.8b	16b
6	SR Only	127a	86.4a	75a
7	SR with 15 kg P ha^{-1}	101b	77.1a	82a
8	SR with 30 kg P ha^{-1}	115b	82.0a	80a
9	SR with 45 kg P ha^{-1}	108b	81.8a	73a
10	SR with 60 kg P ha^{-1}	106b	81.0a	75a
SE±		18.3	9.6	10.3

AI – *Aeschynomene indica*.   SR – *Sesbania rostrata*

Table 5: Effect of natural and *A. histrix* fallows on soil organic carbon and total nitrogen

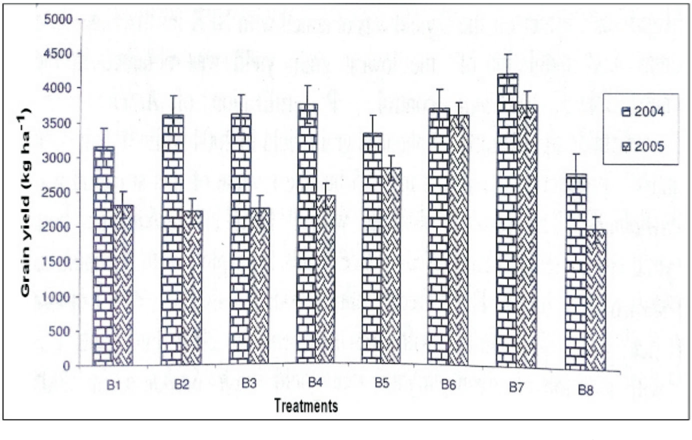
Treatment	Soil organic carbon (g kg^{-1})			Soil total nitrogen (g kg^{-1})		
	Initial value in 2011	Value at Beginning of 2012	Percentage change	Initial value in 2011	Value at Beginning of 2012	Percentage change
	2.30 (0.05)			0.15 (0.015)		
Natural Fallow		4.24 (0.35)[a]	84		0.19 (0.003)NS	19
A.histrix		3.93 (0.07)[a]	71		0.21 (0.003)[a]	40

Standard error of means in parenthesis

a – By t-test between each treatment and initial value indicates significant difference at $p < 0.05$

NS – Not significantly different from initial value at $p < 0.05$

Green manure legumes can be an alternative to inorganic fertilizers as source of N to crops. Studies were carried out both in the greenhouse and on the field to determine the effects of P fertilized *Aeschynomene indica* and *Sesbania rostrata* as pre-rice green manure on the performance of rice in the inland valley swamp of Bida, Nigeria. In the greenhouse, P fertilization had no effect on the growth and yield of the green manure legumes, but *Sesbania* biomass and nodule production were more than 100 % higher than those of *Aeschynomene* (Table 6). On the field, the grain yield of rice manured with the legumes was more than 50 % higher than that of the control (Fig. 4). The conclusion drawn was that the two legumes as pre-rice green manure can be an alternative to inorganic fertilization as source of N in rice production in the inland valley of Bida, Nigeria (Adeboye *et al*., 2009).



SE (2004) = 280
SE (2005) = 188

B1 = Aeschynomene indica (AI)only   B2 = AI with 15kg P ha^{-1} B3 = AI with 45kg P ha^{-1}
B4 = Sesbania rostrata (SR) only   B5 = SR with 15kg P ha^{-1} B6 = with 45 kg P ha^{-1}
B7 = NPK - 80:40:40 kg ha^{-1} B8 = Control

Figure 5: Effect of green manure and organic fertilization on the grain yield of field cropped rice in 2004 and 2005

Table 6: Effect of fallowing and nitrogen fertilization on the grain yield of maize

Treatment	Grain yield (kg ha^{-1})
Fallow (F)	
Natural	1085a
A. histrix	1208a
SE ±	90
Significance	NS
Nitrogen fertilizer (kg ha^{-1}) (N)	
0	547b
60	1290a
90	1436a
120	1492a
SE ±	592
Significance	**
Interaction	
F x N	NS

Means followed by the same letter are not significantly different at $p < 0.05$

**Significant at $p < 0.01$, NS: Not Significant.

Evaluation of Soil Micronutrients Fertility

In recent years, deficiencies of micronutrients have started to manifest on crops due to reduction in length of fallow periods, intensification of cropping, planting of high-yielding varieties of crops and use of high-analysis fertilizers with very little or no micronutrients. The concept of balanced nutrition for realization of the full potentials of soils of vast arable land of lower Gongola river basin brought about the assessment of the micronutrients, boron (B), zinc (Zn), copper (Cu) and manganese (Mn) status of soils of the basin formed from different parent materials. Results showed that all the soils were sufficient in all the micronutrients (Tables 7 and 8). Their deficiencies will not pose problem in the immediate future. It was concluded that all the soils need to be reassessed after a few years of cropping (Adeboye, 2011a; Adeboye, 2011b).

Table 7: The profile distribution of the total and available forms of the micronutrients

Parent material	Depth (cm)	Total B	Available B	Total Zn	Available Zn
		mg kg^{-1}			
Limestone	0-20	510	5.3	60	1.8
	20-60	612	6.6	80	2.0
	60-110	391	5.3	115	1.9
	110-158	476	6.6	140	1.7
Recent Alluvial Deposits	0-30	493	7.9	165	6.5
	30-60	153	5.3	153	4.7
	60-100	221	6.6	130	2.0
	+100	136	7.9	80	1.1
Marine Sediments	0-30	51	4.0	60	1.2
	30-45	68	5.3	60	1.0
	45-80	136	2.6	1105	0.9
	80-190	51	2.6	90	1.1
Coarse Grained Sandstone	0-10	51	5.3	80	1.0
	10-25	34	5.3	40	1.1
	25-56	34	2.6	50	1.2
	56-80	54	6.6	50	0.9

Table 8: Total and extractable copper and manganese distribution in the profile

Profile	Parent material	Depth (cm)	Total Cu	Extractable Cu mg kg^{-1}	Total Mn	Extractable Mn
A	Limestone	0-20	66	1.8	600	0.20
		20-60	55	1.0	830	1.6
		60-110	35	2.1	770	2.1
		110-158	55	2.4	900	3.0
B	Recent Alluvial Deposits	0-30	170	3.5	380	4.3
		30-60	40	2.3	410	4.4
		60-100	33	1.4	100	4.0
		> 100	40	0.5	50	0.8
C	Marine Sediments	0-30	45	0.5	60	5.8
		30-45	55	0.6	40	9.0
		45-80	30	0.8	30	0.1
		80-190	20	0.6	90	0.1
D	Coarse Grained Sandstone	0-10	25	0.3	90	0.1
		10-25	30	0.2	80	24.5
		25-56	25	0.1	50	40.5
		56-80	20	0.2	40	1.5

The micronutrients, Cu, Zn, iron (Fe) and Mn status of the soils of the University Teaching and Research Farm was investigated. Results showed that the soils were sufficient in all the micronutrients for crop production (Table 9). Based on these results, it can be concluded that their deficiencies are not likely to occur in the nearest future with the current use and management of the soils (Lawal *et al.,* 2014).

Table 9: Micronutrients content of the soils

Pedon	Horizon	Soil Depth (cm)	Cu	Zn	Fe	Mn
				mg kg $^{-1}$		
1	Ap	0-23	4.00	3.60	77	37
	BA	23-46	4.40	4.40	63	8
	Btg	46-89	4.60	9.40	130	13
	Btv1	89-117	3.60	7.40	48	40
	Btv2	117-158	5.20	17.00	53	31
	C	158-192	4.00	23.00	256	55
2	Ap	0-19	4.20	3.80	135	30
	Btg1	19-47	5.00	4.60	39	9
	Btg2	47-117	4.20	7.80	39	8
	Btv	117-143	4.60	8.60	184	50
	C	143-167	4.80	18.20	256	42

Evaluation of Soil Fertility using Soil Microbial Biomass and Water-Soluble Organic Carbon

The soil microbial biomass (SMB) is a small, but important pool of plant nutrients, while the water-soluble organic carbon (WSOC) is the soil carbon which is used readily as a source of energy by heterotrophic microorganisms. By investigating their dynamics, the effect of crop rotation on the fertility of the soil and crop productivity can be better understood. The ratio of two main components of SMB, soil microbial biomass C (SMBC) and soil microbial biomass N (SMBN) can be used to determine the type of microbes that predominate in the soil. The dynamics of SMBC, SMBN and WSOC were studied under legume/cereal rotation. Results showed that SMBC was affected by crop rotation and inorganic N fertilization. Soils under legume rotations had higher SMBC and WSOC compared to that of fallow (Table 10).

Table 10: The analysis of variance of effects of crop rotation and N fertilizer on soil microbial biomass

Treatment	SMBC (mg kg^{-1})	SMBN (mg kg^{-1})
Rotation system (R)		
Soybean	382.42a	18.28a
Centro	261.02b	18.73a
Cowpea	199.00c	18.91a
Fallow	187.73c	20.4a
Mean	257.54	19.08
SE ±	12.19	0.84
Significance	***	NS
N fertilizer level (kg N ha^{-1}) (F)		
0	270.28a	18.20a
20	245.62a	19.18a
40	246.08a	19.68a
60	268.19a	19.26a
SE ±	12.19	19.08
Significance	NS	NS
Interaction		
R x F	***	***

Means followed by the same letter(s)within the same treatment group are statistically the same at $p < 0.05$. NS= Not Significant. ***Highly significant at $p < 0.0001$.

The SMBC/SMBN ratio were 7.1, 8.3, 5.7 and 4.9 for soils under soybean, cowpea, *Centrosema* and fallow rotations respectively, suggesting a higher proportion of bacteria in soils under fallow and *Centrosema* rotations, but higher proportion of fungi under soybean and cowpea rotations (Table 11). The SMBC and WSOC were significantly correlated with soil pH and SOC (Table 12). The conclusions were that both SMBC and WSOC best assessed the fertility status of the soils, and the flux of SMB and WSOC were determined by soil pH and SOC under these rotations (Adeboye *et al.*, 2006; Adeboye and Iwuafor, 2007).

Table 11: The proportions of soil organic carbon and total nitrogen as biomass carbon and nitrogen and biomass C/N ratios under different rotation systems

Rotation systems	SMBC	SMBN	Biomass
	Org.C %	Total N %	C/N Ratio
Soybean	4.3	4.7	7.1
Cowpea	5.4	5.8	8.3
Centro	3.5	5.5	5.7
Fallow	3.1	5.6	4.9

Table 12: Matrix of correlation coefficient for soil microbial and chemical properties

Variables	Soil pH	Biomass C	Biomass N	WSOC	Organic C
Biomass C	0.32**				
Biomass N	-0.19*				
WSOC	-0.34***	-0.21*	0.23**		
Organic C	0.37***	-0.18*	0.46***	-0.07NS	
Total N	0.19NS	0.03NS	0.12NS	0.06NS	0.33**

*, **, *** Indicates significant correlation between the two variables at $p < 0.05$, 0.01 and 0.0001 level of significance, respectively. NS - Not significant (n = 128)

Assessment of Soil Quality

The assessment of quality of a soil is an invaluable tool in determining the sustainability and environmental impact of agricultural ecosystems. A study was conducted to assess the quality of soils under arable cultivation, locally irrigated and non-irrigated, forestry plantations of teak (*Tectona gandis* Lin.), gmelina (*Gmelina arborea* Roxb.), and cashew (*Anacardium occidental* Lin.) plantation ecosystems' using SOC, soil N, SMBC, and SMBN at Minna in the southern Guinea savanna of Nigeria. Results showed that soils under irrigated land had higher SMBN, SOC and soil N compared to all the other agroecosystems, but they all had relatively high SMBC/SMBN ratio of greater than 6.6 (Table 13). In conclusion, land under irrigated had better quality in terms of SMBN and SOC than the other agroecosystems, while all of them had a dominance of fungal population (Adeboye *et al.*, 2011).

Table 13: Soil organic carbon, total nitrogen and microbial properties at 0-5 cm depth of the agroecosystems

Agroeco-systems	Depth (cm)	Org. C (g kg^{-1})	Total N (g kg^{-1})	C/N ratio	SMBC (mg kg^{-1})	SMBN (mg kg^{-1})	SMBC/ SMBN	SMBC/ Org. C (%)	SMBN/ Total N (%)
Arable Lands									
Irrigated	0-5	21.00*a	13.78a	1.5	693b	47.40a	14.6	3.3	0.3
	5-10	22.40*a	14.70a	1.5	182d	27.53b	6.6	0.8	0.2
Non-irrigated	0-5	13.50c	7.09b	1.9	640c	22.71d	28.2	4.7	0.3
	5-10	14.45b	6.80b	2.1	240c	18.59e	12.9	1.7	0.3
Plantations									
Teak	0-5	13.71c	6.28c	2.2	766a	29.25c	26.2	5.6	0.5
	5-10	12.50e	5.69c	2.2	244d	23.07c	10.6	2.0	0.4
Gmelina	0-5	15.46b	6.45c	2.4	690b	40.92b	16.9	4.5	0.6
	5-10	15.46b	6.45c	2.4	690b	40.92b	16.9	4.5	1.0
Cashew	0-5	13.46c	6.45c	2.1	483b	41.28b	11.7	3.6	0.6
	5-10	13.60c	5.20d	2.6	315c	21.14d	14.9	2.3	0.4

* Means in the same column that are followed by the same letter are not significantly different at $P = 0.05$ ($n = 50$)

Academic Development

In the area of academic development, during my sabbatical leave at the Department of Soil Science, Faculty of Agriculture, Kebbi State University of Science and Technology, Aliero, Kebbi State, I produced the prospectus for postgraduate programmes of the Department. The prospectus was approved by the Nigerian Universities Commission (NUC), resulting in the commencement of postgraduate studies in the Department, starting with the admission of the first set of students for the Masters programme in 2016/2017 session.

Conclusion

The soil which is the dirt under our feet is the beginner, sustainer, nourisher and end of man on earth and should not be taken for granted in our daily lives, but be given serious attention that it deserves. The wealth of any nation is in her soil and her strength lies in its intelligent development. The more we understand the history of our soils and the more we learn about their properties, the better we are able to make wise decisions concerning their use and management. Our soils are inherently low in fertility and characterised by rapid nutrient depletion with consequent low yields once cropping commences. Our food security will thus be imperilled with disastrous consequences of not only grave economic problems, but destruction of fabric of social stability.

One of the major constraints to achieving the production potential of our soils and restoration of the production potential is the absence of replenishment of plant nutrients. One of the best strategies to combat this constraint to have significant increases in productivity is balanced application of plant nutrients targeted to a specific constraint. The vicious cycle of low soil fertility, soil fertility depletion and poverty in SSA, especially Nigeria will require judicious use of fertilizers and organic amendments. The organic amendments will not only increase the build-up of soil organic matter, but also provide a capital of nutrients that will be slowly released over time. The strategy will ensure higher crop yields per unit land and stop the opening-up of marginal land and forest areas for arable crop production.

Micronutrient malnutrition poses serious human health problems for a substantial number of people worldwide. It is a global nutrient problem caused by inadequate dietary intake in human population most especially in less developed countries. A significant number of the world's population suffers from micronutrient malnutrition with children under the age of five and women most affected in developing countries. Malnutrition is by far the leading cause of death globally, with many of these deaths resulting from micronutrient deficiencies. Agronomic biofortification of staple food crops with essential micronutrients for humans, including Zn and Se, is a cost-effective and low cost way to help alleviate malnutrition of these nutrients in urban poor and rural populations in developing countries where the problem is most widespread. It can help to improve the nutritional content of staple foods urban poor and rural people already eat, thus making possible a comparatively inexpensive, cost-effective, long-term means of delivering more micronutrients to this segment of the population. Agronomic biofortification is an example of the product of agricultural research culminating in agricultural technologies to reach a public health objective.

Recommendations

On the premise of this lecture, I wish to make the following recommendations.

1. Soil Fertility Map

The gradual commercialization of agriculture with the establishment of large-scale farms will require the production of soil fertility maps for the different agroecological zones of the country showing the essential nutrients level in the soils. At a glance, investors would be able to choose a site for their crop production, where they will not have to invest much money on fertilizer inputs, thereby having a high return on their investment.

2. Fertilizer Formulation

The fertilizer industries should be directed by the government to formulate fertilizers based on specific soil nutrient constraints befalling an area. For example, in an area where there is deficiency of Zn in the soil, fertilizers that will be distributed in the area will be formulated with Zn. Different fertilizer formulations will be distributed in different areas depending on the nutrients that are deficient in the soil of a particular area.

3. Soil Testing Laboratories

Soil testing laboratories that are well equipped with the latest instruments and equipment and manned by well trained technologists should be established in every agroecological zone of the country. The laboratories should carry out soil testing at least once every two cropping seasons on the soils of the zone, so as to recommend appropriate nutrient inputs for crops that are commonly cultivated in the area.

4. National Soil Research Institute

National soil research institute should be established for each of the agroecological zones of the country, as a follow up to the established National Institute of Soil Science. Their mandate should be to carry out, on a continuous basis, research on the soils in all fields of Soil Science. The Institute should have a data bank that should serve as a repository of data on the characteristics, appropriate crops and nutrient inputs for each soil identified for optimum and sustainable productivity of the soils.

5. Integration of Legumes into Cropping System

Legumes such as cowpea, groundnut, soybean and others that are commonly cultivated in each area should be integrated into the cropping system of the area. This will not only enhance the fertility of the soil, but also serve as a cash crop for the farmers.

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BRIEF PROFILE OF THE INAUGURAL LECTURER

Professor Ma'ruf Kajogbola Adebayo Adeboye was born on the 3rd of March, 1962 to the family of Alhaji Mustapha Adebiyi Adeboye Shittu and Alhaja Alimotu Arinpe Adeboye. He hails from Offa in Offa Local Government Area of Kwara State. He attended the Christ Apostolic Church LEA Primary School from 1965 to 1971. Thereafter he proceeded to E.C.W.A. Secondary School, Igbaja, Kwara State, from 1972 to 1976 for his secondary education. He attended the then Kwara State College of Technology, School of Basic Studies, from 1976 to 1978, where he obtained his University of Cambridge, England, Advanced Level Certificate. Professor Adeboye was at the University of Ibadan from 1979 to 1983, where he obtained his BSc. Agriculture (Soil Science) and graduated with the best result in the Department of Agronomy. From the same university, he obtained his MSc. Agronomy (Soil Science Option) in 1992. Professor Adeboye obtained his PhD Soil Science specializing in Soil Fertility and Plant Nutrition from Ahmadu Bello University, Zaria in 2004.

Professor Adeboye began his working career as a Clerical Officer in the Kwara State Audit Department from 1978 to 1979 and was a lecturer at Federal College of Education, Yola, in the then Gongola State as a Youth Corp member in 1984. He joined the services of the Kaduna Polytechnic as a Lecturer in 1986 and rose to the rank of Chief Lecturer in 1999. He had a brief stint with the National Agricultural Land Development Authority as Chief Land Development Officer for Kwara State in 1995. On 1st November, 2007, he transferred his services to the Federal University of Technology, Minna as a Senior Lecturer and attained the exalted rank of Professor of Soil Science on 1st October, 2013.

As an academic, he has over sixty publications in reputable local and international Journals and Book of Proceedings. Professor Adeboye is a member of professional bodies including Soil Science Society of Nigeria, International Union of Soil Science, Nigerian Soil Health Consortium, TSBF Institute and African Network for Soil Biology and Fertility (AFNET) and African Leadership Institute, Dayton, Ohio, USA. He has supervised/co-supervised and is still supervising many Undergraduate, and Postgraduate students. He has served and still serving as External Examiner and External Assessor for promotion to Professorial cadres for some Universities. Professor Adeboye is an Associate Editor of the Nigerian Journal of Soil Science and manuscript reviewer for local and international Journals and Book of Proceedings, as well as Editor for Book of Proceedings. He has attended several local and international seminars, conferences and workshops within and outside the country.

A notable administrative duty he performed in the university was serving as the Head of Department for an extended period of six years, from 2009 to 2015 during which he superintendent the re-christening of the name of the Department to Department of Soil Science and Land Management. He served as the Postgraduate Coordinator of the Department from 2007 to 2009. As a member of Senate of the University, he has served as a member of Minor Works Committee and Committee to review Student Disciplinary Handbook.

Professor Adeboye is happily married with children. His hobbies include reading, playing tennis, table tennis, watching movies and sports on big screen.