FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

TOWARDS A SUSTAINABLE SOIL SECURITY IN SUB-SAHARAN AFRICA: THE ROLE OF NITROGEN FIXING LEGUMES

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M.Sc. (Nitra), PhD (Vienna)
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INAUGURAL LECTURE SERIES 35

6TH AUGUST, 2015

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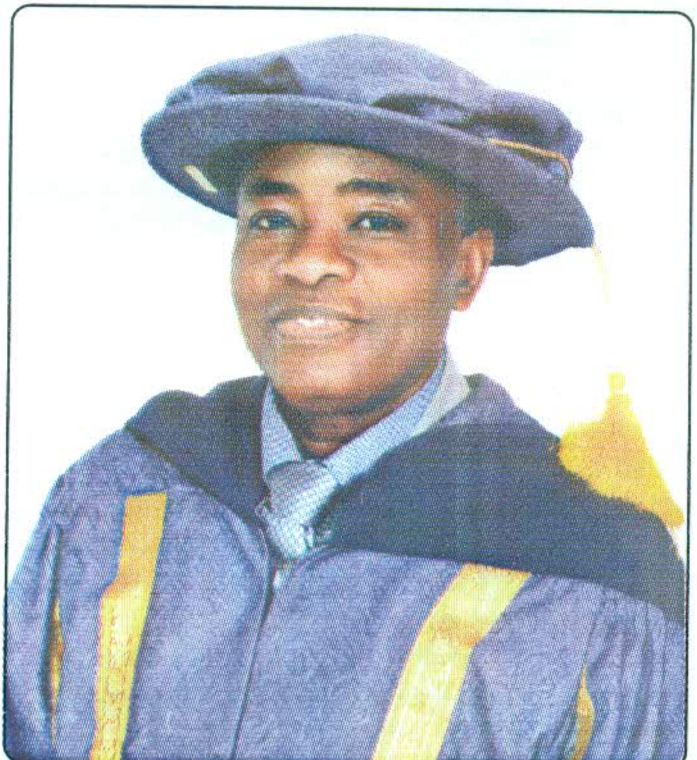
This 35^{th} Inaugural Lecture was delivered under the Chairmanship of:

Professor M. A. Akanji, FNSMBM
Vice-Chancellor
Federal University of Technology, Minna

Published by:
University Seminar and Colloquium Committee,
Federal University of Technology, Minna.

6^{TH} August, 2015

Design + Print:
Global Links Communications, Nigeria
✆: 08056074844, 07036446818



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DEDICATION

This lecture is dedicated to my late father Alhaji Dirisu Adams Osunde who sacrificed so much for my education and provided the proper upbringing and the enabling environment for me to achieve the greatest height in my academic career.

Introduction

It is with deep humility and immense gratitude to my Creator that I stand before this august gathering in the very first week of the month of August to deliver the 35th Inaugural lecture of the Federal University of Technology, Minna. This lecture is the ninth from the School of Agriculture and Agricultural Technology and the second from the Department of Soil Science and Land Management. I feel indeed highly honoured and privileged to be called upon to deliver this lecture covering the subject matter of SOIL SECURITY particularly this year 2015, a year designated by the 68th session of the United Nations General Assembly as the International Year of Soils. I am delivering this inaugural lecture exactly nine years after my elevation to the exalted status of a Professor. Considering the age of this University, if there were to be a categorization of Professors as it is the case in the University of Ibadan, I can be regarded as an Adult Professor in the Federal University of Technology, Minna.

Mr. Vice-Chancellor Sir, this landmark and auspicious occasion can only come once in the life of an academic. Inaugural lectures offer a rare and unique opportunity to assemble the "town and the gown" together to discuss a subject matter of topical interest and to highlight one's contribution to knowledge in a very succinct and simple language that can be comprehended by a larger part of the audience. I have therefore in all sincerity tried my best to remove major scientific technicalities from this lecture thus making it as simple as possible.

The central theme of this lecture is "Soil Security" (which in simple terms means "the well-being of the soil") with particular reference to Sub-Saharan Africa, and it is made up of five main parts. The first part deals with the basic definition of soil and the objectives of the UN declaration of the International Year of Soils. The second part introduces the concept of soil security, the characteristics of the six global environmental challenges and their interrelationship with soil security. The third part highlights the challenges to sustainable soil security in Sub-Saharan Africa; the fourth part discusses the role of nitrogen fixing legumes in the sustenance of soil security, while the fifth part welcomes this august audience to share my personal experience and humble contributions. The lecture concludes with some recommendations and suggestions.

On this note Mr. Vice-Chancellor sir, may I crave your indulgence and permission to present my Inaugural lecture entitled: ***Towards a sustainable soil security in sub-Saharan Africa: The role of Nitrogen Fixing Legumes.***

What is Soil?

There are as divergent definitions of soil as there are concepts and viewpoints concerning this important product of nature. The highway engineer for example views the soil as that material on which a roadbed is to be placed. The mining engineer on the other hand views the soil as the debris covering the rocks and minerals he needs to excavate. The geologist also appears to lean more to the engineering definition of the soil. For a soil scientist however, a simple and unambiguous description of the soil is that of *"the transformation product of unconsolidated mineral and organic substances on the surface of the earth under the influence of environmental factors operating over a very long time and having a defined organization and morphology".* It is the growing medium for plants and the basis of life for animals and humankind.

The upper limit of soil is air or shallow water. At its margins, it grades to deep water or to barren areas of rock or ice. Its lower limit to the not-soil beneath is perhaps the most difficult to define, but is normally considered as the lower limit of biological activity, which generally coincides with the common rooting depth of native perennial plants (Soil Survey Staff, 1975).

2015 – The year of the Soil

Soils are fundamental to life on Earth and are a key enabling resource, central to the creation of a host of goods and services integral to ecosystems and human well-being. They are the reservoir for at least a quarter of global biodiversity, and therefore require the same attention as above-ground biodiversity.

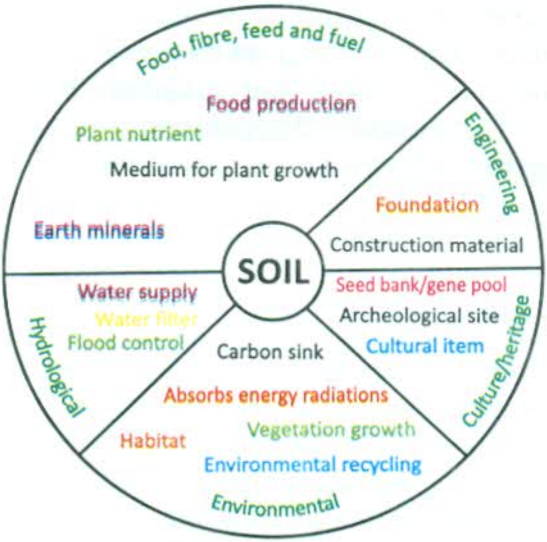

Figure 1. A diagrammatic representation of the various ecosystem roles of soil *(Adapted from: FAO, 2013)*

Recognizing that the sustainability of soils is key to addressing the pressures of a growing population and that recognition, advocacy and support for promoting sustainable management of soils can contribute to healthy soils and thus to a food secure world and to stable and sustainably used ecosystems, the 68th UN General Assembly (A/RES/68/232) designated 5th December as ***World Soil Day*** and declared 2015 the ***International Year of Soils (IYS).***

The specific objectives of the IYS 2015 are to:

- Raise full awareness among civil society and decision makers about the profound importance of soil for human life;

- Educate the public about the crucial role soil plays in food security, climate change adaptation and mitigation, essential ecosystem services, poverty alleviation and sustainable development;
- Support effective policies and actions for the sustainable management and protection of soil resources;
- Promote investment in sustainable soil management activities to develop and maintain healthy soils for different land users and population groups;
- Strengthen initiatives in connection with the SDG process (Sustainable Development Goals) and Post-2015 agenda;
- Advocate for rapid capacity enhancement for soil information collection and monitoring at all levels (global, regional and national).

In line with the above, the Soil Science Society of Nigeria in October, 2014 issued a press statement urging every Nigerian to take good advantage of these events to promote the importance of soil to our health, well being and socioeconomic growth. The Society encourages people to treat our beloved country's soil with the care it deserves so that it will continue to sustain our lives and livelihood.

This lecture, Mr. Chairman, ladies and gentlemen, is in part inspired by the aspiration to draw the attention of global audience to the centrality of soils to human existence and hence the need for its sustainable exploitation and security.

The Concept of Soil Security

The term "Soil Security" is a new concept that has arisen in response to an emerging international concern about the increasingly urgent challenges facing the global soil stock. Soil security thus refers to the maintenance and improvement of the world's soil resources to produce food, fibre and freshwater, contribute to energy and climate sustainability, and maintain the biodiversity and the overall protection of the ecosystem goods and services (Koch *et al.,* 2012, McBratney *et al.,* 2012). In this definition, security is used here for soil in the same sense that it is applied widely for food, water and energy. It is argued that soil has an integral part to play in the global environmental sustainability challenges of food security, water security, energy sustainability, climate stability, biodiversity, and ecosystem service delivery (Bouma and McBratney, 2013). Without secure soil we cannot be sure of secure supplies of food, fibre, clean freshwater or of diversity in the landscape. An insecure soil is short in the potential to act as a sink in the carbon cycle, and cannot provide a core platform for the production of renewable energy sources.

Soil security and the other global environmental challenges (Food Security, Water Security, Energy Security, Climate Change Abatement, Biodiversity Protection and Ecosystem Service Delivery) are strongly interconnected and inter-related (Fig. 2), as they all have similar characteristics and are addressed using a combination of dimensions with a focus on providing services to humanity.

Figure 2. Soil security is a major contributor to a number of global environmental issues, all of which are inter-related *(Source: McBratney et al., 2012).*

Characteristics of the six global environmental challenges and their interrelationship with the soil

The characteristics of each of the six previously recognized global environmental challenges have been recognized for their description, assessment and eventual amelioration (Bouma and McBratney, 2013). It is however instructive to examine these with a view to revealing their interrelationship with the soil and thus necessitating the need to address the issue of soil security. According to Brady and Weil (1999), soils perform five broad functions within an ecosystem: (1) Principal medium for plant growth, (2) System for water supply and purification, (3) Recycling system for nutrients and organic wastes, (4) Habitat for a wide diversity of soil organisms, (5) Engineering medium for human built structures. A fully functioning soil is therefore central to solving the big issues of food security, biodiversity, climate change abatement and fresh-water regulation. The concept of soil security provides a useful model that links soil with good outcomes in sustainable development as shown in Figure 2. This linkage becomes clearer when the above mentioned five functions of soil are aligned against critical global challenges for society and sustainable development as presented in Table 1. The key aim in securing soil is to maintain and optimize its functionality: its structure and form, its diverse and complex ecosystems of soil biota, its nutrient cycling capacity, its roles as a substrate for growing plants, as a regulator, filter and holder of fresh water, and as a potential mediator of climate change through the sequestration of atmospheric carbon dioxide (Koch *et al.,* 2013). Maintaining the myriad of interactions between these processes is what gives soil its resilience, productivity and efficiency in the delivery of ecosystem services.

Food security:

According to the International Food Policy Research Institute(IFPRI) (2002), food security can be described as *"a situation in which all people, at all times, have physical and* *economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active healthy life."* Thus, the word Food security is built on three pillars of availability, access and suitability. Essentially, food "availability" is referring to having sufficient quantity and a reliable source of food supply; "access" focuses on having the resources to obtain the food, while "suitability" refers to its quality in terms of nutrient content (IPNI, 2014). Food security is ensured through improved crop yield and product quality, minimizing loss of productivity by land degradation, pollution, and urbanization, as well as, the need for water supply and storage (Godfray *et al.,* 2010). The functions soil provides in this domain (see Table 1) are biomass production along with its ability for filtering, storing and transforming of nutrients, substances and water (Lal, 2010; Stocking, 2003).

Table 1. The impact of soil functions on the other six global environmental challenges. *(Adapted from: Koch et al., 2013).*

Global environmental challenge	Relevant soil functions
Food security	The quantity, quality and accessibility of food is affected by having functioning soil available to produce food and avoid contamination.
Water security	Soil contributes to provision of clean water and its storage and functions as a filter, minimizing the contamination of ground and surface water, thus maintaining its ability to produce food and protect biodiversity.
Energy security	The soil provides a platform for the production of fuelwood charcoal and plant biomass used for energy production (e.g. ethanol).
Climate change abatement	Carbon and nutrients are sequestered in soil and in the plants that the soil supports, reducing the release of greenhouse gases.
Ecosystem service delivery	Soil provides a wide range of ecosystem services that contribute to soil as natural capital that is formulated by natural stocks and ecosystem goods.
Biodiversity protection	Soil is the habitat for the largest gene pool and diversity of species, which enables plant growth, the recycling of waste and provision of nutrients affecting food and water security.

Water security:

Water impacts all life. It is a vital component of all living things. It has unique properties that promote a wide variety of physical, chemical and biological processes. As water shortage is becoming a reality today, scientists have demonstrated evidence that minimizing soil disturbance (e.g. minimum tillage) can conserve water (Hatfield *et al.,* 2001). The soil functions by ensuring the provision of clean water and its storage, as well as filtering and transforming compounds and nutrient cycling (Table 1). It holds and releases water for plant growth and water supply. The soil further minimizes the contamination of water ways and maintains its ability to produce food and protect biodiversity.

Energy security:

The International Energy Agency (IEA) defines energy security as the uninterrupted availability of energy sources at an affordable price. Uninterrupted availability is defined by having (self) sufficient and diverse supply while affordability on the other hand is defined as having equitable access to affordable energy. This can be further simplified by using an 'energy ladder' account for different sources from electricity as the highest rung, through modern fuels (e.g. petroleum, natural gas, ethanol) down to traditional fuels (e.g. fuel wood, charcoal, crop residues) (McBratney *et al.,* 2014). The soil function here is primarily in the domain of the traditional fuels source particularly fuel wood and crop residues.

Climate change abatement:

Sometimes referred to as Climate change mitigation, generally involves reductions in anthropogenic emissions of greenhouse gases (GHGs). This may also be achieved by increasing the capacity of carbon sinks through reforestation, expanding forests and other "sinks" to remove greater amounts of CO_2 from the atmosphere, managed grazing methods to restore grasslands, reduction in deforestation, agricultural emissions, waste emissions and emissions from various industrial processes (Oppenheimer *et al.* 2014). The sequestration of carbon and nutrients in soil and in plants that the soil supports has some potential to mitigate increases in atmospheric greenhouse gases. This is driven by the fact that there is more carbon stored in the world's soil than in the atmosphere and vegetation combined (Brady and Weil, 1999; Davidson and Janssens, 2006) and the liberation of this carbon will contribute significantly to global warming (Lal, 2004).

Ecosystem service delivery:

The provision of ecosystem services commonly defined as 'the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly' (De Groot *et al.*, 2002) has received considerable attention of recent. Soil provides four categories of ecosystem services namely: supporting, provisioning, regulating and cultural services (Robinson *et al.*, 2009). The supporting service is generally concerned with providing physical support for plants, renewal, retention and delivery of plant nutrients, sustenance of biological activity, diversity and productivity and providing a habitat for seeds dispersion and dissemination of the gene pool for continued evolution. Its excavation for building materials is an example of a provisioning service. The regulating services embrace buffering, filtering, moderation of hydrological cycles and disposal of wastes while the spiritual value, archaeological preservation and heritage constitute the cultural services.

Biodiversity protection:

Biological diversity or 'biodiversity' is described as "the variability among living organisms from all sources (terrestrial, aquatic or marine)". Soil biodiversity refers to the variation on soil life, from genes to communities, and the variations in soil habitats, from micro aggregates to entire landscapes (Turbé *et al.*, 2010). The soil is one of nature's most complex ecosystems and one of the most diverse habitats on earth. It contains a myriad of different organisms, which interact and participate actively in soil processes that affect its formation and function (Lavelle *et al.,* 2006). This is because biodiversity contributes to the maintenance of matter, nutrient and water efficiencies, soil pest and disease regulation (Brussaard *et al.,* 2007) and improvement in soil physical, chemical and biological properties.

The Challenge to Sustainable Soil Security in Sub-Saharan Africa

The major challenge to sustainable soil security in many regions of Sub-Saharan Africa (SSA) is extensive land degradation which manifests as rapid deforestation, soil erosion, nutrient depletion and declining soil fertility. The United Nations Convention to Combat Desertification (UNCCD) defines land degradation as a "reduction or loss, in arid, semi-arid, and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest, and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as: (i) Deforestation and long-term loss of natural vegetation; (ii) soil erosion caused by wind and/or water; and (iii) deterioration of the physical, chemical, and biological or economic properties of soil." (WMO, 2005). Simply put, it is a permanent decline in the rate at which land yields products useful to local livelihoods within a reasonable time frame. The UNCCD report indicates that, over 250 million people are directly affected by land degradation and that some other one billion people in over 100 countries are at risk. Sub-Saharan Africa has the highest rate of land degradation as they have fragile soils, localized high population densities, and generally a low-input form of agriculture. It is estimated that losses in productivity of farmland in SSA are in the order of 0.5-1 per cent annually (WMO, 2005), suggesting productivity loss of at least 25 per cent over the last

50 years. According to UNCCD, the consequences of land degradation include undermining of food production, famine, increased social costs, decline in the quantity and quality of fresh water supplies, increased poverty and political instability, reduction in the land's resilience to natural climate variability and decreased soil productivity.

Deforestation:

Deforestation is a process where vegetation is cut down without any simultaneous replanting for economic or social reasons. Its negative implications on the environment include amongst others: soil erosion, loss of biodiversity ecosystems, loss of wildlife and increased desertification. High rate of deforestation has long been identified as a leading cause of soil degradation in SSA (Stebbing, 1935). Similarly, widespread cases of tree felling, firewood collection and charcoal burning which might contribute to decimation of tree cover have also been well documented in parts of SSA (Braimoh, 2006). Forests play an important part in climate change mitigation as they are among the world's chief carbon sinks. They are reputed to store about 289 Gigatonne (Gt) of carbon in trees and vegetation. The carbon stored in forest biomass and soil together is more than all the carbon in the atmosphere. When a forest is cut down and converted to another use, carbon hitherto stored is released back into the atmosphere. A recent study by the Food and Agriculture Organization (FAO, 2015) reported that the rate of deforestation in several Sub-Saharan African countries exceeded the global annual average of 0.8 percent. Deforestation in most parts of Africa is strongly associated with human activity since an estimated 90 percent of the entire continent's population relies on wood fuel, the major energy source for cooking and heating; and in Sub-Saharan Africa, firewood supply approximately 52 percent of all energy sources. Forests currently cover about 23 percent of the land in Africa, and it has been reported that 75 million hectares of forest land (10 percent of the total forest area) in Africa was converted to other uses (subsistence agriculture, grazing and cash crop cultivation) between 1990 and 2010.

According to FAO data taken over 2000 to 2005, Nigeria located in the western region of Africa, has the largest deforestation rates in the world, having lost 55.7% of its primary forests to logging, timber export, cropping and notably the collection of wood for fuel which remains problematic in the larger part of western Africa (FAO, 2010).

Plate 1. Images of deforestation in West African regions of Nigeria (left) and Niger (right)

Soil erosion:

Soil erosion is simply a term used to describe the removal of topsoil by whatever means and this has been shown through research and historical evidence to have many deleterious effects on the productive capacity of the soil as well as on ecological wellbeing (Obalum *et al*, 2012). By removing the topsoil, erosion reduces the productive capacity of the soil through its effect on the physical, chemical and biological properties of the soil such as the removal of essential plant nutrients in the eroded sediments, depletion of organic matter layer, reduction of biological diversity; and the deformation of soil structure leading to surface sealing, crusting, compaction and formation of restrictive layer in the soil profile which reduces seedling emergence and infiltration. The effect of soil erosion by water and wind appears to be the greatest factor limiting soil productivity worldwide, and is extensive in many parts of SSA with about 25 per cent of the land being prone to water erosion and about 22 per cent, to wind erosion. In most of the humid and sub-humid areas of the region, rainfall is rarely gentle and even. It usually comes as torrential downpours, with accompanying destructive consequences. The annual soil loss to water erosion has been put at over 60 tons ha^{-1} (IFAD, 2009) while soil loss to wind erosion in the West African Sahel has been recently reported to be in the range of 58 – 80 tons ha^{-1} (Ikazaki *et al.*, 2011). Serious soil erosion areas in SSA can be found in Nigeria, Sierra Leone, Liberia, Ghana, Senegal Niger and Guinea in West Africa; in Kenya, Uganda and Ethiopia in East Africa; and in Lesotho, Swaziland, and Zimbabwe in southern Africa (Figure 3).

Soil erosion is caused in most cases by a combination of processes involving both biophysical (climatic characteristics, soil properties, topography of the land, vegetation cover) and anthropogenic factors (deforestation, tillage practices, overgrazing, cropping system, population dynamics, urbanization) (Figure 4). The biophysical factors often require the influence of human activities (anthropogenic) to cause erosion, but can, in fact, interact among themselves to cause soil erosion (Kiage, 2013).

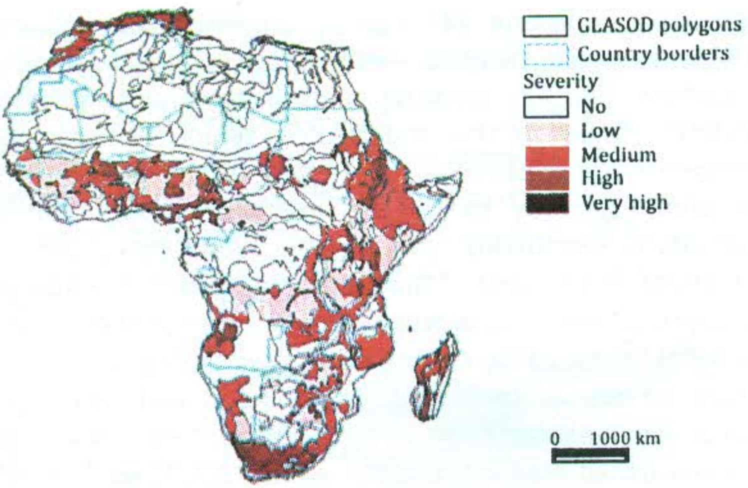

Figure 3. The Global Assessment of Soil Degradation (GLASOD; Oldeman *et al.*, 1990) map of water erosion severity in Africa. What is evident is that most of the areas with serious soil erosion are in Sub-Saharan Africa. *(Source: Kiage, 2013).*

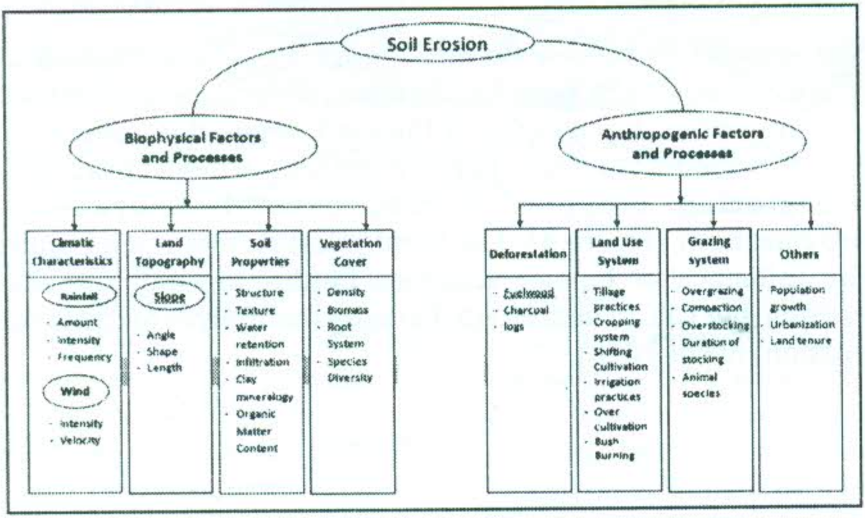

Figure 4. Some causative factors and processes of soil erosion in Sub-Saharan Africa

Nutrient depletion and declining soil fertility:
Substantial amount of nutrients are usually removed from soils that have been subjected to cultivation through the agricultural produce (food, fibre, wood) and crop residues. Continuous nutrient removal may result in a decline of the soil fertility if replenishment with inorganic or organic nutrient inputs is inadequate. A decline in soil fertility implies a decline in the quality of the soil which includes amongst others: (1) Nutrient depletion or nutrient decline (larger removal than addition of nutrients), (2) Nutrient mining (large removal of nutrients and no inputs), (3) Acidification (decline in pH and / or an increase in exchangeable Al), (4) The loss of organic matter and (5) An increase in toxic elements (e.g., Al, Mn).

Nutrient depletion as a form of land degradation has severe economic impact at the global scale, especially in Sub-Saharan Africa. Many countries in SSA have already lost a significant quantity of theirs soil to various forms of degradation. Many areas of SSA are said to be losing over 50 tons of soil per hectare per year (Nana-Sinkam, 1995). This is roughly equivalent to a loss of about 20 billion tones of Nitrogen, 2 billion tones of phosphorus and 41 billion tons of potassium per year. Stoorvogel *et al.,* (1993) estimated the primary nutrient balances for 38 countries in SSA and they reported annual NPK depletion rates of soil fertility in SSA at 26 kg N, 7 kg P_2O_5, and 23 kg K_2O ha^{-1} year^{-1}, a yearly equivalent of about US$5 billion worth of fertilizer. The actual economic cost of soil degradation in this region, including the in-situ productivity loss and the off-site economic and environmental externalities, is definitely much higher.

Of all the factors associated with declining soil fertility, nutrient depletion from the soil is considered the most serious threat to agricultural productivity and has been identified as major biophysical cause of decreased crop yields and stagnant per capita food production in SSA (Henao and Baanante, 2006, Sanchez, 2002). Peasant farmers in most parts of SSA use insufficient fertilizers to replenish the nutrients that are removed from the soil by cultivation of the land, harvesting crops, leaching, soil erosion and other unavoidable losses. The farmers have traditionally relied on clearing land to grow crops then leaving it fallow to regain some of its fertility. But with increasing population pressure, they are now forced to grow crops continually on the same piece of land thus, 'mining' or depleting the soil of nutrients while giving nothing back.

With little access to fertilizers, the farmers are forced to bring less fertile soils on marginal land into production. Inorganic fertilizers are not always available to the peasant farmers in SSA because of limited purchasing power, opportunities for rural credit, as well as escalating prices. In fact, it costs two to six times more to purchase fertilizer at the farm gate in Africa than anywhere else in the world (Spore, 2010). Thus, the quantity of fertilizer affordable at any one time cannot completely maintain the fragile equilibrium of ecosystems. There is therefore a big gap between the external nutrient input and the nutrient mined from the soil increasing the downward spiral of soil fertility loss. A recent FAO report estimated Inorganic fertilizer use on food crops in sub-Saharan Africa to be 10 kg nutrients ha^{-1} $year^{-1}$ (N, P_2O_5, K_2O) which is the lowest in the world (Muchena *et al.,* 2005). This low use of inputs partially accounts for the observed net negative nutrient balances across SSA. The main factors contributing to nutrient depletion in the soil are loss of nitrogen and phosphorus through erosion by wind and water, and leaching of nitrogen and potassium.

Given the high levels of nutrient depletion and soil degradation in many small holder farming systems in SSA, associated with high economic cost of fertilizers, and the problems of their availability, the need to explore alternative soil management avenues becomes imperative. Nitrogen fixing legumes offers considerable potential in sustaining crop productivity, maintaining the productivity of marginal lands and minimizing erosion in low-input farming systems (Osunde and Bala, 2001).

The Role of Nitrogen Fixing Legumes

Nitrogen is the plant nutrient required in the greatest amount for soil productivity and plant growth. Nitrogen fixing legumes through the natural process of biological nitrogen fixation (BNF) in symbioses with root nodule bacteria can play a critical role in the achievement of cost effective, attractive and ecologically sound means of reducing external N inputs and improving the quality of soil resources and ensuring the sustainability of soil security.

Legumes (species of the family - leguminosae) are among the world's most important crops, comprising about 20,000 plant species in over 650 different genera (FAO, 1984). They include grain legumes (cowpea, soybean, etc.), forage legumes (Calopogonium, Centrosema, Trifoleum, etc.) and shrubs and trees (Acacia, Leucaena, Gliricidia, etc.). They are characterized by their possession of seed pods either borne above the ground (soybean, cowpea) or underground (groundnut). A large majority of leguminous plants can obtain most of the nitrogen they require from the vast supply of gaseous nitrogen (N) in the atmosphere (air is 80 percent nitrogen). It is reported that there are about 6400 kg of N above every hectare of land and water (FAO, 1984). However, a majority of organisms cannot use this N in its inert form as it exists in the atmosphere unless complexed with some other atoms to form an ion such as ammonium (NH_4^+) or nitrate (NO_3^-). The nitrogen fixing legumes (*NF-legumes) gather and convert this N into plant usable form through a process called Biological Nitrogen Fixation (BNF).

BNF in legumes is a process by which a NF-legume and bacteria form a symbiosis in which atmospheric nitrogen from the air is converted into ammonia (NH_3) and fixed into plant tissue. The bacteria, collectively called rhizobia, live in nodules on the roots of most NF-legume plants (Plate 1). While most NF-legumes bear nodules on their roots, a few bear nodules on their stems (Plate 2). The symbiotic nature of the relationship between the host NF-legume plant and the bacteria stems from the fact that the host plant provides the bacteria with sugars from photosynthesis for the energy needed for nitrogen fixation in exchange for the nitrogen fixed by the bacteria.

**It should be noted that some members of the family "Leguminosae" neither form nodules nor fix nitrogen hence the distinction between Legume and NF-legume.*

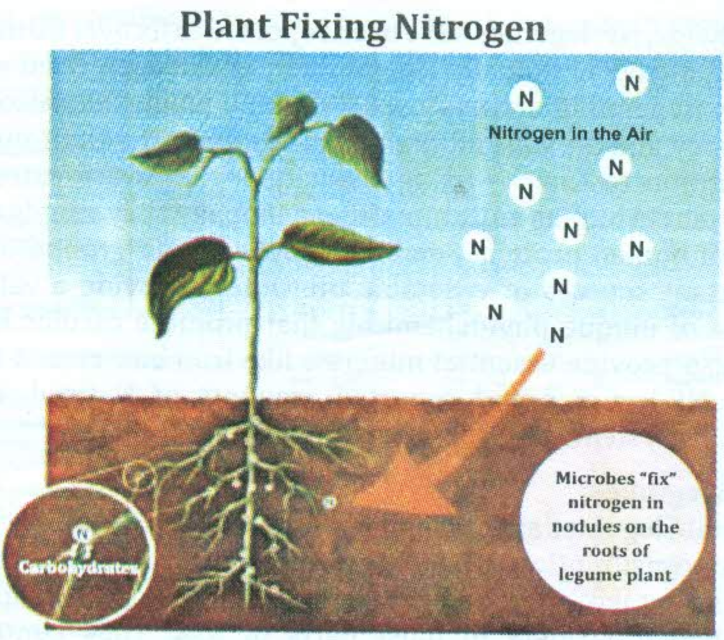

Plate 2. Rhizobia in root nodules fix nitrogen for legume plant while receiving carbohydrate as energy source from the plant. *(Source: www.permaculture.co.uk)*


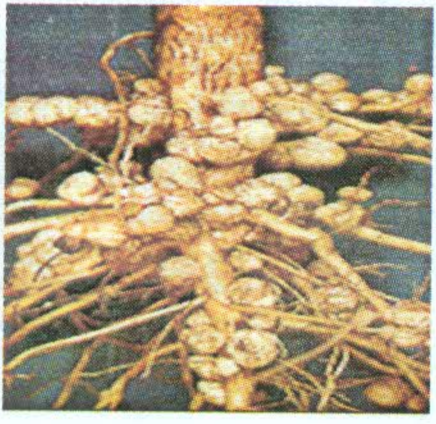

Plate 3. Stem nodules on *Sesbania rostrata* (left), Nodules on soybean roots (right)

Worldwide, NF-legumes have been reported to fix over 80 million tons of nitrogen annually. The amount of nitrogen fixed varies widely depending on the host NF-legume plant, the rhizobium efficiency, and the soil and climatic condition of the environment. In addition to their N-fixing capacity, legumes are extremely important in human and animal diets. Globally, they supply about 33% of human protein. Some like soybean and groundnut are important sources of vegetable oil. Others provide a valuable source of unique phytochemicals that promote cardiac health and also provide essential minerals like iron and zinc. A list of some NF-legumes and reported amounts of N fixed within cropping systems in SSA is given in Table 2.

Grain legumes:

The grain legumes are those that their seeds are used directly for human consumption. They provide up to 70% of human dietary protein intake, and are also important as cash crops for smallholder farmers in most parts of SSA. They contribute substantial amount of nitrogen to the soil when grown sole, intercropped or in rotation with other staple foods such as cereals and tuber crops. Apart from the contribution of part of N fixed for the maintenance of soil fertility, other rotational beneficial effects of NF-grain legumes to a succeeding crop include reduction of disease incidence and/or weed infestation. NF-grain legumes are reported to contribute large amount of N into soils through their leftover stover after grain harvest (Figure 5.), however if the stover is also removed along with the grains, there is often no visible benefit to a succeeding crop. Commonly grown NF-grain legumes in SSA include: groundnut (*Arachis hypogea*), soybean (*Glycine max*), common bean *(Phaseolus vulgaris)*, cowpea *(Vigna unguiculata)* and bambara nut (*Vigna subterrranea*).

Table 2. Estimates of N_2-fixed by some NF-legumes in cropping systems in Sub–Saharan Africa *(Adapted from: Giller, 2001)*

NF - Legume	Amount of N_2 – fixed (Kg ha^{-1})	% N from N_2 fixation	Duration (months)	Country
Grain legumes				
Soybean *(Glycine max)*	114 - 188	84 - 87	2	Nigeria
	14 - 15	36 - 39	1	Congo
Groundnut *(Arachis hypogaea)*	101	-	-	Ghana
Pigeonpea *(Cajanus cajan)*	13 -163	42 - 85	4	Malawi
	1 - 39	64 - 100	-	Zimbabwe
	10 - 157	55 - 71	6	Côte d'Ivoire
Common bean *(Phaseolus vulgaris)*	74 - 91	43 - 52	3	Kenya
	8 - 26	40 - 51	3	Tanzania
Cowpea *(Vigna unguiculata)*	201	-	-	Ghana
	66 - 120	54 - 70	2	Nigeria
Green manure legumes				
Aeschynomene histrix	9 - 137	35 - 86	6	Côte d'Ivoire
Centrosema pubescens	3 - 104	48 79	6	Côte d'Ivoire
	136	-	12	Uganda
Mucuna pruriens (var. utilis)	18 - 213	60 - 83	6	Côte d'Ivoire
	41 - 76	49 - 57	5	Benin
	139 - 224	64 - 86	3	Nigeria
Pueraria phaseoloides	172	76	-	Nigeria
Sesbania rostrata	80 - 110	-	2	Senegal
Trees and shrubs				
Leucaena leucocephala	224 - 274	56	-	Nigeria
Gliricidia sepium	1062	-	27	Nigeria
Tephrosia vogelii	12 - 45	37 - 78	6 - 7	Malawi

Legume based cropping system

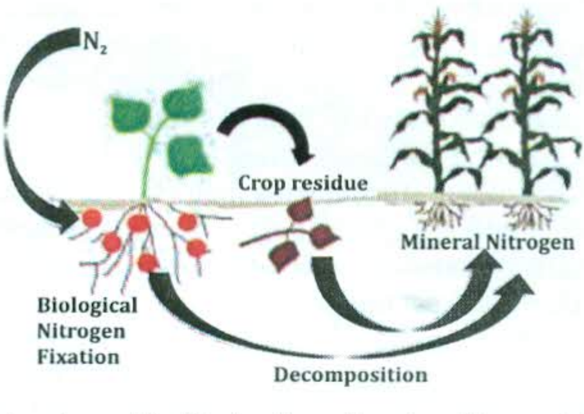

Figure 5. *A schematic illustration showing the contribution N_2 from BNF to companion cereal crop through residue and nodule decomposition.* *(Source: www.extension.org)*

Green manure legumes:

These are legumes grown primarily for use as organic manure. They are also credited with the ability to fix large amounts of N_2 in the field (see table 2). When grown, their tissues are usually incorporated into the soil when the plant material is still green and succulent. Generally, they have higher moisture and N contents than contemporary grain legumes. Apart from being sources of organic replenishment for nutrient deficient soils, they are also commonly used as cover crops to protect the soil from erosion by maintaining a dense canopy over the surface of the soil. They are thus mostly useful as cover crops on steepy sloping lands and for the control of pernicious weeds (Giller, 2001). The main success of NF-legumes used as green manure and cover crops is due to their ability to grow in nutrient poor soils which is due in large part to their ability to fix abundant quantity of nitrogen. Common green manure legumes in use in the cropping systems in SSA include: *Aeschynomene histrix, Mucuna pruriens, Sesbania rostrata, Centrosema pubescens,* and *Pueraria phaseoloides.*

NF- legume trees and shrubs (Woody legumes):

Nitrogen fixing woody legumes are perennial plants which have one or more woody stems. They are generally large, growing to a height of between 4 – 40 metres. They have branches and form symbiotic association with nodule bacteria. Woody legumes have long held position of importance in the traditional farming systems in SSA where they form a major component of the bush fallow system and are also widely grown in cropped land. They provide multiple services to the farmer in form of agricultural benefits (plant stakes, mulch materials, green manure, animal fodder etc), environmental benefits (shade, soil erosion control, nutrient recycling) (Figure 6.) and socioeconomic benefits (fruits, vegetables, nuts, building materials etc) (Kang *et al.,* 1990).

NF-Woody legumes have the added advantage of fixing large amount of nitrogen in their foliage and thus serve as a major source of organic N fertilizer for the replenishment of degraded environment. The nitrogen rich foliage of these trees and shrubs can be used for animal fodder, green manure and for human consumption, in addition to the provision of wood which is generally suitable for fuel, timber or other uses. Leaf litter and root residues of NF-woody legumes have beneficial effects on soil fertility by increasing soil organic matter content, fauna (particularly earthworm) activity and soil water retention. They bring up nutrients released by weathering in the lower horizons of the soil thus increasing the nutrient status of the soil. They trap and recycle nutrients that would otherwise have been lost by leaching, thereby making the plant – soil system more closed (Kang, 1996).

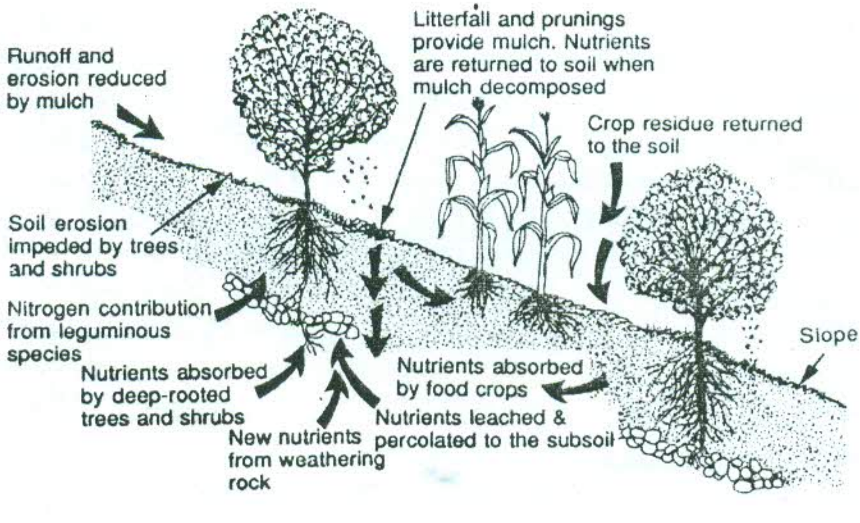

Figure 6. A schematic representation showing the benefits of nutrient cycling and erosion control in alley-cropping (NF-woody legumes and cereal crop)
(Source: Kang and Wilson, 1987)

In addition, the tree prunings provide additional soil cover when added to the soil in form of mulch and help to suppress weeds and improve the soil structure (Salazar *et al.* 1993). They also serve as windbreaks and help to slow the process of soil erosion through closely planted shrub hedges and tree litter as in stable agroforestry systems like "alley–cropping". NF-woody legumes of common use in agroforestry systems in SSA include: *Leucaena leucocephala, Gliricidia sepium, Tephrosia vogelii, Faidherbia albida, Acacia senegal, Acacia tortilis, Calliandra calothyrus,* and *Leucaena diversifolia.*

Research reports on NF-legumes in SSA

A number of research have been conducted in many parts of SSA on the characteristics of rhizobia nodulating NF-legumes, N_2 fixation potential and N contribution of NF-legumes in various cropping systems, and reports well documented for grain legumes (Awonaike *et al.*, 1990, Dakora *et al.*, 1992, Kasa *et al.*, 1999, Mpepereki *et al.*, 2000, Sakala *et al.*, 2000, Sanginga *et al.*, 2001), green manure legumes (Carsky *et al.*, 1998, Houngnandan *et al.*, 2000, Bala *et al.*, 2002, Adeboye *et al.*, 2012, Gbanguba *et al.*, 2012) and trees and shrubs (Sanginga *et al.*, 1990, Odee *et al.*, 1997, Bala and Giller, 2001, Bala *et al.*, 2003a, Akinnifesi *et al.*, 2009). More recent research on NF-legumes is directed towards identifying varieties that are considered to have combined adaptation to biotic and abiotic stresses, such as phosphorus deficiency, drought, soil acidity and other environmental factors that limit the optimal contribution of BNF in cropping systems.

My Contributions

My modest contribution to knowledge in the subject matter area covers studies carried out with my colleagues, international collaborators and my students over the past 25 years. Summaries of some of the studies carried out on nitrogen fixing woody legumes, grain legumes and green manure legumes and our findings are as described below:

Studies on NF-woody legumes

The significant role of NF-woody legumes in improving soil fertility and recovery of degraded lands is already apparent in well established agroforestry systems such as "alley farming" in the humid and sub-humid tropics. Exploiting genetic variability among these woody legumes to nodulate and fix N_2 can improve their growth in the different agroecological zones of SSA particularly in areas under environmental stress. Our study priority was (i) to identify those woody legumes that are able to nodulate profusely and fix nitrogen efficiently in symbiosis with indigenous soil rhizobia in soils of the moist savannas of Nigeria and (ii) to identify those that are better adapted to acid soils and are able to fix nitrogen with minimum P requirement (Osunde and Sanginga, 1989; Osunde, 1993; Osunde *et al.*, 1992; Osunde *et al.*, 1994; Osunde, 1997; Osunde and Alkassoum, 1998; Osunde *et al.*, 2002).

Of the many potential NF woody legumes suitable for integration into stable agroforestry systems in SSA, *Leucaena leucocephala* and *Gliricidia sepium* have been shown to be most promising because of their fast growth, abundant biomass production, deep rooting system and high N_2 fixing ability.

- A greenhouse study conducted on an Ultisol from south-south Nigeria to assess arbuscular mycorrhizal fungi (AMF)/rhizobium symbiotic affinity of *Gliricidia sepium* shows that dual inoculation of the plants with the fungi and rhizobium significantly improved shoot dry biomass by 141%, N-uptake from the soil by 160%, P-uptake by 816% and nodulation by 20% over the uninoculated plants.

- In another study on the same acid Ultisol, the availability of phosphorus from Gafza rock phosphate (RP) and triple super-phosphate to selected lines of *Leucaena leucocephala* was evaluated using ^{32}P radio-isotope techniques. Results obtained showed no significant differences between the *L. leucocephala* lines in their utilization of phosphorus from Gafza RP. The ^{32}P isotopic data data however revealed that the predominant source of phosphorus to the woody legume plants was the Gafza RP rather than the mineral fertilizer.

- In a similar experiment conducted in the same environment, Gafza RP was shown to be a more effective source of P to *Gliricidia sepium* than TSP in an acid Ultisol, and that wide differences exist amongst *Gliricidia sepium* provenances in the uptake and utilization of phosphorus from different P sources.

- Other studies conducted to select acid tolerant lines of *Leucaena leucocephala* and *G. sepium* revealed a large inter-specific plant variation in nodulation of .the Leucaena lines. Some nodulated while others did not. *Gliricidia sepium* was more tolerant and was able to overcome acid soil limitations to utilize N-free nutrient supply for dry matter accumulation.

- Results obtained from some studies conducted on an Alfisol (derived from basement complex) in the southern Guinea savanna of Nigeria showed that variation in growth and biomass production of tested provenances of woody legumes were due largely to differences in their N_2 fixing ability rather than intrinsic growth differences, and that *Albizia lebbeck, Enterolobium cyclocarpum* and *Faidherbia albida* provenances from Burkina Faso and Senegal were most promising for integration into agroforestry technologies in the moist savannas of Nigeria.

- A study carried out with 10 kg soil in pots to assess the response of *Leucaena leucocephala* to varying rates of phosphorus and potassium in a low P Inceptisol of he Nigerian moist savanna showed that fertilizer rates of 112 kg ha^{-1} each of P_2O_5 and K_2O significantly increased shoot and root biomass, nodule number and dry matter, and N, P and K yield of plants compared to lower nutrient rates. The result indicate that for good establishment and growth of *Leucaena leucocephala* in such soils of low inherent fertility, a basal application of P and K fertilizers may be required to overcome the initial nutrient stress.

Studies on NF-grain legumes

The selection criteria for the TGX soybean lines that were bred at IITA, Ibadan in the early 1980's for promiscuity with the indigenous rhizobia in Nigerian soils was based primarily on profuseness of nodulation. However, research results over the years have shown that the symbiotic performance of NF-legume plant does not only depend on the population size but also on the effectiveness of the indigenous rhizobia in the field. This formed the basis of a two-year study to assess the response of two elite promiscuous soybean lines to rhizobial inoculation in five farmers' fields in Niger State (Osunde *et al.,* 2003b). Results obtained showed:

- That the introduced Inoculant strains of rhizobia were less competitive but more effective than the indigenous rhizobial population in the soil, as the proportion of nodules occupied by the Inoculant strains were 17% and 24% in the first and second cropping seasons respectively.

- Rhizobial inoculation increased percent AMF infection of plant roots by an average of 50%, while increasing soybean grain yield by about 40%.

- The proportion of N_2 derived from fixation ranged from 27% to 50% in both cropping seasons, and this was dependent on crop management on farmers' fields rather than any cultivar or inoculation effect.

Results obtained from other studies carried out to assess the contribution of NF-grain legumes to cereal crops within the different cropping systems in the moist savannas of Nigeria (Osunde *et al.*, 2003a; Osunde *et al.*, 2004; Bala *et al.*, 2003b; Osunde and Bala, 2005) varied from one location to another as summarized below:

- In a location where the above ground residues of promiscuous soybean cultivars were harvested along with the grains, the residual N was too low to support a good yield of a subsequent maize crop even with the supplementary addition of 40 kg N ha^{-1}.

- In another location, maize grown after promiscuous soybean cultivar exhibited better growth, biomass production and grain yield compared to those grown in previous fallow plots. This was probably due to decomposition of senesced roots, nodules and fallen leaves of the preceding legume plant. Other rotational benefits to the maize crop (where the legume residue is harvested) are disease control and improvement in soil physical properties.

- In other studies, we observed that farmers' fields previously sown to late maturing cultivars of promiscuous soybean exhibited better residual benefits, producing larger maize yield parameters and less soil N depletion than those previously sown to early and medium maturing cultivars.

- Rhizobial inoculation of promiscuous soybean enhanced arbuscular mycorhizal fungi (AMF) colonization of plant roots by as much as 50%, and this translated to better plant nodulation and higher dry matter yield.

- The magnitude of AMF infection of roots of a succeeding cereal crop in a rotation is dependent on the previous legume treatment in the field, however no significant differences was observed in the degree of AMF colonization of roots of sole cropped maize and that intercropped with a legume plant.

- The average net income obtained for a maize-promiscuous soybean intercrop was over 30% more than that obtained for the sole crops.

- The proportion of N derived from fixation by promiscuous soybean cultivars on farmers' fields around Minna is in the range of 26% to 76%, which is equivalent of 31 to 110 kg N ha^{-1}. This is an indication that promiscuous soybean cultivars differ widely in their ability to fix N in this area, thus the choice of cultivar line influences the potential contributions of fixed N to the farming systems.

- Intercropping promiscuous soybean with maize decreases weed biomass in Minna area by as much as 35%. The weed biomass in a maize field previously cropped to sole soybean is about 50% less than in a field previously cropped to sole maize.

Attempts were also made to exploit genotypic differences to select from a range of cowpea lines those that are adaptable to low P soils of the Nigerian moist savannas (Osunde *et al.,* 2007).

We observed that cowpea lines exhibited differential response to applied phosphorus. Based on the above ground biomass production and grain yield the lines tested were classified into four groups: (Group-I) those that produced low yield with or without applied P, (Group-II) those that produced high yield without P applied and low yield with P applied, (Group-III) those that produced low yield without P applied and high yield with P applied and, (Group-IV) those that produced high yield with or without P applied. Cowpea line IT90K-284-2 consistently outperformed the others at low P, thus showing good prospects for both grain and fodder production in low P soils.

In more recent studies on NF-Grain legumes (Uzoma *et al.*, 2013a,Uzoma *et al.*, 2013b), phosphorus supplied at the rate of 30kg P ha^{-1} as SSP in combination with a starter nitrogen dose of 20 kg N ha^{-1} as Urea significantly increase yield and yield components of soybean (TGX1448-2E) and groundnut (SAMNUT22).

Studies on NF- green manure legumes

There has been resurgence of interest of recent in the use of green manure legumes in both the upland (to improve the growth of crops like maize, sorghum and upland rice) and the lowland (to increase and sustain productivity of lowland rice) cropping systems. Our studies in the inland valley swamps of southern Guinea savanna of Nigeria include (i) the use of *Aeschynomene indica* fertilized with phosphorus as pre-rice green manure (Adeboye *et al.*, 2009); and (ii) nitrogen contribution of some selected green manure legumes to a sorghum based cropping system (Usman *et al.*, 2013). Our findings show that:

- Lowland rice grain and stover yield were significantly increased by the incorporation of *Sesbania rostrata* and *Aeschynomene indica* green manure legumes. The results suggests the suitability of these NF-legumes as pre-rice green manure crops in the Kuta and Musa inland valleys in the Minna area of Niger Sate.

- Application of 40 kg N ha^{-1} to sorghum following the incorporation of a *Mucuna cochichinesis* green manure resulted in significantly higher sorghum grain yield and tissue N concentration than those following fallow control.

- Intercropping sorghum with *Canavalia ensiformis* produced significantly higher grain yield of sorghum than sole cropped sorghum.

Conclusion

Soil is an important natural resource that has an existential bearing on mankind, directly affecting the quality of life and human survival. In addition to its role in the sustenance of food security, soil also plays an integral in the global environmental sustainability challenges of water security, energy sustainability, climate stability, biodiversity, and ecosystem service delivery. The promotion and improvement of a robust soil system that is capable of adequately playing these roles therefore becomes an imperative. This underpins the concept of soil security. The major challenge to sustainable soil security in many regions of SSA is extensive land degradation which manifests as rapid deforestation, soil erosion, nutrient depletion and declining soil fertility. One of the most effective management options that are often used to check these hazards and thus engender sustainable soil security, especially in low-input agricultural systems, is the use of nitrogen fixing legumes. The degree to which a particular legume contributes to soil security depends on its type. While the grain legumes provide nitrogen-rich edible seeds, their residues serve as mulch and contribute to organic matter build-up in the soil. The green manure legumes are grown primarily for use as organic manure and weed suppression, while the NF-woody legumes provide multiple services that include the provision of mulch materials, staking materials and green manure; soil erosion control, nutrient recycling. To the extent that these contributions by NF legumes engender soil security and thus enables the soil to play its role in meeting the global environmental sustainability challenges, especially as it affects SSA, it can be deduced that NF legumes offer a potential for the attainment of a secured continent.

Recommendations

Mr. Vice-Chancellor sir, I crave your indulgence to add my voice to the numerous recommendations previously made by many other soil scientists on ways to mitigate the challenges of soil degradation and thus ensuring a secure soil in our continent.

- The resilience of most soils in SSA is inherently low hence the high level of degradation upon cultivation. The lack of a body charged with the supervision of the use, management and treatment of soils and the coordination of projects and researches on soils in most of the SSA countries has degenerated into progressive abuse of the soil through indiscriminate deforestation, grazing, land clearing etc. This must not be allowed to continue. The establishment of a well - structured National Institute of Soil Science in each of the SSA countries, charged amongst others with compiling research information on the capability of soils for different crops, developing guidelines for soil conservation and management in the different agro ecological zones of SSA, carrying out basic research that would generate baseline data applicable at the farmer's level is imperative and desirable. The establishment of such Institutes will go a long way in arresting the deteriorating situation of incessant soil abuse. For example, the bill for the establishment of the Nigerian Institute of Soil Science has been pending in the Upper Chambers of the National Assembly for over two years now and there is an urgent need for its passage into law.

- Serious efforts should be made by governments to build manpower capacity and upgrade facilities in all their soil research laboratories (in Research Institutes and tertiary Institutions). The laboratories should thus be mandated to embark on soil characterization and suitability assessment of agricultural lands within the area of their jurisdiction. Availability of baseline data for soil and crop selection before embarking on any farming enterprise would limit the extent of soil degradation and crop failure.

- Governments across the SSA countries must make conscious efforts to strengthen their extension services to adequately disseminate information at farm gate on soil suitability, soil conservation strategies and other soil management technologies for sustainable soil security and food production

- Governments across these countries should embark on building a critical mass of educated farmers using the students in Agriculture in the tertiary Institutions as the focal point. It is a well known fact that the educated farmer would easily understand and accept information that emanate from research and development concerning the various technology options which could overcome land degradation. Thus conscious efforts should be made to encourage the study of Agriculture and Soil Science in particular through special concessions such as scholarships or fees subsidy.

Suggestions

The mitigation of soil degradation and the maintenance of a secure soil should however not be left to Government alone. Each and every one of us has the responsibility of ensuring the sustainability of our soil not only through our actions but also by helping to disseminate information to others. In line with the foregoing, it is hereby suggested that individually and collectively we must ensure that we:

- Replenish whatever we take away from the soil
- Keep the soil always vegetated rather than leaving it bare
- Avoid bush burning
- Plant at least two trees for every one cut down
- Integrate NF-legumes (grains, green manure and woody ones) into existing cropping systems.

Acknowledgement

Mr. Vice-Chancellor Sir, I must confess to you that this is the most difficult section for me to write because in the course of my development and sojourn in life as an academic, I have enjoyed tremendous support and encouragement from numerous people both within and outside the academic community, some living and some already departed this world for the great beyond. To appreciate everyone within the space of time for this lecture would be an impossible task. I however wish all my well wishers whose names are not mentioned to know that they are all equally acknowledged and appreciated in my heart.

My Teachers:

Much appreciation goes to all my teachers from the primary to the university level. They provided the rudiments of education, the discipline, encouragement and support, thus creating an amiable platform for me to acquire knowledge.

My Mentors:

I wish to acknowledge the contribution of the following people to my academic development. Prof. Eva Chreneková (of the then University of Agriculture, Nitra), Prof. Ralph Gretzmacher and late Prof. Emeritus Otto Steineck (then of the University of Agriculture & Forestry, Vienna), Dr. Nteranya Sanginga (the current Director General, IITA, Ibadan). They were my mentors and supervisors at different stages in life and indeed served as pivot to my academic carrier; they were great motivators, wonderful teachers and friends combined, they provided the guidance and tutelage for me in the basic tenets of scientific research. They taught me virtues of perseverance, curiosity, broadmindedness and dedication, and impacted strongly on my orientation and approach towards solving research problems.

University Scholarships

I am immensely grateful to the Czechoslovak Government for granting me scholarship for my High School and University

education in Czechoslovakia, and to the old Bendel State Government of Nigeria and the Austrian Ministry of Science and Research for providing funds for my PhD research programme in Vienna, Austria.

My International Collaborators, National and International Associations

I wish to acknowledge with special thanks the research collaboration I have enjoyed with scientists at IITA, Ibadan over the years. This helped in no small measure to strengthen the research capacity of the postgraduate programme in my department in its early years. The travel grants I enjoyed on numerous occasions particularly in the early 1990s to mid 2000 from the International Foundation for Science (IFS) in Sweden, IITA, Ibadan and the African Association for Biological Nitrogen Fixation (AABNF) to present our research findings at International fora are also gratefully acknowledged, coming especially at a time travel grants for International conferences was very lean and almost nonexistent for the academia in Nigeria.

I am most appreciative of the support and encouragement of the President, the executives and members of my professional body, the Soil Science Society of Nigeria. I thank the society for finding me worthy of the honour of fellowship of the society some years back.

Research Funding Agencies

I am deeply indebted to the Australian Centre for International Agricultural Research (ACIAR) for providing the funds that drove most of our collaborative research work with IITA- Ibadan, the FUT, Minna Board of Research for funding some of our research activities in the late 90s and most recently, the Agricultural Research Council of Nigeria for providing funds for an ongoing research project.

The Defunct Family BBQ Club of Minna

I wish to appreciate all family members of the above social club, particularly the families of Prof. & Mrs. F. D. Sikoki, Dr. & Dr. (Mrs.) F. Odafen, Chief & Mrs. F. Okeke, Eng. & Mrs. P. Ozemoya, Mr. & Mrs. Tim Birisibe and Dr. & Mrs. E. B. Oyetola. We were all members of a unique family social club that served as a platform to unwind at the end of every month of the year. I still very much cherish the events at our monthly get-together, the fun, entertainment, social interaction and lively debates we had together.

Benin Welfare Association, Minna

To all members of the Benin Welfare Association in Minna, I say a big thank you for your confidence in me and for your support, understanding and prayers over these past years. I thank my long time friend and brother Engr. Nosa Ogbeide who brought me in close contact with the association. I urge you to stay united for the corporate interest of all ivbi Edo ne uzomo. *Oba mwa gha to O kpeere (Ise!).*

Colleagues at the University of Benin

After my administrative responsibility as the Deputy Vice-Chancellor (Academic), I spent my sabbatical leave at the Department of Soil Science, University of Benin. For this opportunity, I thank the then Vice-Chancellor, Prof. O. G. Oshodin. I am equally very grateful to the Dean, Faculty of Agriculture Prof. E. A. Ogbogodo, all other staff of the Faculty and the Department of Soil Science in particular for making my stay in Benin as comfortable as possible. My special thanks also goes to Dr. J. S. Oghe for graciously accommodating me in his office and for the friendship and understanding we shared together.

My Childhood Friends

To my childhood friends particularly, Osawaru Osemwota (now late), Idahosa Osomwota, Mike Longe *Esq.* (ACG, Nigeria Immigration Services), Momodu Yusuf (DIG (Rtd.), Nigeria Police Force). I say a big thank you all for the friendship and brotherliness we enjoyed together over the years even when distance separated us. I still remember with nostalgia the good old exciting days in the early 70's when we played inter-street football together at Lawani Street, Benin City.

My Later Year Friends

I am most grateful to Allah our creator for bringing me in close contact with these friends who are now deceased, early in my university days in the then Czechoslovakia: Dr. Yekini Eweka, Dr. Gaius Idemudia, Engr. John Olaye and Mr. Magbe Omoregie. They all impacted on me greatly during our student days in Europe. In fact, I consider them my elder brothers rather than friends. May Allah in His infinite mercy continue to grant their souls peaceful repose.

I acknowledge with immense gratitude the *camaraderie* and the encouragements and support I have enjoyed over the years from all my long time friends outside the FUT, Minna community. Prof. Linus Asuquo, Arc. O. Obieromah, Eng. Fidelis Ochili, Dr. Nelson Ifere, Dr. Abiodun Owolabi (Owoblo), Eng. B. A. Afolabi, Prof. M. G. Yisa , Mr. Williams Usigbe (Pa Willy), late Engr. Z. O. Ajani, Mr. James Ebuetse, Chief Remi Agbejule, Engr. Adisa (Adinqua), Mr. Tunde Okoturo, Steve Mbanugo, Mal. Garba Attahiru, CP Ernest Ibhadze (Rtd.) and late Dr. Ade Okogun stand out for mention. They are what we usually refer to as "A friend in need is a friend indeed", and I am indeed proud to have you all as my friends.

F.U.T, Minna Community

I wish to sincerely acknowledge members of my constituency Federal University of Technology, Minna who have been supportive since I joined the University in 1989.

My students, Student Union Government and other Associations on Campus

I wish to appreciate the executives of the SUG and other student associations on campus that worked with me during the course of my administrative responsibilities as Dean of Students' Affairs and as DVC (Academic) for their understanding and cooperation thus ensuring the maintenance of peace on campus.

In the same vein, I wish to thank all the students that have passed through my mentorship both undergraduate and postgraduate for their high sense of responsibility and for making me appreciate more my choice of the noble profession of a teacher.

The University Campus Radio (Search FM 92.3)

Let me also find a space here to appreciate the entire crew of Search FM (92.3) Campus Radio particularly the pioneering members that flagged off broadcast transmission in late 2005 using a locally constructed transmitter. I was then the Dean of Students' Affairs at the time and I guided the entire process from conception to reality. I still today consider the coming on-board of the No. 1 Campus Radio in Nigeria one of my greatest administrative achievements in FUT, Minna and for this, I give immense thanks to Kingsley Oguche (The current Studio Manager and the initiator of the project) for his doggedness, tenacity and drive that kept me constantly on my toes until the Station became functional and a broadcast license obtained from the Nigerian Broadcasting Corporation (NBC).

University Committees

I will like to appreciate all my colleagues and friends and other staff members that worked with me in my various administrative duties in the University. Their cooperation, total commitment, sincerity of purpose and dedication were instrumental to most of the successes achieved in the duties entrusted to me. Notable among them are Professors O. O. Morenikeji, E. E. Udensi (Field Marshall), O. K. Abubakre, S. Sadiku and A. T. Ijaiya. Others are Drs. J. J. Dukiya, A. S. Abdulrahman, T. A. Uthman, Abdulfatai Jimoh, Uno Uno, I. K. Olayemi, Ayo Aremu, I. A. Olatunji, Rotimi Kemiki, Arc. O. F. Adedayo, Bar. Shidali (now late), Mr. O.

Odepidan, Kehinde Lawal, Mayokun Okelola, Mal. M. Babjiya, Yusuf Shakirudeen, Mrs. A. S. A. Ndayako, R. N. Bello, Omolola Alhassan, Mairo Kanko, Funke Adeoye and Hadiza Garba.

Some of our Campus Elders

I have had the privilege of interacting and working closely with some of our elders on campus notably Professors S. A. Garba, G. D. Momoh, K. R. Adeboye and S. L. Lamai; and I am appreciative of some of the things I have learnt from them.

School of Agriculture and Agricultural Technology

My appreciation goes to all the staff of the School for the cordial relationships I had with them through the years in contributing my own quota to the development of the School . I am particularly grateful for the cooperation and support I received from all the past and present Deans of the School from Prof. E. A. Salako in the early 90s to the current Dean, Prof. R. J. Kolo. I must however acknowledge with thanks the special relationship I enjoyed, and the encouragements, guidance and advice I have benefited from Professors O. O. A. Fasanya and J. A. Oladiran over the years.

Department of Soil Science and Land Management

I sincerely wish to thank all the heads and other staff (academic, administrative and technical) of my Department for providing the enabling environment that made me stay focused to contribute to the academic and administrative development of the Department, the School and the University at large. Of note is my posthumous gratitude to Late Professor Izundu Fred Ike, the pioneer Head of Department who also facilitated the establishment of the Department with a solid foundation in 1989. He was a trailblazer for me being the only other academic staff with him then. May His gentle soul continue to rest in perfect peace (Ameen). The support and cooperation I enjoyed under the others: Professors M. I. S. Ezenwa, A. J. Odofin, A. Bala, and M. K. A. Adeboye also deserve my commendation. I am also equally appreciative of the friendship and long term relationship I have had with Chief I. C. Ogbonaya who was one of the pioneer staff of the Department but has just been recently appointed to head the Equipment Maintenance Centre of the University.

Vice-Chancellors and Principal Officers of the University

I thank the current Vice-Chancellor Prof. M. A. Akanji for his encouragement in making sure that I deliver this lecture today, and for the excellent and cherished relationship we have maintained since he took up the mantle of leadership in this University. I also commend him most sincerely for quickly stabilizing the ship of state after the initial turbulence that greeted his assumption of office here some few years ago and the efforts he has put to ensure the sustenance of the culture of Inaugural lectures in the University. Very special appreciation goes to the past Vice-Chancellors of the University, in particular are His Excellency, Professor J. O. Ndagi, who employed me without hesitation from Diaspora, Professor H. T. Sa'ad and Professor M. S. Audu who gave me the opportunity to serve at top administrative positions of Dean of Students' Affairs and Deputy Vice-Chancellor (Academic), respectively. Prof. Sa'ad assumed office in October 2002 as an accomplished, stern faced and no nonsense administrator. By sheer determination, relentless hardwork, commitment and tenacity of purpose, he among other achievements moved the University to its promised land in Gidan Kwano exactly two years after his assumption of office. I learnt the rudiments of University administration from him, for which I am immensely very appreciative. I am particularly grateful to my amiable and easy going Boss, Prof. M. S. Audu, who is aptly described as an embodiment of humility, for the confidence he reposed in me and for providing the enabling environment and "behind the scene" support for me to succeed in my various administrative responsibilities as DVC (Academic). Prof. Audu built on the achievements of his predecessor and brought massive developments to the Main Campus of the University.

I am grateful for the support and cooperation of all other principal officers of the University that I had the privilege of working closely with in management. Notable among these are: Professors T. Z. Adama, M. A. T. Suleiman and A. Bala, Alh. Datti Usman, Mrs. V. N. Kolo and Mr. M. A. Bello.

My Very Special Colleagues

I wish to distinctively appreciate three of my colleagues whose relationships transcends academic to private life. They are 1. Professor Abdullahi Bala the current DVC (Academic) who has been my research partner for over 24 years addressing issues of BNF and legume-rhizobium symbioses. Indeed we've come a long way together sharing office accommodation and so many other things in common. 2. Dr. Yahaya Ahmed Iyaka, the current HOD (Chemistry) was my Deputy during my tenure as the Dean, Students' Affairs and he played a key role in the successes attained in our dealings and negotiations with the ever restless Students Union executives. 3. Dr. Johnson Olusegun Oyero, the current HOD (WAFT) is one of my closest confidants and has worked with me in several committees in the University. They are all considered my mentees and younger brothers within the academic cycle. Their commitment to the service of the University, dedication to duties assigned to them, their encouragement, honesty, friendship and loyalty in the course of my academic and administrative pursuits in the University are unquestionable. I am deeply appreciative and I am proud to be associated with them.

Alhaji Alhassan M. Bahago

I will forever be grateful to Alh. Alhassan Bahago, the then Ag. Establishment Secretary for extending love and friendship to me in my initial period of need and for helping me to weather the storm of frustration when I first assumed duty here in Minna. He provided me with a comfortable 3-bedroom accommodation to let after almost one year of frustrating search and an uncomfortable residency in a hotel in town. In fact, the story is too long to recount here, but I pray the Almighty Allah to bless him with good health and long life.

My Nuclear and Extended Family

Words alone are not enough to express my gratitude to my friend and brother Dr. Babatunde Akinremi (Wing Commander (Rtd.), Nigeria Air Force) for his steadfastness, support and encouragement to me for over 25 years of our association. You are an extended part of my family as our relationship sticks closer than that of my blood brothers. May God in His infinite mercy continue to shower His inestimable blessings on you.

My sincere appreciation and gratitude goes to my late Uncle Dr. Lasisi Osunde for his invaluable assistance that facilitated my scholarship to the then Czechoslovak republic for my high School and University education. May his gentle soul continue to rest in perfect peace.

Special thanks goes to all my brothers, sisters, aunties, uncles, nephews, cousins and nieces for their prayers. I am immensely grateful to my elder sister Alhaja Toyin Osunde for her consistent moral support, encouragements and love and for always rising up to provide the needed motherly support whenever I am confronted with challenges. My Allah continues to bless and guide you. I am also thankful and appreciative of my Uncle Mr. Yusuf Suleiman, who has conveniently stepped into the role of a father to us since the demise of Papa. May God continue to endow you with good health (Ameen).

For my Children Nosa, Ameze, Stephen, Ehis and Wusi, I say thank you all for being sources of blessing to me rather than distraction. To all my grandchildren, you may not understand what is going on today but in the nearest future you will get to know that Grandpa loves you all so much and appreciates you.

For you my darling wife "Zinni", you are an epitome of brain, beauty and humility. I appreciate your love, support, selflessness, commitment and understanding in tolerating the "must be conflict" between academic and family life if one must attain the desired height in academics. You have always been a source of encouragement and a strong pillar of human support to me. You were the motivator that propelled me to action which indeed played a very big role in making this day a reality. I say a big thank you with my usual kiss for patiently bearing with my excesses and inadequacies from the very first time we met as young university students some 40 years ago in Czechoslovakia. May Allah reward you abundantly.

My Parents

I will forever remain grateful to my parents who sacrificed so much for my education and ensured that I had a decent, disciplined, humble, and God-fearing upbringing. They ensured I never suffered any deprivation as a child and they gave me the best within the limits of their resources. To my Father of blessed memory who never spared the rod and instilled strict discipline in us. I say a very big thank you. May Allah grant your soul Aljanat Firdaus. To my aged and ever active mother, I thank you for continuously enveloping me with love and affection and for praying for me non-stop. May Allah (SWT) continue to bless you with long life and good health, so that you can continue to enjoy the fruits of your labour.

The Almighty Creator

I am immensely grateful to Almighty Allah, the most high, the compassionate, the most merciful for sustaining my life all this while and for giving me good health to witness this historic occasion. I cannot thank Him enough for His love and faithfulness.

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Profile of the Inaugural Lecturer

Professor Akim Osarhiemen Osunde is an indigene of Oredo Local Government Area of Edo State, Nigeria. He was born on June 12, 1958 in Ibadan, Oyo State to Alhaji Dirisu Adams Osunde and Alhaja Bilikisu Osunde. He attended St. Patrick's Primary School, Ibadan, Nigeria and Holy Cross II Primary School, Benin City, Nigeria for his primary education; and Edo College, Benin-City, Nigeria and Gymnazium Metodova Ulica, Bratislava in Czechoslovakia for his secondary education. Between 1975 and 1987, Professor Osunde was at the University of Agriculture, Nitra, Czechoslovakia and the University of Agriculture and Forestry, Vienna, Austria where he bagged his M.Sc. Agronomy (with distinction) and PhD Agronomy (Soil Fertility), respectively.

Professor Osunde was a postdoctoral research fellow with the joint FAO/IAEA Division of the International Atomic Energy Agency, Vienna, Austria from 1987 to 1988, investigating the application of ^{15}N and ^{32}P isotopes to soil fertility and plant nutrition studies.

He joined the services of the Federal University of Technology, Minna on January 9th, 1989 as Lecturer I and rose to the rank of Professor of Soil Science on October 1, 2006.

A distinguished academic, Prof. Osunde who is cited in the 'Who Is Who In Nigeria' (Nigerian International Biographical Centre, Lagos, 2002) has won many awards and honours which include: Best Graduating Student (distinction) Award at the University of Agriculture, Nitra, Czechoslovakia in 1980.

Professor Osunde has since 1990 served the University as a member of several Council and Senate committees such as University Staff School Management Board (1990 - 2005), University Health Services Management Board (1994 - 2005), University Board of Research (1996 - 2001), University

Ceremonies Committee (1998 - 2008), PostGraduate School Board (2001 - 2005) and many others.

He has also held several important positions of responsibility in the University which include among others: Chairman, University Transport Committee (1993 - 2000), Head of Department of Soil Science (1998 - 2002), Chairman, University Sports Committee (1998 - 2004), Chairman, University Certificate Screening Committee (2000 - 2002), Dean, Students' Affairs (2005 - 2008), Chairman, Students' Union Independent Electoral Committee (2008 - 2009), Chairman, Anti-Corruption and Transparency Monitoring Unit (2008 - 2009) and Deputy Vice Chancellor (Academic) (2009 - 2013).

Outside the University community, Professor Osunde is a member of some non-governmental and community based associations and has served as the Coordinator, African Association for Biological Nitrogen Fixation for the (Anglophone) West African sub-region (2002 - 2005), Chairman, Nigerian Universities Games Association (NUGA) Chess Committee (2001 - 2004) and was also a member of the NUGA Facility Inspection Team for the 18th and 19th NUGA Games. He is currently the Patron to the Benin Welfare Association (a socio-cultural Association) in Minna.

As an academic, Professor Osunde has over the years been contributing to the production of high level manpower in Agriculture, particularly in Agronomy and Soil Science, through teaching and project/thesis supervision. To date, he has supervised/co-supervised over 50 undergraduate, 28 Master's and 12 Doctoral students. He has served as external examiner and professorial assessor for various Universities; and has reviewed manuscripts for many local and international journals.

As a researcher, Professor Osunde has been actively involved in providing much needed research background for the local use of

BNF as a low-input technology for the management of degraded soils, enhancing food production by Nigerian resource-poor farmers and improving their livelihood. He has published over 70 original research papers in refereed journals, Book chapters and conference proceedings.

He is a member and a Fellow of the Soil Science Society of Nigeria (SSSN). He belongs also to several other professional bodies among which is the International Union of Soil Science (IUSS), African Association for Biological Nitrogen Fixation (AABNF), African Network for Soil Biology and Fertility (AFNET) and African Network for the internationalization of Education (ANIE).

Professor Osunde has attended several professional and management courses within and outside the country, and he is widely travelled across Africa, Europe, Asia and the United States of America (USA). His hobbies include playing tennis, relaxing with melodious music and viewing sports and current affairs programme on TV.

Professor Osunde is married to Engr. Prof. Zinash Osunde the current Chairperson of the University Seminar and Colloquium Committee, and they are blessed with children and grandchildren.

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