Preambles

Mr. Vice-Chancellor Sir, the Principal Officers of the University, distinguished guests, ladies and gentlemen. It is with a grateful heart that I am standing before you today to present the 419th inaugural lecture titled "The Nexus of physics, soil architecture, environmental sustainability and food security". This will make the eighth inaugural lecture to be delivered from the Department of Soil Science and Land Resources Management. Many have asked the question on why I accepted to present at this time considering the unique series number. My answer to them is that before decree 419 which is about acquiring wealth by false pretense, God has provided His own Biblical 4:19 to counter it. The Holy Bible in the book of Philippians chapter 4 verse 19 says: *My God shall supply all your need according to His riches in glory by Christ Jesus*. True wealth comes only from God Almighty.

Introduction

Mr. Vice Chancellor Sir, permit me to dwell a little on my background. I was born at Arigidi-Akoko in Ondo State to Mr. Simeon Abegunde Oyedele and Chief (Mrs) Hannah Idowu Oyedele, both of blessed memory. Both of them were illiterates. My father was farmer while my mother worked as a cook in the only secondary school in my town then. My mother especially was passionate about education. I started my education at Saint Stephen United Primary School, Arigidi in January 1967. I almost never completed school, as I dropped out of school twice. First, I voluntarily dropped out of school when I was in primary two because I thought my classroom teacher, who was also the school headmaster was unnecessarily harsh on me because of my fingernails. I did not realize then that my fingernails grew faster than those of other pupils in the class. When we all trimmed our fingernails on Monday, mine would have grown by Friday and it was always difficult to convince him that I was not just being disobedient. I however found my way back to school after spending the rest of the remaining two terms going to farm with my father. Luckily, the primary two class was overpopulated and I was moved to join my former classmates who were already in primary three and now avoided the teacher who was still teaching the class. The second time was when I was in year one of Modern School. This was because we were more engaged in farming than studying. However, a day I cannot forget was Saturday March 3, 1973 which was also my birthday, when my mother gave me the money for secondary school entrance examination form through which I secured admission to Akoko Anglican Grammar School, Arigidi in September 1973.

My first encounter with physics in secondary school was an interesting one. It was in Form Three and our teacher was a Youth Corp member who made the subject very uninteresting. Even though I was doing well in other science subjects, due to lack of good counsellors, I decided to drop physics in Form 4. I later discovered this to be a big mistake when it was time to apply for university admission as I realized that I needed physics for my course preferences of Engineering, Pharmacy, except Agriculture. I applied for Soil Science at University of Ife as my first choice and for Agronomy at the University of Ibadan as my second-choice course. However, despite my initial school challenges, it is to the glory of God that I still entered the university at the age of 17. On getting to the university, I realized I could not run away from physics. I registered for and failed the first physics course which was PHY 105 and that was the only course I ever failed in the university.

Coming face to face again with physics in my part 3 was another challenge. However, the lecturer - Prof. Patrick Oladipo Aina taught the course in a highly practical and engaging way. Even though the open-book tests were challenging, they deepened my interest and made me appreciate the subject even more and it opened my eyes to the opportunities within the field. It was during that period that I made up my mind to specialize in soil physics, despite having a weak background in physics. I returned for my master's programme immediately after my Youth Service in 1984 and I completed my M.Phil. and Ph.D. degrees respectively in 1988 and 1997 under the supervision of Prof. P.O. Aina. I was employed as an Assistant Lecturer in 1990 and rose through the ranks to become a professor in 2008.

I have always experienced the hand of God in my life. On completion of my M.Phil. degree, I got an offer of employment in Lake Chad Research Institute, Maiduguri and was to be stationed in New Marte (close to Cameroun border). However, as God would have it, my employment letter sent through the DHL was wrongly addressed. There were no email or mobile phones then through which they could contact me. By the time I got the information through someone in the institute, there was already an opening in my department for the position of Soil Physicist. In addition, a few months after my employment, I met the external examiner to my M.Phil. oral, late Prof. Babalola who said he had been trying to contact me to take up an offer under him at the University of Ibadan and I informed him I was already employed at OAU.

Soil architecture also called soil structure refers to the spatial arrangement of soil particles and the pore spaces between them. Young and Crawford (2004) describe soil architecture as a dynamic self-organising system influenced by biological activity. The building blocks are the soil primary particles of sand, silt and clay.

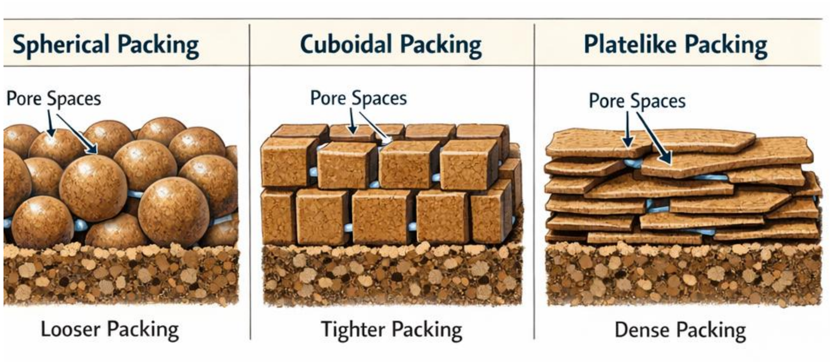


Figure 1: Influence of soil particle packing on soil pore configuration

These primary (raw) materials are provided by geological processes such as the weathering of rocks and minerals. These materials alone without modification will result in structureless mass as it obtains in the moon and planet Mars. On Earth, these materials are bound together through various chemical and biological processes to form soil aggregates. **Soil architects** are the biological organisms that physically build and maintain the soil's structure. These include the primary architects such as earthworms which are also referred to as ecosystem engineers because they redesign the soil environment. Earthworms ingest soil and organic matter and excrete casts, which are enriched with nutrients and coated with gluelike extracellular polysaccharides that makes the aggregates stable and water resistant (Oyedele, Schjonning and Amusan, 2006). Earthworms also create macro-pores within the soil as they move. These pores serve as highways for water and air within the soil. In addition, they are involved in mixing (bioturbation) soil with remains of plant and animal debris. The **micro-architects** are the soil fungi and bacteria. The fungi hyphae act as physical net, wrapping around soil particles to bind them into micro-aggregates. They also produce glomalin that glue soil particles together. Soil bacteria secrete sticky polysaccharides that act as biological cement in binding soil particles together. Plant roots provide the structural support, while their exudates provide substrate to bacteria and fungi that are engaged in the process of soil building. The tunnels left behind by dead plant roots serve as channels for air, water and transport of nutrients. However, when the soil is overused or polluted, these “architects” are killed, the structures collapse leading to inability of the soil to sustain the ecosystem and the soil technically dies. The Yoruba proverb says: *Erin ku magudu fije, efon ku magudu fije, madugu waku ko re ni ti o je ohun* meaning the elephant died and was devoured by magudu, the buffalo died and was similarly devoured by magudu, but at the death of magudu there was no one to eat it. Soil is the magudu being referred to here.

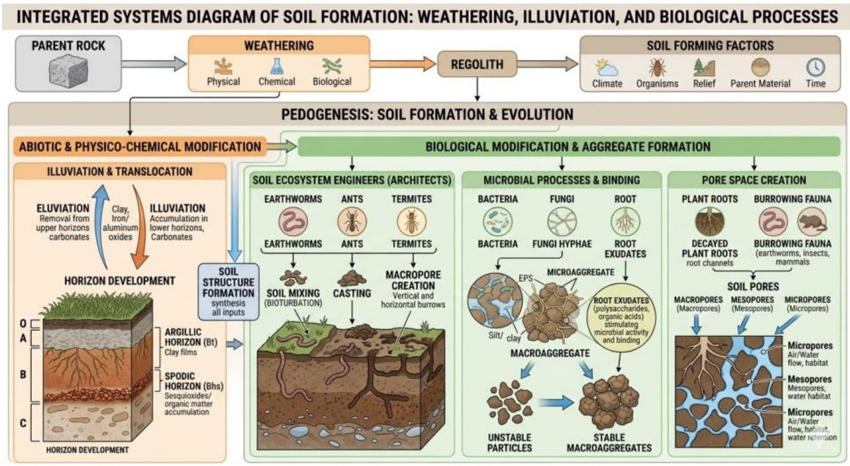


Figure 2: Schematic diagram on interlink among the soil forming processes

The link between physics and soil architecture

Mr. Vice-Chancellor Sir, the soil is not just a collection of particles, but a complex, organized porous medium containing myriads of microbial lives. While soil architecture defines the arrangement of soil particles and the pore space between them, physics explains the implications of these arrangements on soil processes such as air and solute transportation, the response of soil to stress and strain and the impacts of soil structural configuration on the bearing capacity of soil among others. To do this, theoretical models in physics are used to quantify soil physical state and processes occurring in soil.

For example, by the 1830s, Henry Darcy, a French engineer, was tasked with designing a system to bring clean water to the city of Dijon in France. To achieve the goal of bringing water through a 12 km aqueduct to the city, he realized he needed to understand exactly how water moved through sand filters used to purify it. Darcy conducted a series of experiments by pouring water through vertical pipes filled with sand. He measured the pressure of the water and the velocity of flow at the point of discharge. He observed a consistent pattern that regardless of how much sand he used, the velocity of the water flowing through the sand column was directly proportional to the pressure drop and inversely proportional to the distance the water travelled. He however noted that every type of sand or soil had its own “personality” which he termed the hydraulic conductivity (K). The result is the Darcy’s Law which is now universally useful in irrigation and oil exploration (Darcy, 1856). It is mathematically defined as:

$\frac{Q}{A} = q = K\delta h/\delta l$ 1

Where Q is the volumetric water discharge, δh is the pressure drop across the length (l) of the pipe. A is the cross-sectional area of the conducting pipe, while q is the flux or flow velocity.

$K = \frac{n}{\tau^2}$ 2

Where n represents the soil porosity and the τ represents the tortuosity of soil pores which is determined by the soil architecture. Thus, the physical boundary conditions of the physical processes taking place in soil are defined by soil architecture.

However, because of the complexity of the soil, this equation is not able to comprehensively describe fluid flow in soil especially under unsaturated soil conditions when the soil pores are partially filled with water with some spaces occupied by air. As the soil dries, pore connections shrink and K drops exponentially with soil water content, the soil architecture now begins to exert greater influence on soil water flow under unsaturated condition. The pressure potential in saturated flow is therefore replaced by matric potential (negative pressure) and so the equation becomes:

$q = -k(\theta)(\frac{\delta(h_m+z)}{\delta z})$ (Richards, 1931) 3

Where h_m is the matric head

In addition, Vogel et al. (2010) using x-ray micro-tomography demonstrated how a minute change in soil architecture (soil macropore) can increase water flow by several magnitudes in a phenomenon known as preferential flow. This implies that a contaminant in soil can be transported much faster than the predicted average flow rate in larger pores with potential to impair any water body in its flow pathway.

Dexter (2004) introduced the S theory which is a framework connecting soil physical arrangements (soil architecture) to its quality though the soil water retention curve. Thus, by monitoring the soil retention curve, land managers and scientists can make informed decisions about soil management. Moldrop et al. (2001) developed a model relating gas diffusivity and soil pore configuration for repacked (disturbed) soil expressed as

$$\frac{D_p}{D_o} = \epsilon^{2.5}/\phi \qquad \text{.......... 4}$$

Where Dp is the gas diffusion coefficient in soil, Do is the gas diffusion in free air, while ϵ is air-filled porosity, and phi is total soil porosity. However, for undisturbed soil, the equation was adjusted to take into care of the pore complexity with the inclusion of b, which is the pore-size distribution index from the Campbell model thus

$$\frac{D_p}{D_o} = \epsilon^2 \left(\frac{\epsilon}{\phi}\right)^{3/b} \qquad \text{.......... 5}$$

These two models further demonstrate the extent to which the configuration of the soil pores and shapes of soil aggregates influence the ability of the soil to transmit air and water.

In soil mechanics, which deals with soil strength and rheology, the ability of the soil to resist deformation depends on soil architecture. Mechanical strength of structured soils with comparable internal parameters depends on aggregation, actual and maximum pre-drying, and composition and arrangement of the pore system. For comparable grain size distribution and pore water pressure, soil strength increases with aggregation (i.e., coherent < prismatic < blocky < crumbly, platy < subangular blocky) (Horn and Baumgartl, 2002).

Soil degradation and civilization

The history books often tell us about the great early civilizations and how most of them declined and lost their relevance because they were conquered by later stronger civilizations. What most history books do not mention is that the decline of most of these early civilizations started from the poor management of their soils. These societies were fundamentally tied to the health of their soil. The Sumerian civilization for example intensified irrigation in the plains of the rivers Tigris and Euphrates leading to soil salinization which culminated in crop yield decline forcing farmers to switch from wheat to salt-resistant crops like barley and eventually leading to loss of food security (Abdullah, et al., 2020). Similarly, the Maya kingdom collapsed in 9th to 10th century B.C. was attributed to indiscriminate deforestation leading to soil erosion, poor crop yield and eventually loss of food security (Beach et al., 2006). A country that does not manage its soil properly cannot be food secure. Meanwhile, a non-food secure nation cannot withstand external aggression.

Soil and national security

Mr. Vice-Chancellor Sir, Nigeria is currently engaged in fierce battle with insurgents, most of whom operate in uncharted territories of the country. Soil information system is essential and may contribute to our efforts in defeating them. Good information on the soil physical properties such as the soil trafficability, Atterberg limits, cone index, etc., by the military may determine whether a nation winning or losing a battle. The strength of soil is measured as the external pressure the soil can withstand before it yields or before its structure collapses. The load-bearing capacity of a soil is dependent on its strength and moisture contents. This has implications not only for infrastructure like roads, rail lines and buildings that are on the soil, but it also has military implications. For example, the early campaign of Russian army in Ukraine was significantly slowed down by the Ukrainian soils. The deep soils of Ukraine (Chernozems) are some of the best soils for agriculture, but when wet they are not trafficable and could not bear the weight of the heavy Russian tanks, forcing them to move in convoy on paved roads. Thus, their tanks and supply lines became very predictable and vulnerable to attack by Ukrainian drones. In Nigeria, we do not have a detailed information on the properties of our soil across different geographical locations. The few studies done have focused on soil fertility but very few on soil physical properties such as soil strength. A detailed understanding of the mechanical properties of Nigerian soils (such the cone index, trafficability, Atterberg limits, etc.) will be useful for the military in determining the suitability of different vehicles on different terrains in their quest for national security.

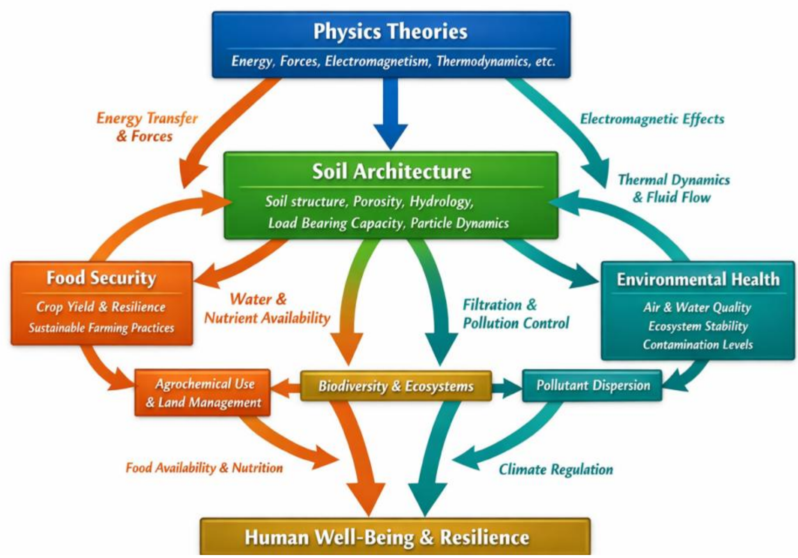


Figure 3: A conceptual sketch of the interlinkages of physics with soil architecture, food security and environmental health.

My contributions

Mr. Vice-Chancellor Sir, the focus of my studies has been on identifying factors that predisposes soil to degradation, how to prevent this and on developing methods to improve soil physical properties and make them resilient to degradation. In the course of these studies, I have collaborated with scientist from diverse disciplines ranging from physics, chemistry, sociology, food science, crop science, agricultural economics, agricultural engineering; within and outside the country.

Soil erosion studies

Soil erosion is an energy process. The kinetic energy possessed by falling rainfall impacting on soil surface and detaching soil particles is the precursor for soil erosion. Falling raindrops, due to their height of fall attain their terminal velocities before impacting the soil surface. The kinetic energy of the raindrops depends on their mass and their terminal velocity at impact. When rainfall intensity exceeds infiltration rate, overland flow is generated and the flowing water begins to acquire sufficient carrying capacities to transport the detached soil particles. We studied the interaction between the rainfall of different intensities and overland flow in causing erosion, with the use of a laboratory rainfall simulator in combination with an overland flow generator (Oyedele and Aina, 1989) (Plate 1). Overland flow was found to constitute a significant erosion on some of the soils causing as much as 16% of the soil loss, while raindrop impacts (rainsplash transportation) alone removed about 20% and this increased with increase in rainfall intensity. Soil erodibility was correlated to some measured soil properties (Table 2). However, the combination of rainfall and overland flow had additive effects in soil removal by erosion. We found out that although overland flow was a minor component of erosion on the three soils studies, it was a significant erosive agent on Iwo soil and may be considered in the evaluation of erodibility of weakly-structured soils studied. An empirical predictive equation relating soil erodibility index to some easily measured soil properties was developed and given as:

$$K_c = 3.2x10^{-3} + 1.52M - 1.99C + 0.69Se + 6.34OM \ldots\ldots\ldots 6$$

Where K_c = soil erodibility index, M = product of fine sand + silt fractions, and medium sand + coarse sand fractions; Se = extractable Fe and Al; OM = soil organic matter; and C= percent clay.

Plate 1: A setup showing (a) overland flow device with soil microplot; and (b) rainfall simulator and runoff collector

Table 1: Correlation coefficient of measured soil erodibility with soil properties

Soil Properties	Correlation coefficient (r)
Soil Fine particle fraction (2 – 20 µm)	0.74^{*}
Cation exchange capacity (CEC)	-0.71^{*}
% Clay	-0.69^{*}
% extractable Fe + Al oxides	-0.66^{*}
% Coarse sand	$0.52^{n.s}$
% Organic matter	-0.61^{*}
Bulk density	$0.40^{n.s}$

pH	$0.19^{n.s}$

Table 2: Influence of rainfall, overland flow and their interactions on soil loss (kg m^{-2} cm^{-1} water applied)

	Overland flow rate (cm hr^{1})								
	0			33			66		
Soil type	Rainfall Intensity (cm hr^{-1})								
	0	12.5	15.7	0	12.5	15.7	0	12.5	15.7
Iwo	0	0.024	0.173	0.002	0.042	0.064	0.087	0.095	0.157
Itagunmodi	0	0.019	0.073	0	0.018	0.050	0.031	0.051	0.062
Ondo	0	0.038	0.110	0.002	0.016	0.048	0.021	0.051	0.078
Okemesi	0	0.002	0.005	0	0.001	0.001	0	0.001	0.002

Achieving a sustained management of eroded soils requires information on the magnitude of yield reduction associated with soil loss and the changes in the physical and chemical soil properties resulting from such under the low technology-input agriculture such as Nigeria. Applying geostatistical tools and factor analyses we also investigated the impact of soil erosion on soil maize productivity across an eroded landscape over a period of three years. Three erosion classes were identified with depth of soil surface ranging from 9 cm to 20 cm at the lower landscape position. Maize grain yields were consistently highest in the deeper Lower landscape positions ranging from 2.8 t ha^{-1} to 3.5 t ha^{-1} (Fig 4).

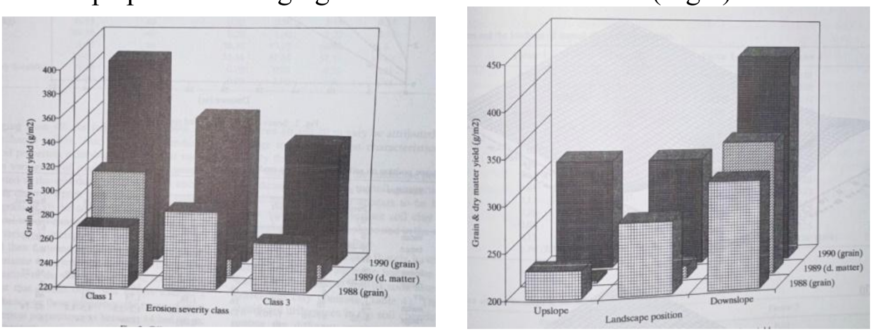


Fig 4: Effects of (a) erosion class and (b) landscape position on maize grain yield (g m^{-2}) on

We quantified the relationships between the depth of soil removal and crop performance in order to be able to predict the impact of erosion on crop yield. Factor analysis was used to disaggregate the contributions of several factors to soil productivity resulting from the process of erosion (Oyedele and Aina, 1998, Oyedele, 1988). Based on factor analysis, the topsoil properties were reduced to 5 principal factors. An empirical relationship was obtained when the maize yield was regressed against the identified factors in the 1989 growing season with the values in bracket representing the percentage contributions of each independent variable to the explanation of the variations in the dependent variable:

$$Y = 0.06F1 - 0.26F2 - 0.08F3 + 0.15F4 - 0.31F5 - 0.02 \quad (R^2 = 0.76^{***}) \quad ....7$$

(8%) (39%) (9%) (11%) (43%)

Water erosion generally results in the removal of the nutrient-rich topsoil, thereby exposing nutrient-poor and poorly structured subsurface soil. In a study to quantify the changes in soil productivity with the depth of topsoil removal in an Iwo soil type in a simulated experiment, topsoil was incrementally removed to depths of 5, 10, 15 and 20 cm with plots without soil removal serving as control (Oyedele and Aina, 2006). We reported a decrease in soil pH with increased depth of soil removal while it was the soil bulk density significantly increased from 1.38 g cm^{-3} to 1.55 gem^{-3} at 20 cm depth of topsoil removal. In the study, soil organic carbon, bulk density, soil shear strength, field moisture capacity, pH and exchangeable magnesium were significantly positively correlated with maize yield. Maize yield was found to reduce exponentially with increased depth of topsoil removal ($r^2 = 0.99$, $P<0.01$) with an average of 55% loss when just 5 cm of topsoil was removed, signifying the potential of soil erosion to cause appreciable crop yield reduction with just the removal of a few layers of the nutrient-rich topsoil confirming an earlier study by (Lal et al., 1994).

Soil and climate change

Soil is the largest terrestrial carbon pool and contains more carbon than in the atmosphere and all the vegetation combined. It holds approximately 1,500 to 2,400 Gt of organic carbon in the first meter alone. By comparison, the atmosphere holds about 800 Gt and terrestrial vegetation about 450 to 650 Gt (Lal, 2004). Soil serves as a sink for the sequestration of organic carbon and thus a major consideration in climate change remediation. The interaction between soil and climate involves coupled cycles. For example, as the climate warms, the rate of decomposition of organic matter increases, reducing the amount of carbon sequestered in soil. On the other hand, higher atmospheric CO_2 increases plant growth and thus more carbon input into the soil. Oyedele, Awotoye and Popoola (2009) in a study of the carbon and nitrogen fractions in soil aggregate sizes under different land use types in an Ultisol in Nigeria showed that land use decisions strongly determine soil carbon storage. In the study, the consistently higher C and N in the fine particle size fractions indicated lower decomposition rates of the organic matter associated with clay and fine silt size particles and aggregates which also have low C:N ratio indicating that these aggregate size fractions offer protection to soil organic matter. Therefore, cultivation practices that encourage the higher contents of these fractions can be used to mitigate the impact of climate change.

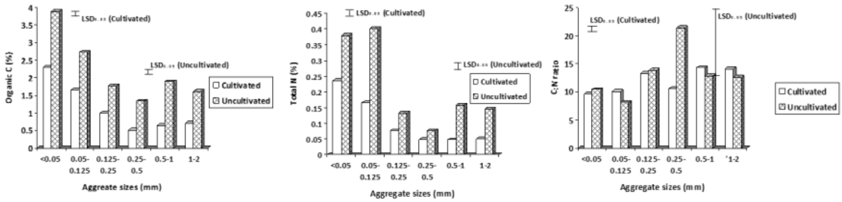
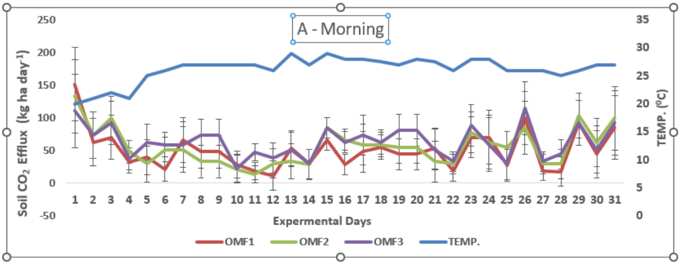
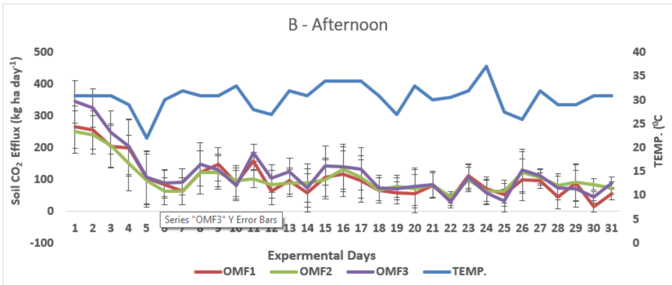


Figure 5: Topsoil (0-15 cm) distribution of (a) organic C, (b) total N and (c) C:N in aggregate size fractions as influenced by cultivation

In a study that investigated the influence of land use on CO_2 evolution from a soil using the static chamber approach, Oyedele and Tijani (2010) reported that CO_2 from the was significantly influenced by both soil water content and soil temperature. We also reported an annual CO_2 emission of between 14 and 18 t ha^{-1} from the soil and concluded that measures that reduces soil's temperature, such as mulching and shading or cover crops should be encouraged to mitigate against soil CO_2 emission. Tijani, Okunkenu, Afolabi, Akinde and Oyedele (2024) monitored CO_2 emission at frequent intervals and equally reported CO_2 emission from the soil reaching its peak at 12 noon, coinciding with the period of maximum daily temperature (Figure 6). Organo-mineral fertilizer at a moderate rate of 40 kg ha^{-1} urea + 2.5 t ha^{-1} organic manure rate was found to comparatively reduce CO_2 emission to a minimum.





A – morning sampling; B – afternoon sampling; OMF1 – Control, OMF2 – organomineral fertilizer at 40 kg Urea-N/ha + 2.5 ton/ha OF, OMF3 – organomineral fertilizer at 40 kg Urea-N/ha + 5 ton/ha OF

Figure 6 (a & b): Effects of varied rate of organomineral fertilizer on soil CO2 efflux among the treatments at sub-daily time scale.

Organic matter and soil architecture.

Soil aggregates are the building blocks of soil. The type and the strength of soil aggregates essentially determine the ability of the soil to sustain crop production and sustain the environment. Tsidall and Oades (1989) hypothesized the hierarchical nature of soil aggregates. The theory suggested the electrochemical forces and soil minerals serve as the binding agent at the microaggregates level, while organic matter is the dominant binding agents at the macro-aggregate level. The organic materials include the decomposed residues of plant and animals, the bacteria and hyphae of fungi and the extra-cellular polysaccharides and mucilage that are byproducts of microbial decomposition. Oyedele, et al. (1999) studied the influence of organic matter incorporation on the aggregation of soils of Nigeria as affected by soil disturbance. The study examined how the addition of plant materials affects the formation and stability of soil aggregates. We observed that incorporated plant materials contributed to the pool of light fraction organic matter (LFOM) in the soil, which were later broken down by soil microbes to increase the soil contents of heavy fraction polysaccharides (HFPS) that were attached to heavy fraction soil minerals with density greater than 1.7 g cm^{-3}. This study confirmed the hierarchical aggregation model. The study further demonstrated that fresh organic matter stimulated microbiological activity leading to the production of extracellular polysaccharides and fungal exudates that bound soil particles together and led to significantly higher soil aggregate stability as measured by higher soil mean weight diameter (Tables 3 and 4). The study identified tillage as one of the drivers of soil structural decline in Nigerian agricultural soils and that this decline can be mitigated or even reversed by strategic incorporation of crop residues especially when combined with reduced tillage.

Table 3: Effects of organic matter incorporation and soil disturbance on soil properties at the end of 41 days incubation (Oyedele et al., 199)

Soil parameter	Plant material treatment				Soil disturbance treatment		
	No plant material	Barley straw	Green ryegrass	$LSD_{0.05}$	Undisturbed	Disturbed	$LSD_{0.05}$
Light fraction organic matter (g kg^{-1})	5.63	8.03	6.70	1.32	6.88	6.70	n.s.
Heavy fraction polysaccharides (g Mg^{-1})	5.44	5.34	5.50	n.s.	5.46	5.39	n.s.
Dispersible clay (g g^{-1})	0.534	0.399	0.327	0.077	0.378	0.462	0.063
Water stable aggregates (g g^{-1})	0.424	0.463	0.461	0.015	0.465	0.434	0.012
Pores < 10 μm^a (m^3 m^{-3})	0.189	0.191	0.191	n.s.	0.186	0.194	0.004
Porosity[b] (m^3 m^{-3})	0.500	0.535	0.526	0.010	0.527	0.514	0.009
Pores > 10 μm^c (m^3 m^{-3})	0.311	0.344	0.335	0.012	0.341	0.320	0.010
Saturated hydraulic conductivity[d] (ms^{-1} x 10^{-5})	8.7	10.8	10.3	1.13[e]	11.0	8.9	1.11[e]

No significant interactions between treatments were found
[a]Water retained at -300 hPa matric potential
[b]Water retained at saturation.
[c]Difference between water retained at saturation and at -300 hPa matric potential
[d]Geometric mean
[e]Least significant quotient

Table 4: Soil type differences for a number of parameters as determined at the end of the incubation period (day 41)

	Soil types		
	Iwo	Itagunmodi	Owode

Light fraction organic matter (g kg^{-1})	7.01	6.13	6.70
Heavy fraction polysaccharides (g Mg^{-1})	6.19	5.34	5.50
Dispersible clay (g g^{-1})	0.263	0.399	0.327
Water stable aggregates (g g^{-1})	0.495	0.463	0.461
Pores < 10 µm^a (m^3 m^{-3})	0.219	0.191	0.191
Porosity^b (m^3 m^{-3})	0.548	0.535	0.526
Pores > 10 µm^c (m^3 m^{-3})	0.329	0.344	0.335
Saturated hydraulic conductivity^d (ms^{-1} x 10^{-5})	10.1	10.8	10.3

[a]Water retained at -300 hPa matric potential
[b]Water retained at saturation.
[c]Difference between water retained at saturation and at -300 hPa matric potential
[d]Geometric mean
[e]Least significant quotient

Oyedele and Pini (2009) used the distribution of soil organic carbon in different soil aggregate size fractions to confirm the hierarchical soil aggregation theory and also to identify the soil aggregate fractions that protect soil organic carbon from being mineralized using a Nigerian Alfisol and an Ultisol. The study provided strong evidence for the hierarchical model of soil aggregation in Tropical soils. It shows that the macro-aggregates were held together by the labile (younger) carbon, while the micro-aggregates are held together by the older more humified carbon and mineral bonds. Thus, when these soils are tilled, the macro-aggregates break first releasing the labile carbon which oxidises and releases CO_2 to the atmosphere. The study demonstrates that to understand if a soil is truly sequestering carbon on a long term, one must look at the carbon stored within the micro-aggregates and the clay-size fractions, as this represents the carbon that is physically and chemically protected from decomposition.

Furthermore, Akinde, Oyedele, Tijani and Ibitoye (2020) evaluated the impact of six distinct land use types on the distribution of soil organic matter fractions. The study was conducted under seven different land use types in Ile Ife. They demonstrated that soil micro-aggregates contained more stable carbon while the unstable fractions were more in the macro-aggregates (Table 5). It was concluded that forest-like agroecological systems promoted the formation of aggregate fractions that physically protect soil organic matter from rapid oxidation. It confirmed that land use conversion from natural forest to arable farming drastically reduces the POM fraction, which is the engine of soil fertility. In a study to evaluate the contribution of ecosystem engineers to soil architecture, Oyedele, Amusan and Schjonning (2006) compared the changes in soil properties in earthworm casts and native soils under three agricultural systems (secondary forest, cacao plantation and arable fallow). It was observed from the study that earthworms' casts were more highly enriched in plant nutrients by ratios of 1.9 to 2.6 compared to the native soils. This was similarly observed by other authors (Fonte and Six, 2010; and Lubbers et al. 2013). The earthworm casts were physically more stable than the parent soil while the quality of the casts however also depended on the land use. This shows that the quality of available surface litters dictated the quality of the casts formed. It was concluded that earthworms act as biological fertilizers by mining organic matter and minerals, concentrating them into a form that is more available to plants. Their activity is a primary mechanism for restoring soil structure and porosity. Farm practices that protect earthworm populations by avoiding heavy pesticides use and encouraging leaving plant residue on the soil surface is therefore recommended to maintain soil health.

Table 5: Organic matter fractions and stable aggregates of earthworm casts compared with the parent soil

Soil horizon	Organic matter				Soil stability indices	
	SOM gkg^{-1})	LFOM (gkg^{-1})	LFOM/SOM (%)	HFPS (mg kg^{-1})	DC (g clay kg^{-1})	WSA g clay kg^{-1} soil)
Cast	52.12 [a]	5.2 [b]	9.98 [b]	92.9 [a]	53.6 [a]	691.4 [a]
A (0-15 cm)	31.4[b]	8.5 [a]	27.00 [a]	47.1 [b]	52.5 [a]	677.9 [a]
B (50-80 cm)	9.8[c]	0.7 [c]	7.14 [b]	33.69 [b]	36.8 [b]	657.3 [b]

Means followed by the same lower-case letters are not significantly different at P<0.05 according to Duncan\s multiple range test. SOM, soil organic matter (%), LFOM. Light fraction organic matter, HFPSS, heavy fraction polysaccharides; DC, dispersible clay; WSA. Water stable soil aggregates > 250 µm

Spatial variability of soil physical properties

Soils are formed from parent rocks and minerals mixed with organic materials under the influence of climate operating over several years (Buol, et al., 2011). Quantitative evaluation of soil resources and their response to management require precise information on the spatial variability of the soil properties (Oyedele, Nurudeen and Aina, 1992). The parent rock and minerals that result in soils are diverse and thus soil properties vary spatially on the field. The variability caused by pedogenetic processes is known as regionalized, with nearby areas considered to be more similar than areas that are farther away (van Es, 1993). Classical statistics are inadequate in explaining soil variabilities due to the spatial dependency of the properties. Geostatistical techniques which are based on the regionalized variables theory of Matheron (1971) provide a tool for the quantitative evaluation of the spatial dependence of soil properties and can be used for interpolation of the spatially dependent variables. Oyedele, Nurudeen and Aina (1992) evaluated the spatial dependence of soil moisture content, cone index and gravel content under an oil palm plantation in Ile Ife. We established significant spatial variabilities of the soil properties studied which all fitted to the hyperbola model with varying spatially dependent parameters (Table 6). In a further study (Nurudeen, Oyedele & Aina, 1993) used the variogram parameters of the soil cone index, moisture content and gravel content to interpolate using Kriging technique for unsampled locations with errors of estimation less than 3.3% in a demonstration of the accuracy of the method for interpolation of spatially variable soil properties (Figure 7). In soil mapping, different soil properties are rated and the ratings combined to produce maps that represents a general soil suitability. This often overestimate or underestimate soil suitability. In a study to move beyond the traditional rating methods, Oyedele, Amusan and Olu Obi (1996) employed the multiple-variable indicator technique (MVIK) to integrate several soil properties into a single probability index. The raw data of soil properties were converted into a binary indicator based on whether it met a threshold. After combining these indicators into a single index, geostatistical interpolation (Kriging technique) was used to estimate values for unsampled locations and a suitability contour map was generated showing the likelihood of a location meeting all criteria (Figures 8a and 8b). This method can incorporate both quantitative data and qualitative factors such as landscape position, making it valuable for both agricultural planning and environmental monitoring. This is a novel method which has now formed the basis of most mapping software.

Table 6: Spatially dependent parameters of the soil properties

Soil property	Range	Sill (C_0 + C_1)	Nugget as % of sill	Nugget as % of S^2	Variogram model
Gravel content (%)	38	85	10.14	5.08	Hyperbola
Moisture content (%)	36.5	29.5	9.49	9.21	Hyperbola
Cone index	38	22.3	6.73	5.82	Hyperbola

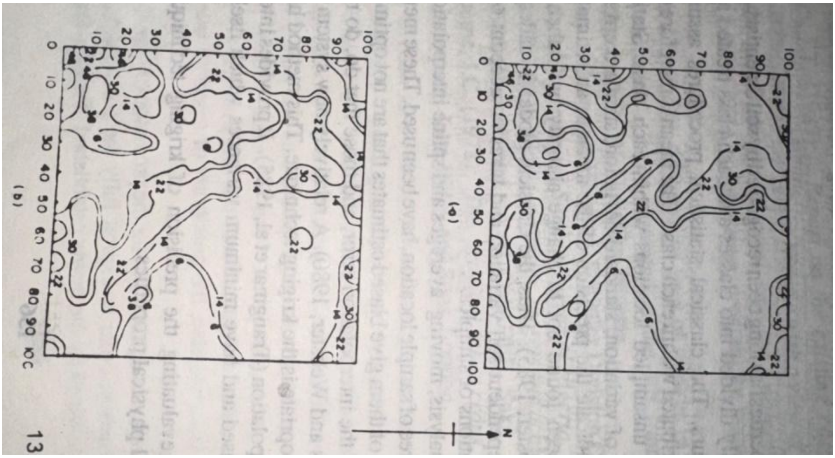


Figure 7: Isarithmic map of % gravel for (a) Kriged estimates and (b) actual samples

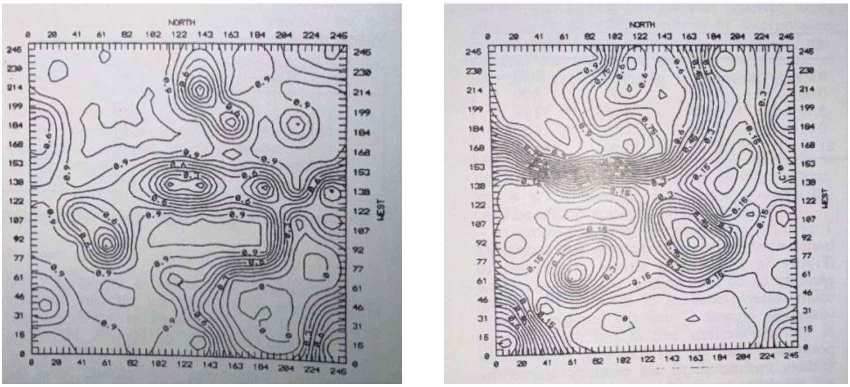
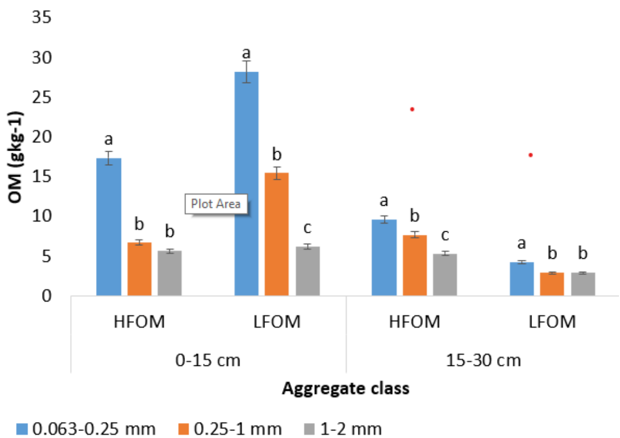


Figure 8: Contour map of (a) soil suitability indicator and (b) soil depth indicator

Impact of land use on soil physical properties

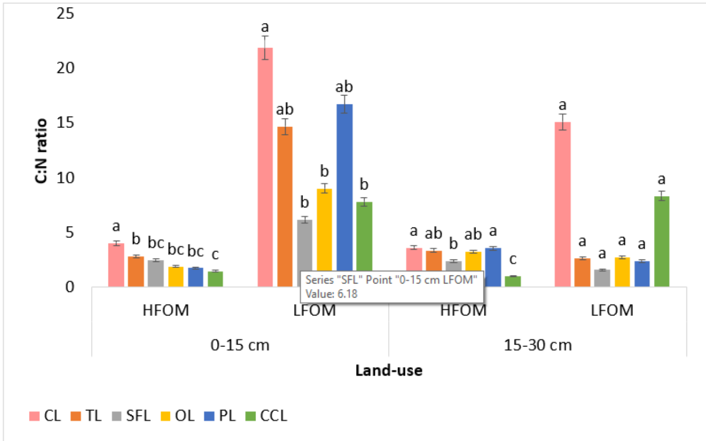
The effect of land use on changes in soil organic matter fraction was studied by comparing soil organic matter fractions under six different land use types in the OAU, Teaching and Research Farm. Soil organic matter fractions distributed within different soil aggregate sizes is an indication of the ability of soil to protect soil organic matter from mineralization and indirectly the ability of the soil to store carbon (Akinde, Oyedele, Tijani and Ibitoye, 2020a). The results from this study showed that the microaggregates with sizes between .0063 mm –

0.25 mm had the highest contents of heavy fraction organic matter (HFOM), light fraction organic matter (LFOM) and highest C:N ratio all indicating that this fraction offered the highest protection against the mineralisation of SOM compared to the macroaggregates. The studies demonstrate that land use type and soil aggregate size are key determinants of soil organic matter quality and stability (Figures 9 and 10). In another study by Akinde, Oyedele, Tijani and Ibitoye (2020b), it was revealed that cultivated soils were more compacted with bulk density as high as 1.55 g cm^{-3} due to repeated tillage and also with least stable soil aggregates. The soil under secondary forest was least compacted while having the highest hydraulic conductivity, indicating its highest ability to transmit water (Tables 7).



OM= Organic matter, HFOM= Heavy organic matter fraction, LFOM= Light organic matter fraction. Means with the same alphabet in each fraction are not significantly different at 5% probability according to Duncan's Multiple Range Test.

Fig. 9: Distribution of densimetric soil organic matter fractions in soil aggregate-size classes at the soil depths



PL= Paddock land-use, OL= Oil palm land-use, TL= Teak land-use, SFL= Secondary forest land-use, CL= Cacao land-use, CCL= Continuously cropped land-use, C:N ratio= Carbon to nitrogen ratio, HFOM= heavy fraction organic matter, LFOM= light fraction organic matter. Means with the same alphabet in each fraction are not significantly different at 5% probability according to Duncan's Multiple Range Test.

Fig. 10: Carbon to nitrogen ratio of the density fractions across the land-use types at the soil depths

Table 7: Effect of land use types on selected soil properties at two soil depths

	0-15 cm				15-30 cm			
Land use type	Db (g cm^{-3})	Cone index (kg m^{-2})	K_{sat} (cm s^{-1})	WSA (%)	Db (g cm^{-3})	Cone index (kg m^{-2})	K_{sat} (cm s^{-1})	WSA (%)
PL	1.14c	4.02b	0.004b	81.07c	1.48ab	8.37a	0.014b	76.91b
OL	1.34b	5.65a	0.006b	90.02b	1.45b	11.05a	0.004b	89.03a
TL	1.12c	3.38bc	0.009a	94.23ab	1.45b	5.34a	0.003b	91.20a
SFL	1.04cd	2.24d	0.022a	95.77a	1.40b	5.39a	0.02a	75.24b
CL	0.94d	3.19bc	0.012a	80.69c	1.51ab	6.48a	0.002b	70.17bc
CCL	1.55a	2.71cd	0.020a	69.65d	1.63a	9.04a	0.002b	62.76c

PL= Paddock land-use, OL= Oil palm land-use, TL= Teak land-use, SFL= Secondary forest land-use, CL= Cacao land-use, CCL= Continuously cropped land-use, Db= Bulk density, K_{sat} = Saturated hydraulic conductivity, WSA= Water stable aggregate. Means with the same alphabet on a column are not significantly different at 5% probability according to Duncan's Multiple Range Test.

Soil water management

Water is the primary agent of nutrient transport in soil and a regulator of soil temperature. It is the universal solvent and fundamental for all chemical and biological processes taking place within the soil (Hillel, 2003). The amount of water present in soil (soil wetness) is quantitatively measured either on weight or volume basis. Different methods are used for the measurement of soil water content and they include the sampling and drying method, the electrical resistance method, the neutron scattering method, the gamma ray attenuation technique, and the time-domain reflectometry (TDR) method. The TDR method is a relatively new method for measuring soil water content and it is based on the high dielectric constant of water (Hillel, 2003). The dielectric constant (relative permittivity) of a material is the tendency of its molecules to orient themselves in an electrostatic force field. The dielectric constant of water is normally about 81, while that of soil solids varies between 4 and 8 and that of air is about one (Jackson and Schmidt, 1989). Therefore, the dielectric constant of soil is largely determined by the fractional volume of water present in the soil. The TDR method involves sending a step voltage through parallel rods inserted into the soil and measuring the time taken to reflect the signal back into the device. The time interval is directly related to the volume of soil water. Topp and Davis (1985) developed a mathematical relationship for this as follows:

$$v = \frac{c}{(\epsilon_r)^{0.3}} \quad \text{...} \ 8$$

Where c is the propagation velocity of an electromagnetic wave in free space (3 x 10^8m/sec), is dielectric constant, and v is the velocity of propagation. Furthermore, Topp *et al.* (1980) upgraded this to a simple empirical equation relating the soil permittivity directly to water content thus:

$$\theta = -5.3\,x\,10^{-2} + 2.9\,x\,10^{-2}\,\epsilon_r - 5.5\,x\,10^{-4}\,\epsilon_r^2 + 4.3\,x\,10^{-6}\,\epsilon_{r^3} \quad \ldots 9$$

Based on this empirical equation, Mayowa, Oyedele and Shittu (2015) designed and fabricated a TDR-based sensor with data logging capability for the measurement of soil water content (Plates 2 and 4). This equipment was used by Shittu et al (2006) to determine the soil water budget required for the computation of crop coefficients and the water use efficiencies of some indigenous vegetables namely, *Solanum scabrum, Amaranthus viridis, Solanum macrocarpon* and *Solanum nigrum* in rainforest and derived savanna agro-ecological zones of Nigeria in a lysimeter study.

Plate 2: Fabricated datalogger and the TDR water sensor installed in the soil

Plate 3: Fabricated data logger for monitoring soil water content

Plate 4: Setup of lysimeter instrumented with fabricated datalogging TDR soil water sensor

Soil strength, trafficability and impacts on crop production

Soil strength refers to the capacity of a soil to withstand applied forces without deforming or structural failure (Baumgartl and Horn, 1991). The two major factors that define soil strength are the force of cohesion which is the internal molecular attraction that holds soil particles together and the internal friction which is the resistance to sliding between individual soil particles. The strength of a soil is determined by its water content, bulk density, soil texture and organic matter content. It is determined as either the tensile strength or the shear. Shittu, Oyedele and Babatunde (2017) in a field study, determined the influence of rates of organic matter incorporation on soil strength at different soil water contents (13%, 14%, 16%, and 19%) and how these impacted on maize yield on an Alfisol in Nigeria. The soil strength was reported to increase with soil depth and decrease with soil water contents at the time of tillage.

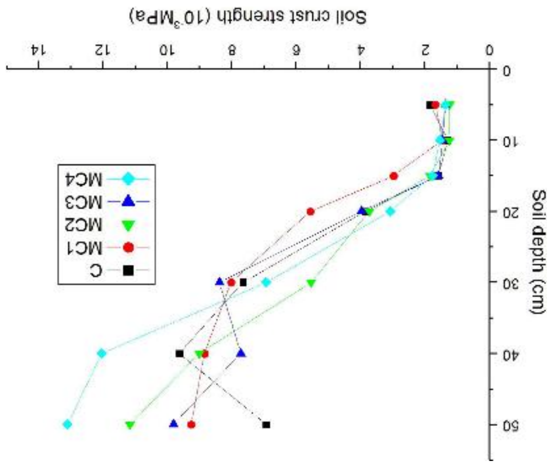
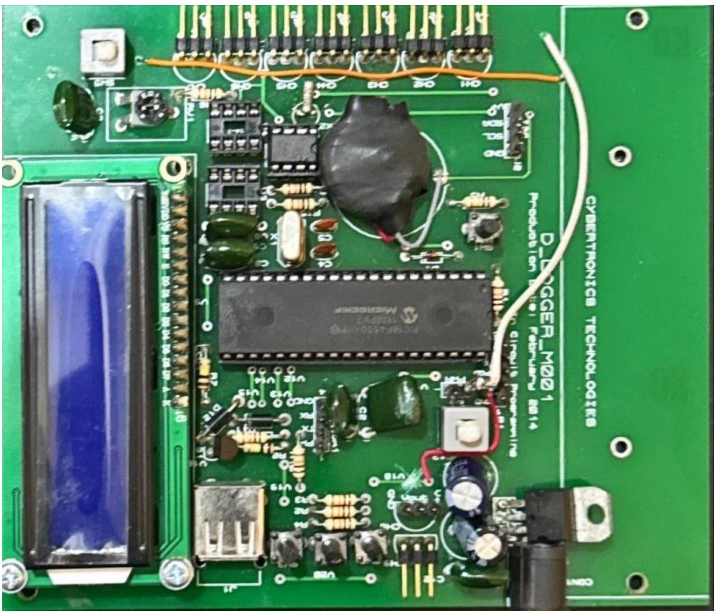


Figure 11: Soil strength (Mpa) at depths in response to rates organic matter incorporation

The study showed that timing of tillage on this soil to coincide with water content close to its field capacity improved field efficiency by reducing the drudgery and fuel used in cultivation in addition to increased maize yield. Furthermore, Babatunde, Oyedele, Adelekun and Shittu (2016) used an innovative method to study the effect of soil strength on seedling emergence. Indirect methods have been previously used to infer the impact of soil strength on seedling emergence. We designed a datalogging device fitted with pressure transducers to continuously monitor the pressure exerted by the germinating maize and okra seedlings as they emerged from differentially compacted soil (Plate 5). The pressure transducer showed that the okra needed to exert greater pressure at each level of soil compaction for their emergence, ranging from 0.3 mbar to 7.3 mbar and from 0.03 mbar to 1.73 mbar for maize seedlings. The emergence rates of maize and okra ranged respectively from 54% and 38% at maximum compaction to 99% and 80% at no compaction.



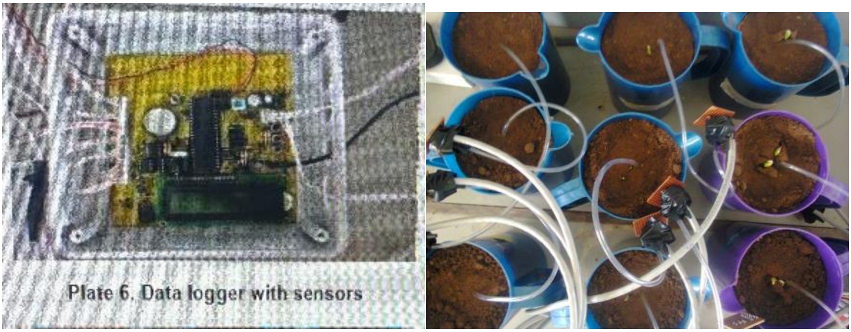


Plate 5: Set up showing (a) board (c) fabricated datalogger and (c) pressure transducer in seed pots

Table 6: Emergence rates of maize and okra seedlings in response to soil compaction

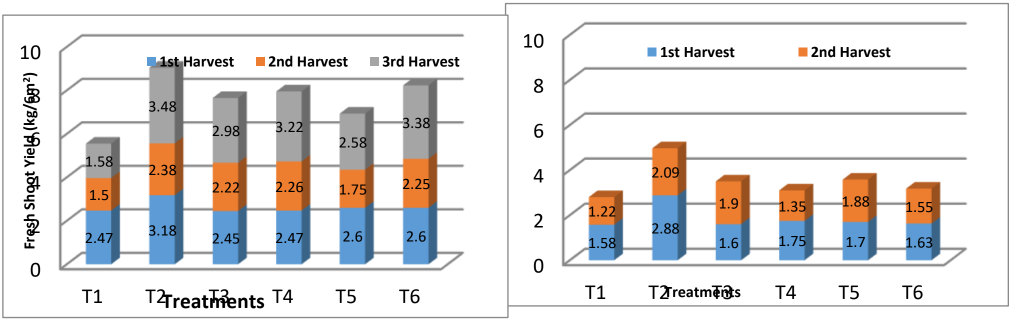
Time (Hr)	Compaction level	Soil Strength	Pressure exerted by maize seedlings	Pressure exerted by okra seedlings	Maize emergence	Okra Emergence
		kg/cm^{-2}	Millibars		%	
43	0	0.92	0.03	0.33	99	80
44	0	0.92	0.03	0.17	99	80
45	0	0.92	0.42	0.12	99	80
46	0	0.92	0.25	0.33	99	80
43	5	14.56	-0.67	4.87	82	81
44	5	14.56	-0.56	5.21	82	81
45	5	14.56	-0.61	5.35	82	81
46	5	14.56	-0.56	4.87	82	81
43	15	18.78	-0.17	4.11	62	50
44	15	18.78	-0.22	4.31	62	50
45	15	18.78	0.06	4.35	62	50
46	15	18.78	-0.11	3.85	62	50
43	25	20.50	1.67	6.82	54	38
44	25	20.50	1.50	7.12	54	38
45	25	20.50	1.25	7.13	54	38
46	25	20.50	1.25	6.28	54	38

Capillary irrigation innovation

And every plant of the field before it was on the earth, and every herb of the field before it grew: for the Lord God had not caused it to rain upon the earth, and there was not a man to till the ground. But there went up a mist from the earth, and watered the whole face of the ground. Genesis 2:5-6.

This passage is the Biblical record of a time before it started to rain on the planet earth and verse 5 mentioned how water came to wet the soil through capillary action. The rate and direction of water in soil is governed its energy state or the potential difference. Water generally moves from a region of higher potential to a region of lower potential. Based on this, we designed and fabricated a PVC pipe-based capillary irrigation device for use on the field (Oyedele et al., 2016). It consists of a buried PVC pipe that serves as the reservoir for water and capillary tubes which are filled with graded sand through which water is conducted upwards and directly to plant roots in response to evapotranspiration demand. The graded sand column inside the capillary tube serves as the conducting medium for the water to move from the reservoir to the drier soil above. The driving force for the movement is the evapotranspiration (representing combined water loss from evaporation at the soil surface and crop transpiration) which makes water to move from the reservoir through the capillary tubes to replenish water loss at the soil surface and at the root zone. Water will only move out of the pipe when there is a demand for it. It is simple to install and it is maintenance free and it is compatible with most arable crops. The system can also be used to supply crop nutrients through fertigation thus ensuring better utilization of fertilizer reducing the cost of fertilizer application. Nutrients will move from the reservoir to the root zone by mass flow and diffusion (Plate 7). The device significantly increased the yield of leafy amaranth by about 130% compared to traditional sprinkling irrigation (Figures 12a and 12b). In addition, the capillary irrigation method saved about 8 million litres of water per annum per hectare compared to the manual sprinkling irrigation.

Plate 7: The setup showing (a) sketch, (b) installation and (c) operationalization of the capillary irrigation device



T1 = Control, T2 = Capillary + fertigation, T3 = Spot, T4 = Drill, T5 = Fertigation, T6 = Broadcast at 80 kg N/ha Irrigation by sprinkler in all except the capillary (T2).

Figures 12a and b: Litres of water required per kg of fresh amaranth in humid forest and humid savanna locations in Nigeria

Soil and recreation

Soil not only serves the purpose of agriculture but also supports recreational activities. Sports such as golf, football, handball, and others require good turf. In order to improve the management of the Obafemi Awolowo University main football field, we have collected a seven-year geospatial data of soil properties and turf health to identify sections of the football field that is most impacted by leg traffic during football games. This will enable the recommendation of a more precise management practices to maintain good quality turf. Preliminary analyses of data revealed an unusual pattern which is the gradual loss of the finer soil particles over a relatively short duration. This means that the soil of the field is becoming more sandy (Figure 13). This is surprising because soil erosion of such magnitude is not expected under grass cover. On a careful observation of past activities on the field, it was suspected that the fine soil particles are being lost due to wind turbulence generated at the landing and taking off of helicopters especially when the field is dry (Plate 8). Mr.

Vice-Chancellor Sir, On the basis of this, I recommend that the University should wet the field before landing and taking off of aircrafts from the field or in the alternative, construct a helipad for the use of our VIP guest, since it is likely we will be many more of them.

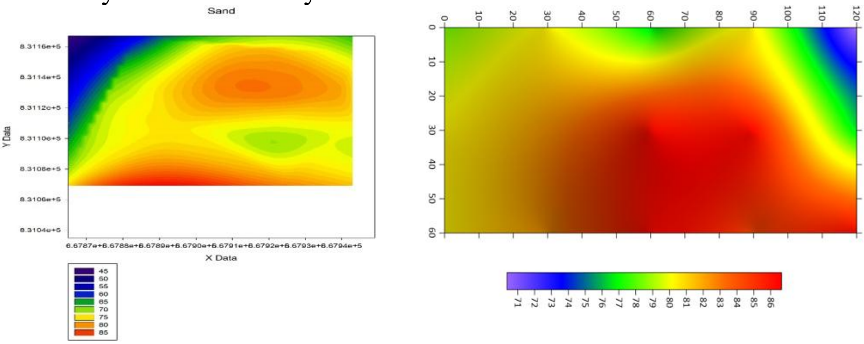


Fig 13: Spatial distribution of soil sand content in the OAU main football field in (a) 2019 and (b) 2025.

Plate 8: Wind erosion from an helicopter landing on the OAU main football field

The Indigenous Vegetables project

In 2011, in collaboration with the Osun State University, Cape Breton University and University of Manitoba, Canada, our multi-disciplinary team consisting of Agronomists, Soil Scientists, Plant Pathologists, Plant Physiologist, Food Scientist, Agricultural Economists, Agricultural Extension Scientists, and Sociologist among others, won a multi-million dollars grant from IDRC/CIDA, Canada for study on the underutilized indigenous vegetables (UIVs) of southwest Nigeria (NICANVEG). I was the principal investigator for the Obafemi Awolowo University team. We identified and documented 50 underutilized vegetables that were almost going into extinction out of which we developed detailed agronomic best cultivation practices for 10. We trained about 1,405 farmers of whom approximately 50% were women, on best agronomic practices for the UIVs. These techniques enable them to increase their yields by about 40%. We launched a very effective radio campaign tagged *Ramo Elefo* which reached thousands of listeners daily. Based on the success this project, IDRC/GAC, Canada awarded a follow-up grant of CAD$4.8 million for the team now joined with the University of Parakou, Benin Republic and University of Saskatchewan, Canada to scale up the earlier project. The project was on synergising fertilizer micro-dosing and indigenous vegetable production to enhance food and economic security of West African farmers. The study was carried out in both Nigeria and Benin. We introduced agronomic technology of fertilizer micro-dosing combined with organic manure that significantly reduced the cost of vegetables production and also improved soil health. An innovative irrigation technology was introduced that saved up to 8 million L/ha of irrigation water per annum for vegetables production. Other innovations developed during the course of the project included (i) low-cost sun drier and charcoal powered oven for converting fresh vegetable leaves to dry ones that stored 12 months for without losing taste or their nutritional values; (ii) a protocol for the extraction of polyphenol from vegetables and their use for fortification of local foods, juices and pastries; (iii) demonstration of the ability of polyphenols from *Telfaria occidentalis* and *Amaranthus viridis*, to reduce the blood pressure of spontaneously hypertensive rats (SHRs) by up to 40 mmHg; (iv) fortification of bread and *chin-chin* with vegetables to extend their shelf-life by up to three days. The project reached a total of 337,931farmers (50.6% female). The total number of farmers (vegetable producers) reached in Nigeria was 229,750 (51.6% female) while in Benin, 108,181 farmers (46.3% female) were reached all who experienced increase the revenue obtained from marketing these IVs (Adebooye, Akponikpe, Oyedele, Peak and Aluko, 2018). In addition, five (5) Ph.D., 8 M.Sc. and 15 B.Sc. students were sponsored by the project, while 2 technical staff and five academic staff were sponsored for short-term trainings in Canada (Plates 8 and 9).

Plate 9: MICOVEG Team meeting in (a) Winnipeg and (b) Cotonou

Plate 10: NICANVEG Team members with farmers at (a) Ilejemeje Ekiti and (b) Omi-Okun, Ile Ife

Soil health and environment health

Soil health is defined as the continued capacity of soil to function as a vital living system, by recognizing that it contains biological elements that are key to ecosystem function within land-use boundaries (Doran and Zeiss 2000; Karlen et al. 2001). These functions are able to sustain biological productivity of soil, maintain the quality of the surrounding air and water environments, as well as promote plant, animal, and human health (Doran et al. 1996). Soil health is the expression of the ability of a soil to meet its range of ecosystem functions as appropriate to its environment. This term is used to describe soil's ability to sustain plant and animal productivity and diversity, maintain or enhance water and air quality, and support human health and habitation. It underscores the fact that soil is not just a growing medium; rather it is a living, dynamic, and ever-so-subtly changing environment.

Effect of bush burning on soil and the environment

We investigated the effects of use fire for land clearing on soil properties and maize production (Ibitoye, Oyedele, Tijani, Gbadegesin and Akinde, 2019). The study tested the impact of bush burning at an average temperature of 200ºC and 400 ºC on soil properties. The post-fire soil sorptivity which is the ability of soil to absorb water by capillarity decreased with the temperature of the fire while soil water repellence or hydrophobicity increased with the temperature (Tables 9 and 10). This combination is expected to restrict entry of water into the soil during rainfall or irrigation and thus result in increased erosion after burning. However, burning improved the immediate soil chemical properties and maize yield. Further studies using standard erosion plots (Plate 3) (Ibitoye, Tijani, Adeboye, Akinde and Oyedele, 2024; Ibitoye et al., 2024) however confirmed the contrary. We recorded runoff of 13.36 mm, 10.80 mm and 12.78 mm in the first, second and third seasons respectively under burning temperature of 200 ºC and average of 12.88 mm, 7.63 mm and 11.96 mm in the respective seasons under 500 ºC burning temperatures. The soil loss from the plots followed a similar trend thus indicating some benefits of prescribed bush burning used by traditional farmers. However, the concentration of nitrates in the runoff significantly increased with the burning temperature in the three seasons of the study. This is a major worry for surface water contamination.

Table 9: Effects of fire intensity on soil sorptivity after burning for the first and second cropping seasons

Treatment	Days after burning			Days after burning		
	1	2	3	1	2	3
		cm hr^{-1}			cm hr^{-1}	
		Season one			Season two	
Control	46.4a	12.5a	59.0a	53.6a	123.8a	178.6b
200 ºC	73.8a	85.1ab	64.1a	50.7a	35.3b	461.8a
400 ºC	68.9a	27.5b	94.5a	11.3b	44.7b	372.2a

Table 10: Effects of fire intensity on soil water repellence after burning for the first and second cropping seasons

Treatment	Days after burning			Days after burning		
	1	7	42	1	7	42
		cm s^{-1}			cm s^{-1}	
		Season one			Season two	
Control	2.49a	2.05a	3.52a	9.03a	2.41a	3.29a
200 ºC	38.30a	8.39a	5.67a	14.39a	5.68a	1.19a
400 ºC	7.05a	28.45a	2.87a	27.80a	5.22a	1.52a

Plate 11: PVC bounded runoff plot installed on the field to harvest runoff and sediment loss into a 25 litre bucket

Soil contamination and environmental toxicity

Mr. Vice-Chancellor Sir, a major contribution to the contamination of soil environment is uncontrolled industrial wastes or effluents. In a study on a major metal smelter in Jos, Nigeria, Oyedele et al. (1995) investigated the contribution of lead (Pb) smelting to soil and vegetables surrounding the factory. It was observed that the extractable Pb contents of the soil and vegetables in the vicinity of the smelter were far above the WHO recommended values with the toxicity potentials ranged from 0.15 to 26 at distances away from the smelter (Table 7).

Table 11: Mean extractable Pb contents of soils around a lead smelter in Nigeria (µg g^{-1}) and their toxicity potential

Soil depth (cm)	Distances from the factory					
	Admin block	Factory site 10 m	50 m	Farm 1 100 m	Farm 2 150 m	Farm 3 200 m
0	680	5600	1160	4560	560	70
0-5	445	3600	587	4400	265	53
5-10	95	3160	64	4000	192	238
10-20	59	2050	68	3560	60	100
20-30	190	680	<0.001	1812	38	48
	Toxicity potential for extractable lead					
0	1.70	11.40	1.33	0.18	14.00	2.41
0-20	0.15	8.90	0.15	0.25	5.13	0.17

In another study Oyedele, Gasu and Awotoye (2008) reported that dump sites soils and associated vegetations were enriched with Zn, Cu and Cd with their concentrations varying with the age of the dump sites (Figures 11). The transfer factor (TF) which is an expression of the degree of plant enrichment of heavy metals was least for Pb (0.05) and highest for Cd (0.80). Similarly, Awotoye, Oyedele and Anwadike (2010) reported a high TF for maize and okra planted in a field with co-applied Ogun rock phosphate and cow dung (Table 12) confirming earlier report that rock phosphates fertilizers are a source of soil heavy metals (Oyedele et al. 2006). This study indicated that animal wastes enhanced the release and uptake of this metal by plants, underpinning the need to monitor the soil and plant heavy metals metal contents when wastes are used as an alternative to chemical fertilizers.

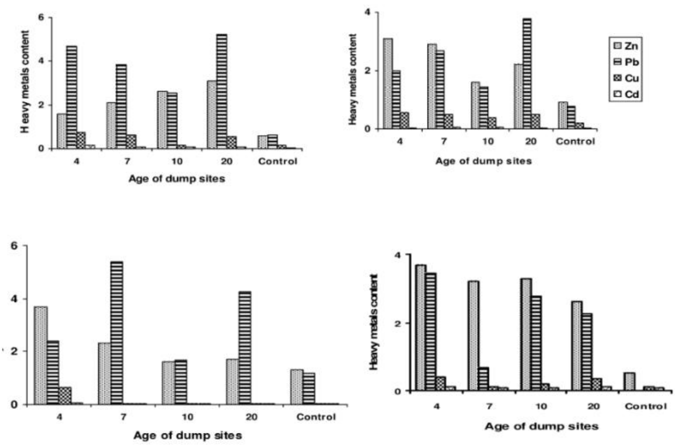


Figure 11: Influence of the age of dump site on the distribution of heavy metal (µg g^{-1}) in the topsoil (0-15 cm) during the wet season (b) and

In a further study using *Amaranthus cruentus* and *Solanum macrocarpon*, we demonstrated that micro-dosing reduced nutrient mining from the soil while maintaining high yield, suggesting that micro-dosing is more sustainable and environmentally friendly compared to broadcasting (Olaleye, et al., 2020).

Table 12: Transfer factor of heavy metals from soil to *Zea mays* and *Abelmuschus esculentum* as influenced by ORP and cow dung applications

Plant specie	Treatment	Pb	Zn	Cu	Cd	As
Zea mays	- ORP-CD	11.40	32.70	36.40	0.20	0.90
	ORP	14.70	35.60	25.60	0.30	0.60
	ORP-CD_1	17.90	35.90	20.00	0.30	0.02
	ORP-CD_2	32.10	34.40	17.30	0.30	0.10
	ORP-CD_3	25.40	43.20	20.30	0.30	0.80
	ORP-CD_4	19.20	43.30	22.70	0.30	`0.50
Abelmuschus	- ORP-CD	14.40	39.80	19.20	0.40	1.30
	ORP	22.80	44.40	29.80	0.50	1.70
	ORP-CD_1	18.20	35.70	22.90	0.30	1.30
	ORP-CD_2	25.00	39.40	14.80	0.50	2.10
	ORP-CD_3	12.60	44.10	20.70	0.30	0.90
	ORP-CD_4	16.20	38.10	15.00	0.20	1.20

ORP = Ogun Rock Phosphate, CD = Cow dung, ORPCD $_{1-4}$ = Represent Ogun Rock Phosphate and cow dung at different levels, 1, 2, 3 and 4 represent tons of cow dung. - ORP-CD represents no organic rock phosphate and cow dung application.

Concluding remarks

Mr. Vice-Chancellor Sir, in this presentation I have tried to draw our attention to how physics provides the platform for defining and quantifying soil architecture and predicting the possible implications of soil disturbance on soil processes and the capacity of the soil to provide its ecosystem functions. Soil physical shape and pore configurations influence the rate of chemical and biological processes taking place within the soil. Agents of soil degradation includes soil erosion, cultivation under unfavourable soil water regime, soil contamination with pollutants, and soil exhaustion due to over use. All these negatively impact food security and soil health. A heathy soil is a productive soil; a productive soil leads to a food secure nation, and secure nation is able to stand its ground in face of external aggression.

Therefore, I recommend that National Soil Information system be established in Nigeria. Nigeria must urgently build a comprehensive soil database covering physical properties (trafficability, cone index, Atterberg limits). This will support agriculture, infrastructure, and national defense.

There should be a legislation to enforce a national soil conservation policy to guide on crop and soil specific tillage practices.

Teaching and Community Service

Teaching

Mr. Vice-Chancellor sir, I have had the benefit of teaching some of the best brains and God has helped me to bring the best out of them. It is always my delight to see them performing excellently, around the world. Apart from hundreds of undergraduates, I have successfully supervised 24 Master's and 7 Ph.D. candidates, many of who are now professors in Nigeria, USA and Canada. I have successfully linked many of my students to scholarships and grants for further studies.

Town and gown

Mr. Vice-Chancellor, Sir, I have served as consultants to different companies involved in agricultural development projects and on environmental impact assessment of the impact of developmental projects and oil and gas exploration in various parts of the country. These studies have made me to traverse the length and breath of the country - from the rivers and the creeks of the Niger Delta to the desert fringes of Northern Nigeria.

In response to complaints by tomato farmers in Wasimi area of Osun State who suddenly started to observed a drastic reduction and even failures in the yield of their tomato, our team consisting of Professors Adeagbo Amusan, Kola Adekunle and I, visited their farms. The studies we conducted revealed the cause of premature abortion of tomato flowers to be due to nematode infestation. With a little grant from the University Town and Gown unit then headed by Prof. Adewusi, our team set up an experimental site on the farmers' field and successfully developed a farmer-friendly indigenous method with the use of African Marigold plant to control the nematodes (Ogundele, Oyedele and Adekunle, 2016). The farmers were able to successfully continue with their tomato farming.

Administratively, I had the opportunity of serving in various capacities in the university. I was a member of the Departmental and Faculty Examination Committees (1991 – 2003), Acting Head of Department of Soil Science and Land Resources Management, substantive Head, Department of Soil Science and Land Resources Management, Dean, Faculty of Agriculture, Representative of the University Senate on the Governing Board of the Institute of Agriculture, Research and Training

(IAR&T). I was a two-term representative of Senate on the University Governing Council. I have chaired various university ad-hoc committees.

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My appreciation goes to every member of the Department of Soil Science and Land Resources Management, who have contributed to academic progress

I acknowledge the inaugural lecture planning committee, you have been wonderful. I am really grateful.

I thank all my students and mentees who have made my academic journey very interesting. Many of them are making waves in different parts of the world. It is always my joy to receive news of your success and exploits. Some of them are professors in Nigeria, Canada and USA.

International

A string of coincidences brought Prof. Wole Akinremi and me together in 1996 while I was on postdoc in Denmark. This has initiated a lasting friendship and a productive academic collaboration between us that has blossomed with years and through which many staff and students from the Department of Soil Science received trainings at the University of Manitoba and has led to a strong and virile OAU community in Winnipeg, Canada and led to the IDRC research grants.

I appreciate the research team at the University of Manitoba - “Team work, makes the dream work”.

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I acknowledge support of various granting agencies that enabled me to accomplish in my academic journey.

Church

My Vice-Chancellor Sir, permit me to recognize many people who have contributed to my spiritual development. First, I thank God for Pastor and

Pastor (Mrs.) E.A. Adeboye, the General Overseer of RCCG and all my spiritual leaders in the mission. I am grateful for the leadership of my Pastor of the Region, Pastor Ajisola, the Pastor in Charge of Osun Province 7, Pastor Temitope and his assistants – Pastor O. Salami, the APICP Administration and Pastor (Prof.) A. B. Ayanwale, APICP CSR.

Family

I appreciate my parents, Mr. Simeon Abegunde Oyedele and Chief (Mrs.) Hannah Idowu Oyedele, for giving me the best education they could hardly afford. To my siblings, Chief Moses Bamidele Oyedele, Mrs. Abigail Balogun - who had to drop out of school so that she could take of us, even though she was the brightest among us; to my immediate elder brother TPL Kayode Oyedele, who was my home teacher, and ensured I always had advanced knowledge ahead of my classmates. I remember my late younger brother, Toyin Oyedele this moment and Magistrate Funke Oyeniyi, I say thank you.

My appreciation to by brother from another womb and his wife, Evangelist and Mrs. Fola-Alao. I am grateful to the Pastor and Mrs. Sanmi-Kayode, Mr. and Mrs. Ojo-Seriki.

To my mother in-Law and my father in-Law, sister in-Laws and their husbands; and my children from other men's loins. I am indeed very grateful.

To my biological children - Ayomikun, Jesutomisin, Teminijesu and Mojoyinjesu, thank you for enduring those years when I was either always on the road, in the air or in the office. Thank you for making us proud.

To my wife, my partner, encourager and a jewel of inestimable value, thank you for your love and care.

Finally, I give glory to God almighty for the gift of life and for lifting me up from the miry clay and setting my feet on the solid rock. I sing unto You: *eba yin Oluwa halleluyah, eni ba more Jesu ko ba mi gbega...*

Mr. Vice-Chancellor Sir, distinguished audience, thank you most sincerely for your attention.

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