FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

NIGERIAN SOIL RESOURCES: THE NEGLECTED BASE OF OUR NATIONAL DEVELOPMENT

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B.Agric. (Ife), MSc (Ibadan), PhD (Minna)
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INAUGURAL LECTURE SERIES 56

19TH OCTOBER, 2017

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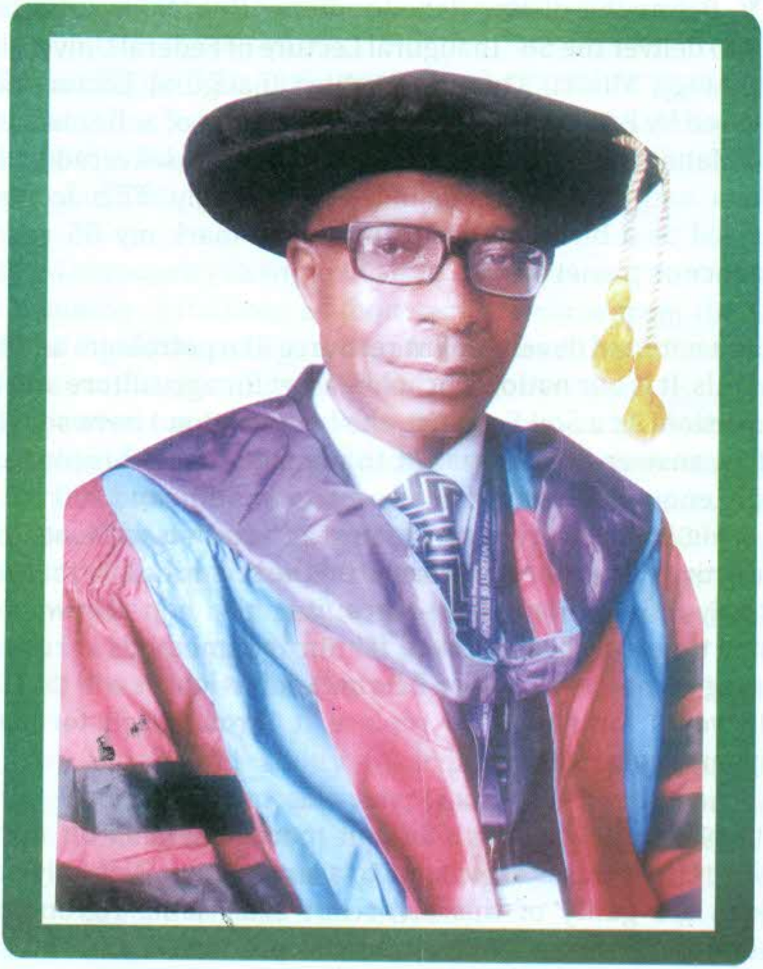

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1.0 INTRODUCTION

With immeasurable gratitude to Almighty God, I stand before this distinguished audience this 19th day of October, 2017 to deliver the 56th Inaugural Lecture of Federal University of Technology, Minna. This is the third Inaugural Lecture to be delivered by Professors from the Department of Soil Science and Land Management; the first and second were delivered by Prof. A. Bala and Prof. A. O. Osunde, respectively. This lecture is intended as a birthday gift to myself to mark my 65 years of existence on planet earth.

Soil is a national development resource like petroleum and solid minerals. It is our nation's primary asset for agriculture and food production. As a Soil Scientist, the big question I have sought to find an answer to is how best to manage our soil resources to supply enough food for the present generation and still pass on the same soil resources to the next generation without loss of productivity. My concern is based on the scientific fact that soil is not only a finite natural resource; it is also non-renewable on human timescale. For instance, if improper methods are used for farming and a single inch or 2.5 cm of soil is lost, it will take 300-1000 years for nature to replace it through soil formation! (Huypers *et al.,* 1994).

Quite often, the emphasis in soil management is on mineral fertilizers and this is erroneous to a large extent. Not only policy makers are guilty of this error but even some Agronomists. Mineral fertilizers might sustain soil productivity in the short term but certainly not in the long term, as research and practical field experience in the tropics have shown. In this lecture, I will expound on two soil management practices which, in my professional opinion, are more fundamental to long-term tropical soil productivity than mineral fertilizers, and which majority of Nigerian farmers must embrace, if the nation's soil resources are to be exploited in a sustainable manner to supply enough food for our burgeoning population and reposition the agricultural sector as a base for our national development.

2.0 BACKGROUND TO THE INAUGURAL LECTURE TOPIC

Vice Chancellor Sir, my distinguished audience, the choice of the topic for this inaugural lecture was informed by the following analysis and findings:

2.1 Food Insecurity in Nigeria

Two common definitions of food security come from the UN's Food and Agriculture Organization (FAO) and the United States Department of Agriculture (USDA).

(i) Food security exists when 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 and healthy life (FAO, 2006).

(ii) Food security for a household means access by all members at all times to enough food for an active, healthy life. Food security includes at a minimum:

   a) the ready availability of nutritionally adequate and safe foods,
   b) an assured ability to acquire acceptable foods in socially acceptable ways (that is, without resorting to emergency food supplies, scavenging, stealing, or other coping strategies (Originally from USDA and reported in Mark *et al.*, 2008).

A household is considered food secure when its occupants do not live in hunger or fear of starvation (FAO, 2001). Food security involves not only food availability but also food access through domestic production. It is also the contention of the FAO (2010) that for a country to have sustainable food security, food supplies must keep pace with increase in population and urbanization. As such, matching food production growth rate with population growth rate is vital to achieving food security.

Nigeria is a country with a huge food deficit and a colossal food import bill. According to a 2006 report quoted by Ojo and Adebayo (2012), 65% of the Nigerian population was suffering from lack of food security. The food insecurity situation of the country was more recently highlighted by the 2015 Global Hunger Index which ranked Nigeria 91st out of a total of 104 countries (14th most hunger-stricken nation) (Metu *et al.,* 2016). Nigeria posts a dismal stunted children rate of 31.5%, the highest in sub-Saharan Africa, with more than 50% of this figure from North East and North West States (Sun, August 1, 2017).

Nigeria's population currently stands at 182 million, including 14 million malnourished children; and food accounts for the highest share of consumer price index, with an average Nigerian spending 73% of his/her income on food and beverages (Sunday Punch, May 28, 2017). With inflation rate as high as 16.5%, food prices have hit the roof top and crime rate has expectedly increased exponentially (Punch, August 3, 2016). As if the food insecurity situation is not bad enough, forecasts suggest that the country's population would be about 203.13 million by the year 2020. In fact, a United Nation's report stated that by the year 2050, Nigeria would be the world's third most populous country behind China and India (Saturday Punch, February 4, 2017). While the growth in the population of Nigeria is at the rate of 3.2%, the growth in food production has been less than one (Metu *et al.,* 2016). Further escalation of food deficits and food insecurity problems is hence imminent.

2.2 Nigeria's soil resources and agricultural sector: decades of neglect and attendant consequences

Among the most damaging impacts of the discovery of oil in

Nigeria and the easy money from the sector are: (i) the long, steady decline of the country's agricultural sector due to inadequate funding, and (ii) the attendant massive importation of food items (Ojo and Adebayo, 2012). Thus, the state of hunger in the country is largely due to the neglect of the agricultural sector. Before Nigeria attained independence, agriculture was the most important sector of the economy, and accounted for more than 50% of GDP and more than 75% of export earnings. Nigeria was able to feed her citizens and there were surplus food items to export. Subsequently however, with the rapid expansion of the petroleum industry, agricultural development was neglected, and the sector started declining. Thus, between mid-1960s and mid-1980s, Nigeria moved from a position of self-sufficiency in basic foodstuffs to one of heavy dependence on food imports (Aregheore, 2009).

To amplify the neglect of the nation's agricultural sector in quantitative terms, analysis of federal budget shows that, over the years, the sector has not received up to 10% allocation which is the minimum requirement according to Maputo Declaration of sufficient food production. The highest the sector has received was about 7% in 2008 budget. Up to 2007, budgetary provision to agriculture was at times as low as 3% (Ojo and Adebayo, 2012; Adeniyi and Adeyemo, 2014). Vaughan *et al.* (2014) revealed that Nigeria imported about N1.0 billion worth of food per day in the period 1990-2011. Food import bill was in multiples of five times (516.65%) of food export and 18.81% of aggregate import. Mean annual food import for the period was 243.33% of 2010 Federal Government agriculture budget and 332.03% of the actual allocation (Tables 1 & 2). Table 3 is list of the top ten food commodities with highest import bills in the period 2006-2010. The first five commodities accounted for over 84% of the total import bills of those ten commodities. Among the ten commodities, the only one that Nigeria lacks comparative advantage to produce is wheat. Since 2011, food import bill has risen further such that food import now rivals the country's annual budget. For instance, by 2016, Nigeria's annual spending on food import stood at $22 billion (about N6.9 trillion). In comparison, the country's 2017 budget stands at N7.298 trillion (Saturday Punch, February 4, 2017).

Table 1: Twenty-two year statistics of import and export from 1990 to 2011 (N million)

Variable	Total	Mean
Aggregate import	42,315,824.86	1,923,446.58
Food import	7,961,170.90	361,871.40
Aggregate export	90,226,890.83	4,101,222.31
Food export	1,540,930.74	70,042.31

Source: Vaughan *et al.* (2014)

Table 2: Analysis of twenty-two year statistics of import and export from 1990 to 2011

Description	Value
Food import as a percentage of aggregate import	18.81
Food import as a percentage of food export	516.65
Mean food import as a percentage of 2010 Federal Govt Agric. Budget*	243.33
Mean food import as a percentage of 2010 Federal Govt Agric. Allocation*	332.03
Mean daily food import	About ₦1.0 billion

*2010 Agriculture budget was N148,716 million while allocation was N108,986 million.

Source: Vaughan *et al.* (2014)

Table 3: Top ten food commodities with highest import bills (2006-2010)

Ranking	Commodity	Total import (₦bil)	Average import/yr (₦bil)
1	Wheat	823.84	164.77
2	Fish	568.17	113.63
3	Milk/Dairy	312.57	62.51
4	Rice	271.19	54.24
5	Sugar	193.07	38.61
6	Prepared cereals	159.6	31.92
7	Prepared vegetables & fruits	111.98	22.4
8	Oils	104.82	20.96
9	Oil seeds	25.51	5.1
10	Cocoa	3.31	0.66

Source: Vaughan *et al.* (2014)

These statistics clearly show how we, as a nation, used oil money to import food rather than stepping up the exploitation of our soil resources and developing our agriculture and agro-allied industry to provide adequate and affordable food for the people, and this is certainly unsustainable fiscally, economically and politically. Due to the neglect of our nation's soil resources, the agricultural sector could not perform its expected roles – employment opportunities, self-reliance in food production, higher per capital income and foreign exchange earnings, including earnings from cash crops. Instead, our heavy reliance on food importation has given rise to high food prices, hunger, domestic inflation, depletion of foreign reserves, and rural-urban migration. It has also stunted local food and cash crop production, and created massive unemployment (Adeniyi and Adeyemo, 2014; Daily Sun, December 12, 2016). The National Bureau of Statistics (NBS) in its Unemployment/Under-employment Report for the Fourth Quarter of 2016 stated that 29 million Nigerians were jobless as unemployment rose to 14.2 % (Vanguard, June 6, 2017).

The Nigerian Sugar Company, Bacita in Kwara State typifies the neglect of Nigeria's agriculture and agro-industry. The company, which cultivated 5,600 ha of sugarcane for its sugar factory, is no longer existing and all the workers have lost their jobs while sugar importation continues to rise. Sugar is among Nigeria's top five food import commodities (Table 3). A similar fate befell cocoa, cotton, groundnut, palm oil and rubber. Today, little or nothing is heard about these sources of foreign exchange. Tyre makers, Michelin and Dunlop closed down their manufacturing plants in Nigeria in 2007 and 2008, respectively (Daily Sun, August 7, 2017).

The bulk of the money spent on food importation would have been retained within the economy if the nation's soil resources had been tapped to increase domestic food production. Just imagine the extent to which food insecurity would have been alleviated and the quality of life of rural dwellers improved if half of the money spent on food importation had gone into the hands of Nigerian farmers! Intensification of agriculture and agro-industrialization remains the only logical option if food import bills are to be considerably reduced and the country is to become a net exporter of food as she was before mid-1960s.

2.3 Productivity potential of Nigerian soils

Nigeria's soil resources occupy an agricultural land area of about 84 million ha out of which 33 million ha is under cultivation. About 3 million ha of the agricultural land is irrigable but only about 220,000 ha is actually irrigated. There is a lot of misconception about the fertility and productivity of Nigerian soil resources for crop production. Such statements as "Nigeria is blessed with vast expanse of fertile land for agriculture"

(Aribisala, 1983) are common among politicians and policy makers. Even among intellectuals in the agriculture profession, there seems to be an erroneous assumption that Nigerian soils have an unconditional capacity to support a high level of crop yields for as long as required. Available data from research and practical farming, however, show that most Nigerian soils are of low to medium quality and can only support low to moderate levels of crop yields (Ogunkunle, 1988; Lal, 2009). FAO statistics (Table 4) reinforce this fact as no Nigerian soil is classified under high productivity grade (Class 1) while 5.5% are classified as good (Class 2), 46.5% as medium (Class 3) and the rest 48% as low (Classes 4 & 5) (Adegbola, 1979). The soils are characterized by coarse texture and low cation exchange capacity (CEC). Organic matter content of the soils is low, rarely reaching 2%, and total nitrogen content hardly exceeds 0.1% (Federal Ministry of Agriculture, 1990).

Wudiri and Fatoba (1992) showed that the gap between the yields of most of the cereals and tuber crops in Nigeria compared to their potentials under high quality soils combined with good soil management is 25-400% (Table 5). Also, in the 10 sub-Saharan African countries (including Nigeria) covered in another yield gap study, it was estimated that farmers obtained just 20-30% of the yields possible, meaning that agricultural yields could more than triple if the exploitation of soil and crop resources were optimized (Klucas, 2015). Similarly, Tittonell and Giller (2013) and Macauley (2015) reported that yield gaps are pervasive in African smallholder agriculture and are large for almost all crops in all regions. The various studies identified poor inherent soil fertility and nutrient availability as the two major biophysical limitations to agricultural production on the continent. It is clear therefore that the role of soil quality and soil management in crop production cannot be taken for granted. Unless soil conditions are conducive in terms of the physical, chemical and biological characteristics, the potential of the crops cannot be attained. All the investments of several years of research in breeding, fertilizer application, weed and pest control, and other crop husbandry practices will continue to be a waste when due consideration is not given to adequate soil management (Tittonell and Giller, 2013; Ogunkunle, 2016).

Table 4: Productivity potential of Nigerian soils

Soil Productivity Grade	Soil Classes	Area km^2	Area % of total
High (1)		-	-
Good (2)	Fluvisols, Gleysols, Regosols	50.4	5.52
Medium (3)	Lixisols, Cambisols, Luvisols, Nitosols	423.6	46.45
Low (4)	Acrisols, Ferrasols, Alfisols, Vertisols	289.2	31.72
Low (5)	Arenosols, Nitosols	148.8	16.32

Source: Originally from FAO and reported in Adegbola (1979)

Table 5: Average and potential yields of cereals and tuber crops in Nigeria

Crop	Average Yield (t/ha)	Potential Yield (t/ha)	Gap (%)
Cereals			
Upland rice	0.8-1.2	1.5-2.5	88-108
Lowland rice	1.0-2.0	2.5-8.0	50-300
Maize	1.5-2.0	3.5-10.0	133-400
Sorghum	0.5-1.2	2.0-2.5	108-300
Millet	0.5-1.0	1.0-2.0	100
Tubers			
Cassava	11-12	20-25	82-108
Cocoyam	5-6	8-10	60-67
Irish potato	10-12	14-15	25-40
Sweet potato	10-12	14-15	25-40
Yam	12-14	18-20	43-50

Source: Wudiri and Fatoba (1992)

It is obvious from the foregoing that, in order to bridge the yield gap, raise the growth of food production to the same rate as population growth, and reverse the nation's agricultural trade imbalance, soil quality and productivity must be improved and sustained. I further submit that the two soil management practices to pay attention to, simultaneously and above all others, should be erosion control and soil organic carbon management. These practices are imperative for reducing the degradation of agricultural lands to the barest minimum and rejuvenating already degraded agricultural lands due to past abuse. While the goal of erosion control is to reduce soil degradation to the barest minimum, the goal of soil organic carbon management is to improve soil quality.

3.0 SOIL EROSION

3.1 What is Soil Erosion?

Among the various forms of soil degradation, soil erosion by water and wind is generally considered as the most serious and least reversible worldwide. In the light of this, it was not surprising that in the United Nation's report of 1984, soil erosion was rated to be among the leading threats to mankind (Huypers *et al.,* 1994). Water erosion poses the greatest threat to Nigerian soils and affects 80% of the land (NEST, 1991). While erosion by wind is largely confined to the arid and semi-arid north, erosion by water is ubiquitous throughout the country.

Soil erosion by water is the detachment and transportation of soil from a field and subsequent deposition of the eroded soil on land or in surface water bodies. It makes the soil to become progressively shallower and less productive. Ultimately, it brings about complete topsoil removal, thereby exposing a subsoil which provides little or no support for crop growth. In the tropics where the soils are more fragile and the rains are more intense than in temperate regions, total removal of topsoil from sloping fields in 3-4 years is possible, especially under large scale mechanized farming.

There are four different types of water erosion: sheet, rill, gully and streambank erosion. Only the first three occur on farmlands. Sheet erosion is the washing of a uniform layer of soil from the soil surface. When sheet erosion is not checked, surface runoff becomes channelized and sheet erosion advances to rill erosion which in turn advances to gully erosion. Gully erosion is the most visible stage and the most widely recognized consequence of water erosion. However, soil scientists know that most soil is lost at the sheet and rill erosion stages even though these stages are less visible. So, as far as agriculture is concerned, stabilizing or reclaiming gullies is like treating the symptoms of a disease rather than the disease itself.

If sheet erosion is checked, soil erosion is 'nipped in the bud', sheet erosion being the beginning of the erosion process. Sheet erosion is primarily caused by the effect of raindrops hitting the soil surface. Where soil is protected against raindrop impact by plant residues, little sheet erosion takes place. Therefore, the key to erosion control is to keep the soil covered.

3.2 Tillage, Major Cause of Erosion

The major soil management practice that causes soil erosion is tillage, the process of preparing a field for seeding which renders the soil bare and unprotected (Plate 1). Erosion is consequently most severe during the period between land preparation and crop establishment. In addition to rendering the soil bare, tillage directly shatters soil aggregates and tends to oxidize soil organic matter. Continuous ploughing to the same depth leads to the development of a plough pan which reduces infiltration capacity and consequently increases runoff and erosion (Tripathi and Singh, 2008). On the whole, tillage, especially tractorized tillage alters the soil profile and predisposes the soil to dangerous levels of erosion.

But if the soil can be kept covered by adopting conservation agriculture (CA) and eliminating or minimizing tillage, erosion can be prevented or reduced to the barest minimum. In tillage-based agriculture, the goal of erosion control practices is to prevent rill erosion, but in CA, the goal is to prevent rainsplash erosion and ensuing sheet erosion. Therefore, the way to dramatically reduce soil erosion is the CA approach. This method reduces soil disturbance and keeps the soil covered with crop and weed residues (Plates 2 & 3).

Table 6 highlights the utility of CA to check runoff and erosion. The residues on the soil surface break the impact of falling raindrops and soil sealing is reduced dramatically. They also act as small barriers, slowing runoff and giving water a greater opportunity to infiltrate. The channels created by decomposed plant roots and soil organisms such as worms and soil insects that are found in the CA system enhance water infiltration.

Table 6: Four-year comparison of runoff and erosion on a no-till and moldboard plowed watershed at the North Appalachian Experimental Watershed

Year	Rainfall (inches)	Runoff (inches)		Erosion (lbs/acre)	
		No-till	Moldboard	No-till	Moldboard
1979	44	0.14	5.52	8	436
1980	46	0.19	12.47	15	8455
1981	42	0	5.6	1	7645
1982	35	0	4.46	0	2461
Average		0.09	7.01	6	4748

Source: CTIC (2002)

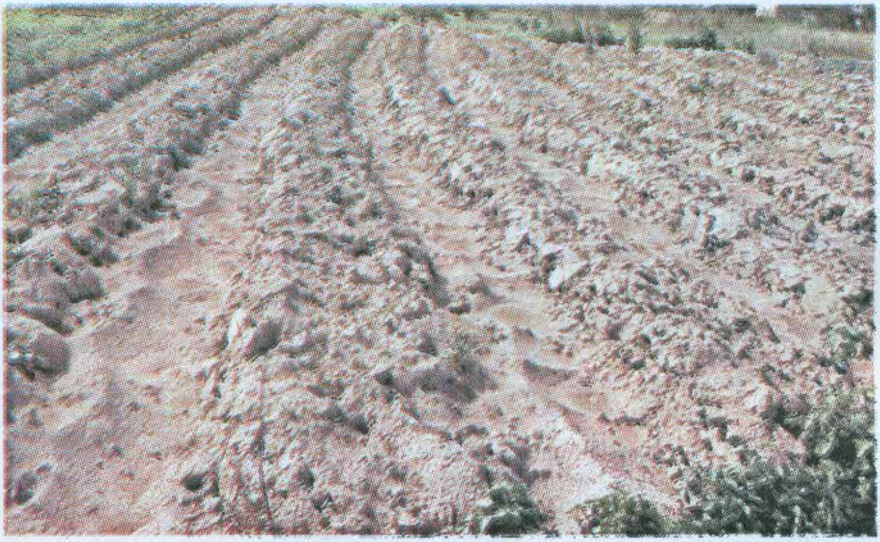

Plate 1: Tillage agriculture at Minna

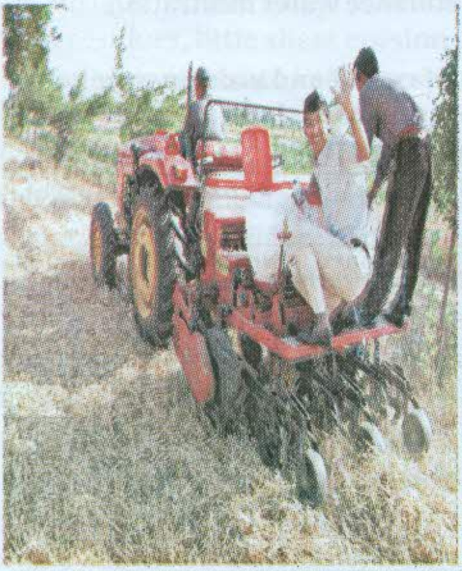

Plate 2: Conservation agriculture

Source: Kassam *et al.* (2014)

Plate 3: Conservation agriculture

Source: Kassam *et al.* (2014)

3.3 Conservation Agriculture, The Agriculture of the Future – The Future of Agriculture

According to FAO (2014a), CA is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. It is built around a set of three interrelated core practices that integrate agriculture with ecology through the complete or partial removal of tillage. These practices may be summarized as: (i) continuous no- or minimal mechanical soil disturbance (ii) maintenance of a permanent (year-round) organic soil cover, and (iii) mixing or rotating at least three different crops, with a balanced mix of legume and non-legume crops (IIRR and ACT, 2005; Dumanski *et al.,* 2006; Kassam *et al.,* 2015). In order to make reduced or no tillage possible, tillage is replaced with herbicides as a means of pre-planting weed control. CA functions best when all three features are adequately combined in the field.

In CA, planting holes are made in lines with cutlass, dibble stick or jab planter for direct sowing (zero tillage). In the case of minimum tillage, tillage is reduced to (i) ripping planting lines with tractor, hoe or draught animals to a depth of 15-20 cm (ii) or making small mounds (or basins) in lines with a hoe, leaving the rest of the soil unturned. The disturbed area must be less than 15 cm wide or less than 25% of the cropped area (whichever is lower). There should be no periodic tillage that disturbs a greater area than the aforementioned limits. Strip tillage is allowed if the disturbed area is less than the set limits (Nyanga, 2012; Kassam *et al.,* 2015). It is possible to use rippers/subsoilers and jab planters that sow seeds and apply fertilizer at the same time, so saving time and work. In line with Practice 2 of CA, area with less than 30% cover is not considered as CA and removal of surface residues is prohibited (Kern and Johnson, 1993; Smart and Bradford, 1999). Surface residues are regarded as important organic resources that must be preserved to provide a protective blanket for the soil. They are basically derived from weeds killed with contact or systemic herbicide before planting, plus the surviving litter of previous crop and weeds. Surface residues are effective for soil and moisture conservation only when significant amounts are present on the soil surface, thus emphasizing the need to preserve crop and weed residues in CA systems at all cost. CA is farming in harmony with nature.

By 2013, CA was practised on approximately 157 million ha globally, representing 11% of total global cropland (Table 7). The top five CA countries (Table 8) are USA (35.6 M ha), Brazil (31.8 M ha), Argentina (29.2 M ha), Canada (18.3 M ha) and Australia (17.7 M ha). On the continents of South America, North America and Australia/New Zealand, 60%, 24% and 36%, respectively of the croplands are under CA compared with Africa's 1%. Since 2008/2009, the rate of expansion of CA has been about 10 M ha annually, showing the increased interest of farmers in the CA system approach, mainly in North and South America and in Australia, and more recently in Kazakhstan with large farms, and in India and China with small farms, where large increases in the adoption of CA are expected and are indeed occurring (Kassam *et al.,* 2015). Also, the number of countries where CA has been adopted has increased from 36 in 2008/2009 to at least 55 in 2013 (FAO, 2014b).

3.4 Conservation Agriculture in Africa

In Africa, practitioners are few and far apart. However, farmers in at least 15 sub-Saharan African countries are now using CA, with eastern and southern African countries setting the pace (Table 9). Large-scale farmers are practicing CA in Zimbabwe, Kenya, South Africa, and Namibia, and it is also being actively promoted among smallholder farmers in Cameroon, Ghana, Kenya, Madagascar, Malawi, Namibia, Tanzania, Uganda, Zambia and

Zimbabwe (IIRR and ACT, 2005). In Nigeria, however, based on literature search, area under CA is negligible and it is not being promoted in any part of the country by agricultural extension bodies or other organizations. At Minna and its environs in Niger State and also at Yauri in Kebbi State, the Inaugural Lecturer was pleasantly surprised to come across few conservation tillage fields (Plates 4 & 5).

3.5 Benefits of Conservation Agriculture

3.5.1 Agronomic benefits

- Erosion control;
- A peasant farmer can save significant amounts of time and labour (Table 10);
- More timely planting;
- Mechanized reduced tillage cuts energy requirement by about half compared with mouldboard or disc ploughing (Lal, 2004);
- Tillage machinery expenses are eliminated or reduced;
- CA is more profitable than tillage-based agricultural systems, even if yields are the same because costs are reduced.

Table 7: Cropland area under CA (M ha), CA area as % of total cropland, and CA area as % of cropland by continent, in 2013

Continent	Cropland under CA (M ha)	% of global CA area	% of cropland
South America	66.4	42.3	60.0
North America	54.0	34.4	24.0
Australia & New Zealand	17.9	11.4	35.9
Asia	10.3	6.6	3.0
Russia & Ukraine	5.2	3.3	3.3
Europe	2.0	1.3	2.8
Africa	1.2	0.8	0.9
Global total	**157.0**	**100**	**10.9**

Source: Kassam *et al.* (2015)

Table 8: Top five CA countries, and country* with the highest % of cropland under CA

Country	M ha	% of cropland
USA	35.6	20
Brazil	31.8	54
Argentina	29.2	80
Canada	18.3	40
Australia	17.7	37
*Paraguay	3.0	99

Source: Kassam *et al.* (2014)

Table 9: CA adoption in Africa (1.2 M ha & 0.9% of cropland)

S/N	Country	'000 ha	% of crop land
1	South Africa	400	2.5
2	Zimbabwe	300	10
3	Zambia	200	3.8
4	Mozambique	200	3.6
5	Malawi	70	2.8
6	Kenya	30	0.7
7	Ghana	30	0.7
8	Tanzania	30	0.6
9	Sudan	10	0.06
10	Tunisia	8	0.28
11	Madagascar	6	0.2
12	Morocco	4	0.05
13	Lesotho	2	0.6
14	Namibia	0.3	0.04

Source: Kassam *et al.* (2014)

Plate 4: Reduced tillage field at Minna
(before spraying with herbicide)

Plate 5: Another reduced tillage field at Minna
(after spraying with herbicide)

- CA farmer can manage a bigger holding than a farmer practicing tillage-based agriculture;
- By eliminating manual tillage or minimizing it, CA considerably reduces the drudgery associated with agricultural production by peasant farmers who use human muscle as the power source, tillage being the most physically daunting farm operation;
- Soil organic matter content increases;
- Soil structure, water retention and water infiltration improve;
- After several years (2-5 cropping seasons) of gradual physical, chemical and biological improvement of the soil, CA begins to manifest consistent yield advantage over tillage-based agriculture (Benites *et al.,* 2002; Baudron *et al.,* 2015; Kassam *et al.,* 2015);
- CA is female gender-friendly and can make farming more attractive to educated youthful generation;
- Mechanized CA is more suitable for tropical soils than mechanized tillage agriculture.

3.5.2 Environmental benefits

- Climate change mitigation (due to improved carbon sequestration);
- Cleaner air (due to less use of fossil fuel);
- Improved water quality (due to reduced sediment load);
- Increased water infiltration in CA systems induces more regular stream flow throughout the year and improves the recharge of aquifers, leading to more reliable yields of water from wells and boreholes

3.6 Constraints and challenges facing Conservation Agriculture

The benefits of CA are many as enumerated but its adoption is not automatic. It faces various challenges which include:

Necessity for a change of mindset about tillage

The primary restriction to CA adoption is the mindset (tradition and prejudice) that soil tillage is essential for agricultural production (Kassam *et al.*, 2010). Therefore, switching to CA involves a fundamental change of this mindset. For example, farmers must give CA a chance and be prepared to drop their long-term practice of preparing the land with a hoe or plough, and instead rely on "biological tillage" by plant roots and earthworms. The resistance to change by researchers, academia and advisors can be much greater than that of farmers. Many advisors that are accustomed to promoting good ploughing practices are not yet ready to reverse their philosophy and deliver a message favouring CA (Ashburner *et al.*, 2002).

Table 10: Covered distances (km) by man for the cultivation of one hectare of maize, using animal traction under conservation agriculture and tillage agriculture

Operation	Conservation Agriculture	Tillage Agriculture
Ploughing	-	40
Harrowing	-	15
Furrowing	-	10
Planting	5	5
Fertilization	10	10
Knife roller	7.5	-
Weeding	-	30
Nitrogen application	10	10
Bending over of the cobs	10	10
Harvest	15	15
Total distance (km)	**57.5**	**145**

Source: Vieira and Wambeke (2002)

Preservation of surface residues is difficult but not impossible:

Keeping the soil permanently covered, especially in the northern parts of Nigeria where there is a long dry season and a thriving livestock sub-sector will certainly not be easy. Free grazing on stubble is the norm, and crop residues are a vital source of fodder. Farmers also have other uses for crop residues, such as fencing, roofing and fuel. Another serious challenge is the preservation of surface residues against bush fires. As a result of these factors, most fields are left with little or no protective residue cover at the onset of rains, thereby exposing the fields to severe erosion even before tillage. Burning is an inefficient shortcut to accelerated nutrient availability but when residues are preserved and left in the field as mulch, soil improvement in terms of humus, CEC and nutrient recycling is maximized. Lack of organic resources to provide sufficient surface mulch consistently ranks amongst the top constraints to CA (Valbuena *et al.,* 2012). CA without surface mulch usually results in depressed yields (Baudron *et al.,* 2012). In order to improve the supply of fodder and reduce competing demand for crop residues, leguminous shrubs or trees can be included in the production system, inter-cropped or planted as living fences (Ashburner *et al.,* 2002).

Conversion without loss of crop productivity

In the initial 2-5 years of adoption, CA usually produces lower yields than tillage agriculture (Baudron *et al.,* 2015). In Latin America, building up soil organic matter with intercropped green manure or cover crops over a period of 1-3 years before moving to CA is the strategy followed by most farmers (Benites *et al.,* 2002). In this way, the conversion takes place without loss of crop productivity. Another strategy is to increase the dose of mineral fertilizer for the first three years of CA (additional 10-30 kg N/ha for cereal crops) to obtain the same yield with tillage agriculture (Kassam *et al.,* 2015).

The major reason for the initial yield advantage of tillage agriculture over CA is the drastic modification of nitrogen dynamics under CA compared with tillage practices. Firstly, reduced or no tillage leads to slower nitrogen release from the mineralization of soil organic matter compared to ploughing (Giller *et al.,* 1997). Secondly, the retention of dead plant materials with a wide carbon/nitrogen ratio (such as cereal residues) may lead to temporary nitrogen immobilization, even though retained as surface mulch and not incorporated in the soil (Abiven and Recous, 2007). As a result, nitrogen deficiency is commonly observed early in the season in CA systems, leading to depressed plant vigour, growth and ultimately yield. CA may actually not lead to an increase in crop's nitrogen demand, but it appears to affect the timing of this demand, seemingly with a higher demand early in the season and lower demand later on (Verhulst and Govaerts, 2010).

4.0 SOIL ORGANIC CARBON AND ITS MANAGEMENT

4.1 Soil Organic Carbon

Soil organic carbon, more commonly referred to as soil organic matter is an all-round soil amendment that is rivaled only by mineral fertilizers in agronomic importance. Soil organic matter is composed of organic materials at various stages of decomposition. Organic materials are decomposed by soil micro-organisms (bacteria, fungi and actinomycetes) to their chemical component forms or groups: polysaccharides (celluloses, sugars and starches), lignins, proteins, fats and waxes (Sanginga and Woomer, 2009). Further breakdown results in the release of plant nutrients. The celluloses, lignins, fats and waxes decompose much more slowly than the starch and protein components. Thus, the residual (relatively stable) organic matter, otherwise referred to as humus, is largely composed of celluloses, lignins, fats and waxes while the starches and proteins are the sources of plant nutrients that are released into the soil.

The cation exchange capacity (CEC) of soils, which is a measure of their ability to retain plant nutrients against leaching, depends on colloidal clays and humus (Table 11). Tropical soils are, however, generally coarse-textured (less than 15% clay content) and the clay type is predominantly low-activity kaolinite and hydrous clays of Fe and Al. Consequently, tropical soils rely largely on humus for their CEC, with this soil constituent often providing over 80% of the CEC. Therefore, for tropical soils dominated by low-activity kaolinitic clays, the most important factor in determining soil quality is soil organic carbon (CTIC, 2002). In addition to the contribution of the humus fraction to CEC, the mineralizable fraction of organic matter contributes more than 95% of the total nitrogen, between 20 to 80% of the total phosphorus, and more than 90% of the total sulphur in unfertilized soils. Thus, organic matter supplies most of the nitrogen and sulphur and an appreciable fraction of the phosphorus taken up by unfertilized crops. The other essential nutrients (secondary and micro-nutrients) are also released from soil organic matter to supplement mineral sources, thereby increasing mineral fertilizer use efficiency. Organic matter has a stabilizing effect on soil physical properties and enhances microbiological activities, especially of *Rhizobium* in nitrogen fixation, and *Nitrosomonas* as well as *Nitrobacter* in the mineralization of organic nitrogen (Acquaye, 1993; Inckel *et al.*, 2005). In view of its numerous positive effects on soil physical, chemical and biological conditions, resilience and buffering capacity, organic matter is considered as being more or less synonymous with tropical soil fertility and productivity and is often described as the lifeblood of tropical soils.

Unfortunately, unlike clay minerals which remain unchanged within human timescale, organic matter is a transient soil fraction. It decomposes very fast under the hot tropical environment because of its aliphatic structure, so that its benefits are often short-lived. Consequently, while the simple addition of mineral fertilizers might sustain the productivity of kaolinitic tropical soils in the short run, a rapid yield decline often follows after only a few years of cropping because the soil suffers rapid degradation as organic matter is mineralized and nutrients are depleted through uptake or leaching (Kang and Wilson, 1987). The soil becomes increasingly acid, loses its fertility and structure, and becomes vulnerable to erosion. Other published results have shown that chemical fertilizers alone cannot sustain crop yields on poorly buffered kaolinitic soils (Kang *et al.,* 1990; Hossner and Juo, 1999).

Table 11: Soil colloids and their cation exchange capacity (CEC) values

	Soil colloids	CEC (cmol kg^{-1})
1	Humus	100-550
2	Vermiculite	100-180
3	Smectite (montmorillonite)	80-120
4	Illite	20-50
5	Hydrous micas/chlorites	15-40
6	Kaolinite	2-5
7	Hydrous oxides of Fe & Al	4

Sources: Schroeder (1984); Brady and Weil (1999)

Long-term studies in northern Nigeria, however, showed that the application of 5 t ha^{-1} of cattle dung annually combined with 100 kg N and 50 kg P_2O_5 could maintain yield under continuous cultivation (Chude et al., 2012). Studies on alley cropping by IITA at Ibadan in the forest savanna transition zone highlighted how soil productivity and crop yields could be sustained on kaolinitic upland tropical soils by continuous green leaf manuring (Figure 1) (AFNETA, 1992; Juo *et al.,* 1994). Under maize monoculture without fertilizer, a rapid yield decline was observed (lowest curve); but with alley cropping, maize yields of 2-3 t ha^{-1} were sustained over a period of 10 years without fertilizer N application (middle curve). Higher stable yields of 4-5 t ha^{-1} were obtained under alley cropping by top dressing with 45-60 kg ha^{-1} of fertilizer N (uppermost curve). Thus, the problem of maintaining satisfactory levels of soil organic matter (> 14 g kg^{-1}) in order to achieve long-term sustainability of soil productivity and crop yield is one of the major banes of tropical agriculture. On the contrary, in temperate regions, fertile soils such as Mollisols and Alfisols with high activity clays can support high and non-declining yields of cereals under continuous monocropping.

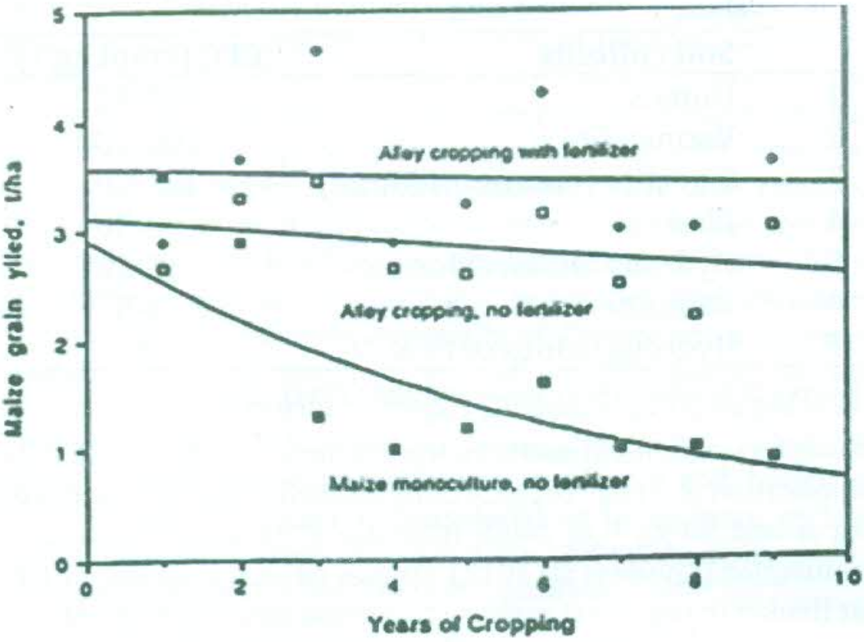

Figure 1: Maize grain yield under continuous cultivation, with or without green leaf manuring/fertilizer (Juo et al., 1994)

4.2 Soil Organic Carbon Management

4.2.1 *Fallowing*

The traditional way of accumulating organic matter in the soil for the purpose of restoring soil fertility is bush fallowing. However, fallowing is only capable of supporting low to moderate yield improvement for about two to three years. Obviously, fallowing is not meeting the food demands of today, let alone the future. To achieve food security, land cultivation must be intensive, making it imperative to adopt alternatives that are more effective than fallowing for the maintenance of soil organic matter levels. Such alternatives include organic manures and biochar technology.

4.2.2 *Oganic Manures*

Organic manures include animal/farmyard manure, compost, green manure, in situ mulch, live mulch and green leaf manure. Animal manure is the waste products of animals i.e. faeces and urine. Farmyard manure is composed of not only the manure of animals but also the beddings such as straw and wood shavings which are applied to the floor for insulation, to absorb urine and for easy cleaning. Compost is an organic fertilizer that can be made on the farm through the process of decomposition of organic wastes such as crop residues, animal or farmyard manure, and kitchen waste in a heap. Green manuring is the practice of growing short-duration, succulent and leafy leguminous plants and incorporating the plants into the soil in the same field before they form seeds. Examples of green manure plants are *Sesbania, Crotalaria* and even cowpea. In situ mulch refers to the residues of dead or chemically killed cover crops, usually leguminous, which are left to decay on the same field on which they are grown. The cover crop is followed by a food crop either in the same or next cropping season. The live mulch system is a crop production technique in which food crops are planted directly in a low-growing cover crop with minimum soil disturbance, based on the concept of using cover crops in tree plantations. Green leaf manuring is associated with alley cropping which is a crop-based agroforestry system in which arable crops are grown in the alleys formed by the hedgerows of trees and shrubs which are usually leguminous. The hedgerows are cut back at planting and kept pruned during cropping in order to supply organic material for green leaf manuring.

Generally, the effect of organic manures on crop yield, like that of fallowing, is short-lived. For instance, additional organic matter supplied by organic manuring is mineralized in a season or two. As explained earlier, the short duration of the beneficial effect of organic manures is due to the transient nature of organic matter, especially under tropical conditions. Rates of decomposition of organic matter are three to five times greater in the tropics compared with the temperate environment.

4.2.3 *Biochar Technology*

One emerging and very promising way by which soil organic carbon levels can be raised and sustained is by addition of biochar (Hunt *et al.,* 2010; Fagbenro and Onawumi, 2013) (Plates 6-8). Biochar is created by heating organic material under conditions of limited or no oxygen (Lehmann, 2007). The type of organic matter (or feedstock) that is used and the conditions under which a biochar is produced greatly affect its relative quality as a soil amendment (McClellan *et al.,* 2007; McLaughlin *et al.,* 2009). The most important measures of biochar quality appear to be high adsorption capacity, cation exchange capacity and low levels of mobile matter (tars, resins, and other short-lived compounds) (Glaser *et al.,* 2002; Liang *et al.,* 2006). Any type of biomass is a potential feedstock for the production of biochar. A sustainable model of biochar production primarily uses waste biomass, such as green waste from municipal and agricultural land clearing, forestry (wood), or agriculture (manure, crop residues). Woody shrubs and trees from nearby bush can be brought in to add to the organic materials already present on the farm and then charred under slash-and-char system.

How long does biochar last?

The various forms of organic manures discussed earlier decompose rapidly in soil but biochar is very stable because of its aromatic structure (McLaughlin *et al.,* 2009). This is the strongest selling point of biochar over uncharred organic manures. This important physical property makes biochar a more sustainable soil amendment than the parent biomass.

Plate 6: Biochar soil amendment

Plate 7: Biochar application (manual)

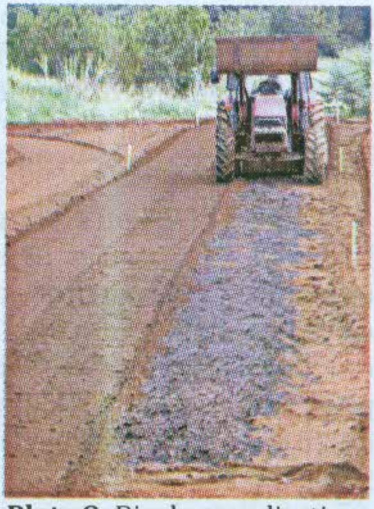

Plate 8: Biochar application (mechanized)

Source: Hunt *et al.* (2010)

Trials on the Amazon Basin's Terra Preta soils and naturally occurring biochar from forest and grassland fires suggested that biochar could persist for millennia with very little decay. Laboratory studies using the latest technology estimated that biochar's mean residence time in soils is in the order of 1300–4000 years (Cheng *et al.,* 2008; Liang *et al.* 2008). Considerable uncertainties remain about just how fast biochar may decompose under different conditions. Nonetheless, a conservative half-life as short as a few centuries could still provide man with a useful tool to manage soils and global climate sustainably.

How much biochar should be applied?

The optimum application rate for biochar depends on the specific soil type and crop management. Observations of crop growth after biochar applications of between 5 to 20% by volume of soil have consistently yielded positive and noticeable results. Some research findings indicated that much lower application rates yielded positive results (Glaser *et al.,* 2002). Biochar can also be applied incrementally and incorporated with fertilizer regimens or compost applications.

5.0 MY CONTRIBUTIONS

5.1 Effects of CA on soil hydrology

I carried out a series of experiments from 2000 to 2002 to quantify the effects of zero tillage on soil water budget components, namely runoff, drainage and actual evapotranspiration, at Minna, using tractorized tillage (disc ploughing and harrowing) as control (Odofin, 2005b; Odofin *et al.,* 2012). The zero tillage plots were mulched with rice straw at 5 t ha^{-1}.

Runoff

To measure runoff generation, mini runoff plots with dimensions of 2.5 m x 2 m were demarcated with asbestos sheets inserted 20 cm below ground surface. Each runoff plot collected runoff water and discharged it via a plastic pipe into a 320-litre tank installed in a pit just below ground level. A rain gauge was installed for on-site measurement of rainfall events. The data obtained are presented in Table 12. Zero tillage significantly reduced runoff relative to tractorized tillage. Runoff volume has direct positive relationship with soil loss, water pollution and flooding.

Table 12: Zero tillage effect on runoff generation from plots on a land slope of 2 % in 2000-2002 cropping periods

Treatments	Rainfall	Runoff	
	(mm)	(mm)	(% of rainfall)
Zero tillage	2,016	230	11.4
Ploughing and harrowing	2,016	546	27.1
$LSD_{.01}$	-	-	12.7

Source: Odofin (2005b)

Drainage flux

Drainage beyond maize rooting depth of 80 cm was estimated by using Darcy Buckingham's equation for unsaturated, one-dimensional, vertical flow with depth (z) taken positive upward, expressed in the form:

$$Jw = -K(h)\,\delta H/\delta z$$

where Jw (cm d^{-1}) is the drainage flux through a soil layer, K(h) (cm d^{-1}) is the hydraulic conductivity (K) of the soil layer as a function of matric potential head (h), and $\delta H/\delta z$ (cm cm^{-1}) is the hydraulic gradient across the boundaries of the soil layer (Kang et al., 2012).

Average daily readings of triplicate tensiometers installed at 70 and 90 cm soil depths were used for calculating $\delta H/\delta z$ across that depth interval. The K(h) function of the same depth interval was determined in situ by the instantaneous profile method (Da Silva et al., 2009) which entailed the simultaneous measurement of volumetric water content (θ) and matric potential head (h) as functions of time and soil depth during redistribution of water in an initially saturated, bare soil profile. Unsaturated hydraulic conductivity for the different soil layers was then calculated with the θ and h data generated for different soil depth intervals, using the equation:

$$K(h) = \int_{z_0}^{z_b} (\delta\theta / \delta t) / (\delta H / \delta z)_{z_b}$$

where K(h) is hydraulic conductivity (cm d^{-1}), θ is volumetric water content ($cm^3 \, cm^{-3}$), t is time (d), δH/δz is hydraulic gradient across the boundaries of the soil layer (cm cm^{-1}), z is soil depth (cm) with z taken positive upward, z_o is depth of zero flux plane which is at the soil surface (z_o = 0 cm), and z_b is depth (cm) below zero flux plane (Minhas et al., 1994).

Having determined δH/δz and K(h) for the 70 to 90 cm depth interval, drainage flux (Jw) through 80 cm depth was calculated for each day by solving the Darcy-Buckingham's equation given earlier. The signs of calculated Jw values were used to partition downward flux (drainage) and upward flux (capillary rise). Table 13 below shows the comparative drainage flux data obtained.

Table 13: Drainage flux beyond 80 cm soil depth for a period of 97 days

Treatment	Daily average (mm)	Cumulative (mm)	% of rainfall
Zero tillage	1.51**	146.55	22.00
Ploughing and harrowing	0.25	24.53	3.68

** = significantly different from control at 1% (t test)

Source: Odofin *et al.* (2012)

Zero tillage increased drainage approximately five times and altered the drainage fraction of rainfall from 4 to 22 % compared with tractorized tillage. Drainage flux slowly recharges surface and ground water resources with clean water.

5.2 Effects of CA on maize yield parameters and yield-cost ratio

In a field trial at Minna from 2008 to 2009, herbicide-based zero tillage was compared with disc ploughing and harrowing, and manual ridging (check) (Odofin *et al.*, 2011). The tillage methods were costed using prevailing wages, price of paraquat and tractor-hiring rate in Minna for 2009. Yield-cost ratio was computed as an index of cost effectiveness or economic efficiency by dividing the pooled yield with the cost of each tillage method. Zero tillage recorded the lowest value for grain yield but yield differences were not statistically significant (Table 14). Zero tillage was, however, more cost-effective than manual ridging and tractorized tillage.

Table 14: Pooled maize grain yield (2008 and 2009) and yield-cost ratio of two tillage methods compared with those of manual ridging

Tillage method	Pooled grain yield ($kg\ ha^{-1}$)	Average cost (₦ ha^{-1})	Yield-cost ratio
Zero tillage	2,120^{ns}	13,600	0.16*
Ploughing and harrowing	2,433^{ns}	37,300	0.07^{ns}
Manual ridging (check)	2,387	27,000	0.09

ns = not significantly different from the check, * = significantly different from the check.

Source: Odofin *et al.* (2011)

5.3 Effects of CA on soil physical properties, biological nitrogen fixation and cowpea performance

This is an on-going experiment in which three factors (tillage, phosphorus and variety) are being evaluated (Odofin and

Okpoho, unpublished data). For the tillage factor, the methods being compared are zero tillage, reduced tillage and manual ridging. On the reduced tillage plots, only the planting lines are tilled to a depth of 20 cm and a width of 15 cm using a hand hoe. Two crops of cowpea (early and late) are planted each year.

First year results for early and late crops showed that CA (zero tillage and reduced tillage) improved soil organic carbon content, aggregate stability (measured as mean weight diameter) and soil moisture content compared with tillage agriculture (manual ridging) (Tables 15 & 16). CA also improved biological nitrogen fixation measured as nitrogen fixed per plant and percent nitrogen fixed from atmosphere (Table 17). Finally, CA plots recorded higher fodder yield than manual ridging but grain yields under the three tillage methods were statistically similar (Table 18).

Table 15: Effects of tillage method on soil organic carbon (SOC) and mean weight diameter (MWD) in 2015

Tillage methods	Early crop		Late crop	
	SOC ($g\ kg^{-1}$)	MWD (mm)	SOC ($g\ kg^{-1}$)	MWD (mm)
Zero tillage	4.48^{a}	0.46^{a}	4.09^{a}	0.44^{a}
Reduced tillage	4.02^{b}	0.40^{b}	3.76^{a}	0.39^{b}
Manual ridging (control)	3.57^{c}	0.36^{c}	3.24^{b}	0.35^{c}

Source: Odofin and Okpoho (unpublished data)

Table 16: Effect of tillage on soil moisture content (SMC) ($cm^{3}\ cm^{-3}$)

Tillage methods	Early crop			Late crop		
	SMC at 50% flowering	SMC at pod filling	SMA at full maturity	SMC at 50% flowering	SMC at pod filling	SMA at full maturity
Zero tillage	0.231^{a}	0.260^{a}	0.249^{a}	0.093^{a}	0.078^{a}	0.042^{a}
Reduced tillage	0.208^{b}	0.227^{b}	0.241^{b}	0.084^{b}	0.069^{b}	0.039^{b}
Manual ridging (control)	0.182^{c}	0.194^{c}	0.202^{c}	0.067^{c}	0.051^{c}	0.029^{c}

Source: Odofin and Okpoho (unpublished data)

Table 17: Effects of tillage on biological nitrogen fixation by cowpea

Tillage methods	Early crop		Late crop	
	Nitrogen fixed (g plant^{-1})	% nitrogen derived from atmosphere	Nitrogen fixed (g plant^{-1})	% nitrogen derived from atmosphere
Zero tillage	1.79^{a}	28.2^{a}	0.24^{a}	16.7^{a}
Reduced tillage	1.67^{b}	27.0^{a}	0.23^{a}	17.2^{a}
Manual ridging (control)	1.64^{b}	27.6^{a}	0.19^{b}	15.7^{b}

Source: Odofin and Okpoho (unpublished data)

Table 18: Effects of tillage on cowpea grain and fodder yield

Tillage methods	Early crop		Late crop	
	Fodder yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Fodder yield (kg ha^{-1})	Grain yield (kg ha^{-1})
Zero tillage	4,446^{a}	1067^{a}	1089^{a}	592^{a}
Reduced tillage	4,347^{b}	1095^{a}	1064^{a}	614^{a}
Manual ridging (control)	4,165^{c}	1048^{a}	985^{b}	569^{a}

Source: Odofin and Okpoho (unpublished data)

5.4 Environmental impact assessment (EIA) of Kwadna earth dam, Gidan Kwano, Federal University of Technology, Minna

The Department of Soil Science and Land Management represented by Dr. B.A. Lawal and I participated in the aforementioned EIA at the invitation of Prof. Jimoh of the Department of Civil Engineering who headed the team. A summary of our input is presented below:

Observations

The Teaching and Research Farm (TRF) of the School of Agriculture and Agricultural Technology, Federal University of Technology, Minna is located upstream of the proposed dam between latitudes 9° 30' 30.10" N and 9° 31' 2.92" N and longitudes 6° 25' 57.61" E and 6° 27' 2.00" E at elevation ranging from 190 to 216 m above sea level. The farm drains completely towards the proposed dam site (Figure 2). On-going activities are arable crop production and livestock husbandry. Location of TRF within the watershed of the proposed dam is not environmentally sound for the following reasons:

a) Agricultural activities in the watershed of the reservoir will cause accelerated erosion by water, depending on the intensity of cultivation. Eroded soil constitutes the number one pollutant of surface water bodies. Soil makes water bodies muddy, and muddy water requires difficult and expensive purification to make it potable.

b) Discharge of muddy water into a water reservoir as a result of agriculturally induced erosion can cause rapid siltation, with adverse effect on the life span of the reservoir.

c) The use of chemicals such as fertilizers, pesticides and herbicides, which have varying levels of toxicity, are unavoidable in agriculture. A proportion of these chemicals will certainly get washed downstream. Therefore, it is unsafe to allow the use of these chemicals upstream of the proposed water reservoir.

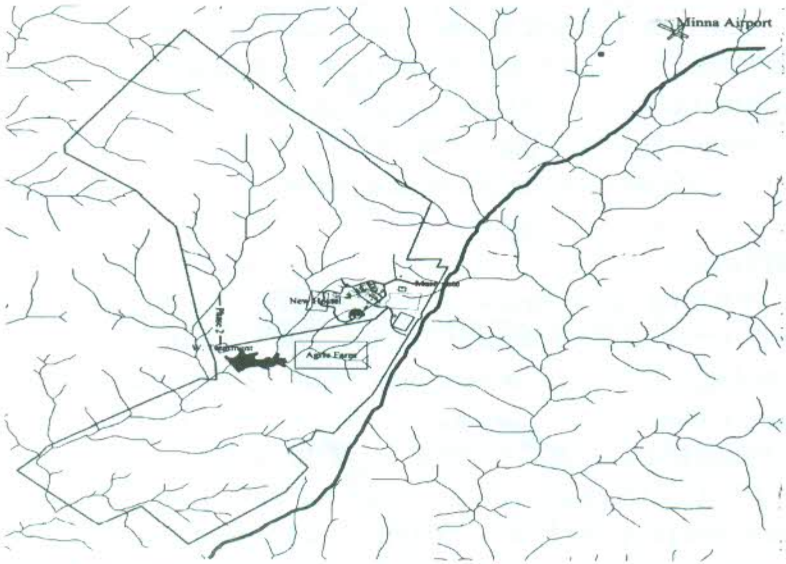

Figure 2: Map of proposed site and watershed for Kwadna earth dam

Suggestions

On the basis of the foregoing, it is suggested that:

a) The TRF be relocated to a new and safer site which is roughly rectangular and covers approximately 200 hectares, with the four corners having the following coordinates:
Location 1: 9° 30' 17.42" N & 6° 26' 41.26" E
Location 2: 9° 29' 45.29" N & 6° 26' 45.92" E
Location 3: 9° 29' 37.82" N & 6° 25' 40.78" E
Location 4: 9° 30' 11.26" N & 6° 25' 36.16" E.

b) Forestry rather than agriculture is the best land use for the watershed of any reservoir. Forest vegetation has the ability to convert virtually all rain water that falls on it to sub-surface flow which supplies cleaner water. Therefore, deliberate afforestation of the watershed of the proposed reservoir should be embarked upon after relocating the TRF, particularly the section for arable cropping activities.

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The various organic manures enumerated earlier were actually designed or developed for tillage-based agriculture. If a farmer adopts CA and adheres strictly to the three core principles of CA, addition of organic manures will be unnecessary. Conservation agriculture is thus an integrated technique for preventing accelerated erosion and maintaining adequate levels of soil organic matter. Notably with CA, the two foremost banes of tropical agriculture are taken care of.

6.2 Recommendations

Support for farmers

CA will only spread rapidly and widely when and where government is involved in its promotion. Policy support and the provision of incentives and subsidies are needed, including direct payments to farmers that are tied to CA adoption. Experiences in other countries have shown that financial support, especially for small farmers, is often a major requirement to catalyse the conversion process (Benites *et al.*, 2002). According to Akinwumi Adesina, The President of African Development Bank (AfDB), there is a need for Growth Enhancement Support (GES) for farmers: a system whereby small-scale farmers are provided with targeted input support to be able to use new technologies (Sun, December 12, 2016). In Paraguay, South America where tillage practices have disappeared almost completely, government support included the provision of grants for buying no-till equipment (Kassam *et al.*, 2010). Accordingly, it is recommended that government should officially recognize CA as a production system to be actively promoted and supported, the first step being the addition of CA to the schedule of a Director in the Federal Ministry of Agriculture and the appointment of a Desk Officer for CA. This should also be replicated in all the States and in the Federal Capital Territory.

Prioritization of investment in agriculture and food production is an imperative necessity

Government at all levels needs to invest much more in agriculture and food production and priority must be given to the soil where agricultural production begins. With the imminent switch from fossil fuel to electricity and other cleaner sources of energy to power vehicles (Buekers *et al.*, 2014; BNEF, 2016), the days of the country's dependence on oil are numbered and the country needs to fast-track economic diversification for life after oil. Many countries in Europe and Asia have signaled their intention to switch from powering their vehicles and machinery with petrol and diesel from 2025 to reduce air pollution and meet targets to keep global warming below 2^0C Celsius or 3.6^0 Fahrenheit (Sun, August 7, 2017; Punch, September 8 & 14, 2017). Norway said it would completely ban diesel-using vehicles by 2025 and make all new passenger cars and vans sold from then to be zero emitters. India said that every vehicle sold in the country should be powered by electricity by 2030. The Scottish government said it would phase out petrol and diesel cars by 2032. UK and France have announced that they would ban sale of diesel and gasoline fuelled cars by 2040. China, Austria, Denmark, Germany, Ireland, Japan, the Netherlands, Portugal, Korea and Spain, plus at least eight States in the United States have also set official targets for electric car sales. On the part of auto manufacturing giants, Volvo AB, said in July 2017 that it would manufacture only electric or hybrid vehicles from 2019. UK-based Jaguar Land Rover announced that all new models from 2020 would be fully electric or hybrid. Thus, the electric car technology is a serious threat to Nigeria's oil export and economy. The hand writing is clearly on the wall.

Closing remarks

I will like to end the lecture with the following golden statements by three obviously wise men. William Couper Brain wrote, *"No man can be a patriot on an empty stomach".* Norman Borlang, father of the Green Revolution, stated matter of factly, *"If you desire peace, cultivate justice; but at the same time, <u>cultivate fields to produce more bread</u>; otherwise there will be no peace".* According to Rattan Lal, President, International Union of Soil Sciences, *"The strong link between soil health and global peace must not be ignored. A healthy living soil is a crucial ally to food security and nutrition. <u>If adequate attention is not paid to soils,</u> crops will fail even if rains do not; hunger will perpetuate even with emphasis on biotechnology and genetically modified crops; civil strife and political instability will plaque the developing world even with sermons on human rights and democratic ideals; and humanity will suffer even with great scientific strides. Political stability and global peace are threatened because of soil degradation, food insecurity, and desperateness".*

ACKNOWLEDGMENTS

Almighty God

First and foremost, I give all glory, praise and thanksgiving unto God. He is the One that has preserved and sustained me from birth. And without the intellect He endowed me with and His constant help, I would not have been able to attain the highly esteemed position of Professor which qualified me to be the Inaugural Lecturer today. I had a near zero beginning. I was born to illiterate parents and matters were made worse when I lost my father in 1957 at age 5. My mother struggled to see me through Primary School and I attended Secondary School and Higher School (Advanced Level) only by the special grace of God. I was able to obtain my first degree because the Federal Government gave me scholarship that covered tuition, feeding and accommodation. Though intellectually above average, I did not have an ambition as a young graduate to pursue an academic career, but fate and destiny decided otherwise and I started my academic career in 1993. In spite of an earlier period of 15 years of non-academic working career with the then Nigerian Sugar Company, Bacita and Niger River Basin Development Authority, Ilorin, God still made it possible for me to attain the peak of my academic career. I am a testimony of God's unlimited power to lift people up from humble beginnings. I bless the name of the Lord with all my heart!

FUTMinna

It is impossible for me at this occasion to acknowledge everyone or every institution that has been a blessing to me, directly or indirectly, from the time I was born. My acknowledgements today are therefore largely limited to my academic career in the university. The Federal University of Technology, Minna which provided me with a platform for a successful career in academics deserves special appreciation. I have had a fulfilling career at

FUTMinna and the University brought me into contact with wonderful colleagues who added much value to my life academically and socially. Certainly, no other institution has contributed to my life more than FUTMinna where I have spent approximately 25 out a total working career of 40 years without any regrets. Of course, it is staff and students that constitute the University, so I am grateful to every member of the University community who has impacted on my life, one way or the other, directly or indirectly, knowingly or unknowingly.

Vice Chancellor, Prof. M. A. Akanji

I am happy that I am delivering this lecture during the tenure of Prof. M. A. Akanji, our highly revered, outgoing Vice Chancellor. Sir, my promotion to Associate Professor in 2012 as well as my promotion to the distinguished rank of Professor in 2015 took place during your tenure. This is what I will personally remember you for, far more than anything else. You will certainly be missed by FUTMinna for your energetic and fast-paced administration. I personally admire you for the priority you attached to Senate meetings, inaugural lectures and FUTMinna-hosted conferences. It is doubtful whether you missed any of these events throughout your 5-year tenure! Not only that, you personally and masterfully took charge of proceedings at those events. Transparency and staff welfare were two of the watchwords of your administration and you put service and social responsibility before personal reward. Clearly, you came to FUTMinna to serve rather than to be served! I pray that your years after FUTMinna will be years of greater successes and honour.

Department of Soil Science and Land Management of FUTMinna

My primary constituency, Department of Soil Science and Land Management, is the pillar behind my academic career. When I was doing my PhD in the Department, everybody in the Department was involved in one way or the other. The Heads of Department then, Prof. M. I. S. Ezenwa at first, and Prof. A. O. Osunde who succeeded him, were very supportive. They both went an extra mile to alleviate the difficulties that I experienced along the way. This is an opportunity for me to appreciate them for their immense contributions to my academic career. I also recall with gratitude how Mrs. D. G. Pada, Ibrahim Erena and Alh. Yahaya Umar joyfully laboured with me to carry out various activities during the four years of field trials. Please permit me, however, to single out one person in the Department for special appreciation, and that person in Abdulmalik Mohammed. Assuming FUTMinna had a statutory provision for the award of a single degree to more than one individual, the PhD that was awarded to me would have been awarded jointly to Abdulmalik Mohammed and myself. For four years, during both wet and dry seasons, we went to the field together, and he actually labored more than I did even though it was my PhD project. He exhibited 100% commitment and never complained or gave excuses to be absent. And when I lost my wife in 2003 and could not go to the field for about two months, he covered up effectively. Words are inadequate to express my gratitude to Mal. Abdulmalik Mohammed.

I thank God for the privilege of knowing Prof. A. O. Osunde and working with him for the past 25 years. I consider him as the most exemplary character I have worked with directly in my entire working career. In performing his duties, he strives for perfection, pays attention to detail, and displays integrity and sound ethics. The Oxford Advanced Learner's Dictionary defines the word "dutiful" as doing everything that you are expected to do. In Prof. Osunde's case, he is always prepared to do more than he is officially expected to do. Also, in the Department, he is ever willing to obey, cooperate with and show respect to whoever is the Head of Department.

The Department also afforded me the privilege of knowing and working with cerebral Prof. Bala. Actually, Prof. Bala was my MTech student at FUTMinna for one semester before his departure to the University of Reading on Commonwealth scholarship for a fresh Master's degree. At the end of that semester at FUTMinna, Prof. Bala wrote two of my examination papers and I had to admit to Prof. Osunde, that even if I, who set the questions, had written the same papers, I would have scored lower marks than Prof. Bala. He is level-headed and respectful. He treats me as his former lecturer and senior brother.

My family

I wish to posthumously appreciate the wife of my youth, late Mrs. Matilda Modupe Odofin, who was called to glory in 2003, after 22 years of marriage. In the story of my life, she definitely occupies a position of prominence. She gave me unconditional love and did much more than I expected of her as a wife. She taught me that it is possible for a man or woman to love his/her spouse more than self. I eulogize her today for her extreme submissiveness and near-perfect chaste conduct.

After seven years of widowerhood, I got married to my present wife, Helen Omaye Odofin who has restored love and sunshine into my life. As you can see, she is very beautiful. But I tell you, she is actually more beautiful inside than outside! I discovered in her an inner beauty that is much more precious than her physical beauty. She is a perfect match for me and she has made our home to be a small paradise here on earth! I wish at this special occasion to publicly reaffirm my un-diminishing love for you, Omaye.

I thank my children, step-children and special children for the love, joy and peace that we share as a family.

Distinguished guests

Finally, words are inadequate for me to express my gratitude to each distinguished guest present at this lecture. My family and I consider the presence of each of you as a great honour. We thank you most profoundly for coming to celebrate with us at this special occasion. We sincerely appreciate your love for our family.

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PROFILE OF THE INAUGURAL LECTURER

Prof. Ayodele Joshua Odofin was born 65 years ago on 22nd October, 1952. He hails from Isanlu in Yagba East Local Government Area of Kogi State. After completing Primary School in 1965, he attended Government Secondary School, Okene from 1966 to 1970 for WAEC School Certificate, graduating with the best result. He remained in the same school from 1970 to 1972 for WAEC Higher School Certificate and graduated again with the best Advanced Level result. He was at the former University of Ife, now Obafemi Awolowo University, Ile-Ife from 1973 to 1976 for Bachelor's degree in General Agriculture. Ten years later, from 1986 to 1987, he was at University of Ibadan for Master's degree in Agronomy. He obtained PhD Soil Science (Soil Physics) from the Federal University of Technology, Minna in 2005.

Regarding his working career, Prof. Odofin served the nation as a Youth Corper in the then Benue-Plateau State in 1976/1977, after which he joined the services of the defunct Nigerian Sugar Company, Bacita as an Agronomist. He left the company after five years and joined the then Niger River Basin Development Authority, Ilorin in 1982 where he rose to the rank of a Chief Agronomist in 1992. On 1st January, 1993, he transferred his service to the Federal University of Technology, Minna as Lecture 1. He attained the distinguished rank of Professor on 1st October, 2015, having published over thirty papers in reputable local and international journals and Proceedings.

Prof. Odofin is a member of several professional bodies, namely: Soil Science Society of Nigeria, International Union of Soil Science, International Soil Tillage Research Organization, Nigerian Biochar Initiative, and Organic Agriculture Project in Tertiary Institutions in Nigeria. He has supervised 31 undergraduates, 3 postgraduate diploma students, 23 Masters students and 8 PhD students between 1993 to-date. He has served as External Examiner and External Assessor for several universities and as Manuscript Reviewer for many reputable local and international journals. He is an Editor and Member of the Editorial Board of the Nigerian Journal of Soil Science. He has attended numerous local and international conferences and workshops.

At various times, he performed virtually all administrative responsibilities found at departmental level such as Level Adviser, Departmental Secretary, Examination Officer and Postgraduate Coordinator. At School level, he served as School Examination Officer from 2000-2003 and as Member or Chairman of numerous School committees at various times. He was Head of Department from 2006 to 2008 and has being occupying the same position for the second time since 2015 to-date. He has also served on few University committees. Prof. Odofin is a recipient of SERVICOM Award for Commitment to Service at FUTMinna.

Prof. Odofin's community services outside the University include: Leader of Men's Fellowship of ECWA Goodnews Church, Minna (1993-1996), Elder in ECWA Goodnews Church, Minna for a total of 12 years (1996-2002, 2006-2012), Treasurer (2009-2012), Vice President (2012-2015) and President/Trustee (2015 to-date) of North West State Association of The Gideons International in Nigeria.

Prof. Odofin was married to late Mrs. Matilda Modupe Odofin from 1981 to 2003 when she went to be with the Lord. He remarried in 2010 to Mrs. Helen Omaye Odofin. He is blessed with three children (Femi, Foluso and Tolu), four step-children (Ojajogbu, Ashimili, Linda and Apusu), two special children (Mr. and Mrs. Danjuma Akpasu) and one grandchild (Dupe). Prof. Odofin's hobbies include jogging and observing nature and wild life (live or on TV).

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