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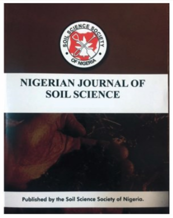

Structural dynamics and productivity of a paleudult amended with agro-wastes in Abakaliki, southeast Nigeria

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ABSTRACT

This research was conducted in 2015, 2016 and 2017 cropping seasons in the Department of Soil Science and Environmental Management, Ebonyi State University Research Farm to determine the effect of agro-wastes on soil structural dynamics, productivity and maize grain yield. Treatments were laid out in Randomized Complete Block Design (RCBD) with four treatments replicated five times. The treatments were: burnt rice mill dust, unburnt rice mill dust, sawmill dust and control (non-application of amendment) applied at 20 t ha^{-1}. Auger and core soil samples were collected and used for the determination of soil chemical and physical properties, respectively. The highest significant bulk density values of 1.60, 1.68 and 1.68 Mg m^{-3} were observed in the control plots whereas the lowest bulk density of 1.53, 1.55 and 1.55 Mg m^{-3} were found in burnt rice mill dust (BRMD) amended plots in 2015, 2016 and 2017 cropping seasons. The order of increase in aggregate stability in 2015 and 2016 was Control < Sawmill dust < Unburnt rice mill dust < Burnt rice mill dust plots whereas in 2017 the order of increase was Control < Sawmill dust < Burnt rice mill dust. Control recorded the lowest mean weight diameters (MWD) of 2.66, 2.66 and 2.53 mm in 2015, 2016 and 2017, respectively whereas MWD in the amended plots was Burnt rice mill dust > Unburnt rice mill dust > Sawmill dust for 2015, 2016 2017. Control plots recorded the lowest maize grain yield of 2.09, 2.08 and 2.07 t ha^{-1} in 2015, 2016 and 2017 cropping seasons whereas burnt rice mill dust plots recorded the highest maize grain yield of 2.27 t ha^{-1} in 2015 cropping; both burnt and unburnt rice mill dust recorded the highest maize grain yield of 2.24 and 2.23 t ha^{-1} in 2016 and 2017 cropping seasons, respectively. Thus, agro-wastes such as rice mill wastes are recommended for improvement of soil structural properties, productivity, and increase in maize grain yield in the study area.

1. Introduction

Agro-wastes of processed paddy rice from milling industries and timber sawmill, which were previously ignored as soil amendment materials, are now increasingly used because of their soil restoration value. Rice and sawmill wastes contain a moderate amount of organic carbon (10 – 15 g kg^{-1}), calcium (2.5 – 3 cmol$_{(+)}$kg^{-1}) and magnesium (1.5 – 2.5 cmol$_{(+)}$kg^{-1}) (Okonkwo and *et al.*, 2010; Uguru *et al.,* 2015; Ohaekweiro, 2016 as well as carbon-nitrogen ratio of 25 – 30 g kg^{-1} (Biswas and Murkherjee, 2008). The moderate amount of C:N the waste contained facilitate their effective decomposition and mineralization. The mineralized materials are valuable and are essential for structural stabilization of soils. For instance, organic carbon, calcium, and magnesium bind loose particles of mineral soil together (Obi, 2000) to form peds.

The importance of soil structure stems from the fact that the degree of nutrients supply and availability and water transmission, retention, or even soil conservation are often linked to good structural stabilization (Nwite, 2015). Apart from its agricultural value, soil structure has some implications in engineering fields such as road building, water storage cisterns, and embankments (Obi, 2000). Management practices to promote good soil structure are challenging, although, generally some of these smacks of conservative approaches. Continuous tillage, low input of amendments, bush burning, deforestation, and over-grazing constitute constraints to good soil structure. Consequently, zero tillage and optimal amendments are advocated to induce proper aggregation of soil. Besides, the extent of soil structural stabilization is dependent on the amount and quality of amendments (Anon, 2013).

For this reason, amendments which contain high sodium, potassium, or other monovalent cations are not ideal for soil structural stabilization as they tend to cause dispersion (Obi, 2000). It is, therefore, hypothesized that rice and sawmill wastes would have the potential to enhance good soil structural stabilization. Additionally, this study posits that these agro-wastes can cause structural dynamics based on the effectiveness and quality of respective nutrient elements each of them contained.

In the Abakaliki agricultural area of southeastern Nigeria, continuous cultivation with low soil amendments input characterizes the farming culture. This condition, which is occasioned by population pressure and exacerbated by limited land space poses a great risk on good soil structure and consequently, poor productive capacity. This research is necessitated by the need towards evolving a sound sustainable basis in arresting and reversing the trend. The objectives of this work were to: (i) assess burnt, and fresh rice wastes, as well as sawmill waste in inducing soil structural stabilization and (ii), evaluate maize seed yields under different agro wastes treatment.

2.0 Materials and Methods

2.1 Study Site Description

This experiment was conducted at the experimental field or research and training farm of the Department of Soil Science and Environmental Management, Ebonyi State University, Abakaliki from 2016 to 2017 planting season. The area is located between latitude 06^o 4`N and longitude 08$^o$ 65`E in the derived savannah zone of Southeastern Nigeria, with an elevation of 65 metres above sea level. The mean annual rainfall is 1800 mm, and it is distributed over nine to ten months in a bimodal rainfall pattern. It starts from April to October and terminates in November with two peak periods in July and September while the dry spell is experienced in August. However, due to climate change, the onset of rainfall is often delayed until May, and t the beginning of rains is usually characterized by lightning and thunders. Temperatures are evenly distributed throughout the year, although slight variations are common. The minimum temperature is 27^{o}C, and it is obtained during the rainy season and rises to 31^{o}C, which is the maximum temperature in the dry season. The relative humidity ranges from 60 – 80% for the lowest and highest humidity, respectively, during rainy and dry seasons (ODNRI, 1989). The soil of the area is underlain by sedimentary rocks derived from successive marine deposits of the tertiary and cretaceous period (Nwite *et al.,* 2019). Abakaliki agro-ecological area has been described to have been lain within “ASU river group” and consists of olive-brown sandy shales, fine-grained sandstones and mudstone (FDALR, 1985). The soil is shallow with unconsolidated parent materials (shale residuum) within 1m of the soil surface. The order is Ultisol and classified as Typic Haplustut (FDALR, 1985).The experimental site was fallowed for three years, and the vegetations are primarily derived savannah with bush regrowth (such as Tridax and elephant grass) and scanty economic trees (such as Gmelina). The common farming systems are mixed cropping and mono-cropping in rare cases

2.2 Experimental procedure

The land area used for this experiment is approximately 0.02 t ha^{-1}. The site was cleared of existing vegetation using machete. Debris left after clearing was removed without burning before seedbeds were prepared manually with a traditional hoe. Treatments were laid out in randomized complete Block Design (RCBD). The plots measured 2 m x 2 m and were separated by 0.5 m spaces. The treatments of burnt rice mill dust (BRMD) was collected from the mountainous heaps of already burnt rice mill dust in the rice mill processing site which has been existing for about twenty years. Unburnt rice mill (URMD) and sawmill dust (SMD) collected respectively from rice milling industry and timber processing industry both at Abakaliki were applied at 20 t ha^{-1} and control (C) and replicated five times in RCBD, to give twenty experimental plots for the study. The amendments were spread on the plots and incorporated into the beds using traditional hoe during seedbed preparation. After the incorporation of the amendments, seedbeds were allowed for two weeks to age before planting of maize seeds. The maize seeds (variety) were sourced from Ebonyi State Agricultural Development Programme Azuebonyi, Izzi. Blanket application of NPK 20:20:10 fertilizer at the rate of 400 kg ha^{-1} was done to all the beds at two weeks after germination of the maize seeds, Banding method was used for the fertilizer application at 5 cm distance from maize plants. Weeds were removed with hand hoe at three weekly intervals till harvest. The same procedure was used for the entire process in the three cropping seasons except for non-application of amendments in the third (2017) cropping seasons to test the residual effect of the treatments.

2.3 Soil Sampling for properties determination

A composite soil sample was collected from the site using auger at 0–20 cm depth randomly from 20 points for assessment of initial properties before cultivation. Samples were further collected at 0-20 cm dept from all the plots for post-harvest soil analysis. Auger samples were air-dried at an ambient temperature of 26^{o}C for three days and passed through a 2 mm mesh sieve size for determination of chemical soil properties. Three core samples were collected using a core of 50 cm^3 from each plot and was used to assess physical properties and structural dynamics.

2.*4 Determination of properties of the amendments and maize yield parameters*

Three replicate samples each of burnt rice mill dust, unburnt rice mill dust and sawmill dust were taken to the laboratory for the determination of its properties. At maturity of maize seeds which was determined by dried husks, shriveled silk, and tassels, cobs were harvested. The cobs were dehusked, shelled, and grains further dried in the sun. The yield of maize seed was assessed at 14% moisture content. Maize yield data was taken on six maize plants from each plot.

2.5 Laboratory Analyses and Procedures

Particle size distribution (PSD) was carried out by the hydrometer method as described by Gee and Bauder (1986).

Bulk density was determined using the core of diameter of 5 cm and height of 6 cm as reviewed by Nwite *et al.* (2019). This core was fixed on the auger and used to collect the soil sample. The core was carefully removed and trimmed. A rubber band was used to tie a calico cloth at the bottom part of the core before drying in the oven to constant weight and a temperature of 105 °C for three days.

Bulk density was determined with a formula:

weight of dry soil (after removing weight of the rubber band, calico cloth and core) (Mg)
Volume of bulk soil (cm^3)
where the volume of bulk soil is approximated by volume of the core as Лr^2h
r = radius of core
h = height of core and
Л = $^{22}/_{7}$

Distribution of aggregates was determined by wet sieving technique. A sieved soil sample was weighed out of 50 g of material <4.76 mm aggregates and pre-soaked in distilled water for 10 minutes before oscillating vertically in water for 20 minutes along with a 4 cm amplitude. The resistant aggregates collected from each sieve were dried at 105°C for 24 hours before being weighed. The mass of material <0.25 mm aggregate was obtained by the difference between initial weight, and the sum of sample weights collected onset of sieves of 2, 1, 0.5, and 0.25 mm. Percent of water-stable aggregates (WSA) on each sieve was assessed as:

$$WSA = \frac{Ma+S-Ms}{Mt-Ms} = \frac{100}{1} \ldots\ldots\ldots\ldots 2$$

Where:
Ma + S = Resistant aggregates plus sand (g)
Mt = Total mass of sieved soil weight (g)
Ms = Sand fraction alone (g)

Soil samples which fell between 4.76 and 0.25 mm were used to express WSA>0.25 mm as an index of soil stability (Kemper and Rosenau, 1986), as well as mean weight diameter (MWD) determination using the procedure below:

$$MWD = \sum X_i W_i \ldots\ldots\ldots\ldots 3$$

Where

X_i = Mean diameter of each size fraction (mm)
W_i = Total sample weight corresponding to size fraction after deducting the weight of stone usually after dispersion and passing through the same sieve.
n = Number of sample fraction

Higher values of MWD show predominance of less erodible large aggregates of soil. Total porosity was determined after collecting soil with a core of the same dimensions used for bulk density(Obi, 2000). The core with soil was soaked in water for 24 hours after which it was removed, weighed and dried in an oven at 105°C to constant weight. The values of total porosity were derived using the formula:

$$\text{Total porosity} = \frac{Wws - Wcr - Dws - Wcr}{\text{Volume of core}} \ldots\ldots\ldots\ldots 4$$

Where:
Wws = Wet weight of soil (g)
Wcr = Weight of core calico cloth and rubber band (g)
Dws = Dry weight of soil (g)

While the volume of core is approximated by Лr^2h as in bulk density determination. Soil pH was determined both in distilled water and in 0.1N KCl solution in a soil/water solution ratio of 2:5 (Mclean, 1982). Total nitrogen determination was carried out using the micro-Kjeldahl distillation method of Bremner (1996). Phosphorus was determined with Bray-2 method as described by Olsen and Sommers (1982) method and values read off from the standard curve obtained from optical density using a colorimeter. Organic carbon determination was carried out using the wet oxidation method of Walkey and Black as described by Nelson and Sommers (1986). Percentage organic matter was estimated by multiplying the value of organic carbon by 1.724. Exchangeable calcium, magnesium, potassium, and sodium were extracted with 1N NH_4OAC solution. Calcium and magnesium were obtained by ethylenediamine tetraacetic acid (EDTA) titration method as described by Mba (2004) while potassium and sodium were read with a flame photometer. Ammonium acetate (NH_4OAC) displacement method of Jackson (1952) was used to determine cation exchange capacity. Percentage base saturation was estimated as follows:

$$\%BS = \frac{TEB}{ECEC} \times \frac{100}{1} \ldots\ldots\ldots\ldots 5$$

Where:
%BS = Percentage base saturation
TEB = Total exchangeable bases (cmol kg^{-1})
ECEC = Effective Cation exchange capacity (cmol kg^{-1})

2.6 Data Analysis

Statistical Analysis System (SAS, 1985) was used to analyze both soil and crop data obtained from the study. Treatment means were separated with FLSD and significance accepted at 5% probability level.

3.0 Results and Discussions

3.1 *Pre-treatment soil analyses*

The Properties of soil obtained at the beginning of the study is shown in Table 1. The particle size analysis showed that sand dominated other fractions with a value of 658 g kg^{-1} and the textural class was sandy loam. The pH of the soil with the values of 5.50 (H2O) and 5.00 (KCl) was strongly acidic (Landon, 1991). Organic carbon was 1.80 a and was moderate, according to Landon (1991) while total nitrogen and available phosphorus recorded 0.20 g kg^{-1} and 4.68 mg kg^{-1}, respectively and were according to Landon (1991). Exchangeable calcium and magnesium with values 5.10 and 3.78 cmol$_{(+)}$kg-^{1}, respectively were predominantly higher than potassium and sodium with values 0.17 and 0.16 cmol$_{(+)}$kg-^{1}, respectively. Cation exchange capacity, as well as exchangeable acidity, were of low values, but base saturation was moderate (Landon, 1991). Strongly acidic nature of the soil influenced its nutrients content (Schoenerberger *et al.,* 2002). Available phosphorus availability is reduced by low activity clay and pH (Njoku and Mbah, 2012). Low nitrogen and organic carbon could be attributed to poor farming culture and inadequate amendments exacerbated by continuous cultivation, leaching losses as well as soil degradation occasioned by high temperatures. The presence of calcium, magnesium and base saturation could not salvage the soil from low fertility due to probably because some nutrients such as available phosphorous entered into complexes as a result of strong acidity (Njoku and Mbah, 2012).

Table1. Properties of Soil at the beginning of Study

Properties of soil	Values
Sand (g kg^{-1})	658
Silt (g kg^{-1})	212
Clay (g kg^{-1})	130
Textural class	Sandy loam
pH (H_2O)	5.50
pH (KCI)	5.00
Organic carbon (g kg^{-1})	1.80
Total nitrogen (g kg^{-1})	0.20
Available phosphorus (mg kg^{-1})	4.68
Exchangeable calcium $cmol_{(+)}$ kg^{-1}	5.10
Exchangeable magnesium $cmol_{(+)}$ kg^{-1}	3.78
Exchangeable potassium $cmol_{(+)}$ kg^{-1}	0.17
Exchangeable sodium $cmol_{(+)}$ kg^{-1}	0.16
Cation exchange capacity $cmol_{(+)}kg^{-1}$	10.20
% Base saturation	68.00
Exchangeable acidity $cmol_{(+)}$ kg^{-1}	0.70

3.2 Some Compositions of Agro-wastes

Table 2 shows the nutrients content of agro-wastes used as a soil amendment. The soil organic carbon content of URMD was 16.38 g $kg^{-1,}$ that of SMD was 8.98 g kg^{-1} whereas that of BRMD was 6.90 g kg^{-1}. The result obtained showed that URMD contained more organic carbon when compared to the values obtained in SMD and BRMD. According to Landon (1991), available phosphorus, and total nitrogen contents of the wastes were very low (Table 1). The respective values for calcium and magnesium were of low values with values of 1.16 & 0.26 $cmol_{(+)}kg^{-1}$, 0.49 & 0.11 $cmol_{(+)}kg^{-1}$ and 0.28 – 0.09 $cmol_{(+)}kg^{-1}$ for BRMD, URMD, SMD, respectively.

Table 2. Some Composition of Agro-wastes

Agro wastes	Parameter	Values
Burnt rice mill dust	pH	6.70
	Organic carbon (g kg^{-1})	6.90
	Nitrogen (g kg^{-1})	0.28
	Phosphorus (mg kg^{-1})	13.00
	Calcium ($cmol_{(+)}$ kg^{-1})	1.16
	Magnesium ($cmol_{(+)}$ kg^{-1})	0.26
	Carbon-nitrogen ratio	25
Unburnt rice mill dust	pH	11.40
	Organic carbon (gkg^{-1})	16.38
	Nitrogen gkg^{-1}	0.47
	Phosphorus $mgkg^{-1}$	6.00
	Calcium (cmol $_{(+)}$ kg^{-1})	0.49
	Magnesium (cmol $_{(+)}$ kg^{-1})	0.11
	Carbon-nitrogen ratio	35
Sawmill dust	pH	6.90
	Organic carbon (g kg^{-1})	8.98
	Nitrogen (g kg^{-1})	0.27
	Phosphorus (mg kg^{-1})	2.00
	Calcium (cmol $_{(+)}$ kg^{-1})	0.28
	Magnesium (cmol $_{(+)}$ kg^{-1})	0.09
	Carbon-nitrogen ratio	32

3.3 Particle Size Distribution of Soil

Table 3 shows the effect of agro-wastes on the particle size distribution and textural class. Sand fraction generally dominated silt and clay fractions across the treatments and control with slight variations for both periods of amendments and under residual study (Table 3). For instance, the order of increase in sand fraction was 2016 < 2015 < 2017 for control and burnt rice mill dust; 2016 < 2017 < 2015 for unburnt rice mill dust. Although there was no clear trend in finer particles, fine silt particle was predominantly higher than clay across the seasons. The textural class remained sandy loam throughout the amendments and seasons. The high sand content in the soils could be attributable on the one hand to parent material as well as climate obtainable in the area (Akamigbo, 2010). Federal Department of Agricultural Land Resources (FDALR, 1987) reported that the sand content of Southeastern Nigeria was due to soils formed on unconsolidated coastal plain and sandstones occasioned by numerous rivers which lacerate the region. Agro-wastes negligibly improved particle size distribution, although with a higher impact on silt fraction (Table 3) which was not able to alter sandy loam texture of the soil after amendment. This could be because the texture has been described as a “permanent property” of soil which cannot be easily modified by medium-term cultural practices (Obi, 2000). Texture as an index for structural assessment has the attributes to enhance nutrient retention and supply, increase moisture retention and all hydrological processes, porosity, aeration, specific surface area, compatibility and compressibility (Smith *et al.,* 1998), which improve the productivity of soils. Generally, the agro-wastes could be rated low in inducing structural dynamics as texture remained medium (Obi, 2000) both before and after amendments for the seasons.

Table 3. Particle Size Distribution after Amendment

	gkg^{-1}	2015		gkg^{-1}	2016	gkg^{-1}					2017	
Treatment	**Sand**	**Silt**	**Clay**	**Texture**	**Sand**	**Silt**	**Clay**	**Texture**	**Sand**	**Silt**	**Clay**	**Texture**
Control	650	260	100	SL	560	310	130	SL	660	210	130	SL
Burnt rice mill dust	620	260	120	SL	570	290	140	SL	630	270	100	SL
Unburnt rice mill dust	630	230	140	SL	550	270	180	SL	610	280	130	SL
Saw mill dust	650	260	100	SL	580	270	150	SL	640	240	120	SL

SL – Sandy loam

3.4 Bulk Density

Bulk density as an index of soil structure and productivity is shown in Table 4. Bulk densities were significantly ($P<0.05$) lower under amendments of agro-wastes, in contrast, to control across the seasons. Furthermore, bulk densities (1.53, 1.55 Mgm^{-3} and 1.55 Mgm^{-3}) obtained under treatment of burnt rice mill dust (BRMD) were significantly lower compared to their counterparts under unburnt rice mill dust (URMD) and sawmill dust (SMD) respectively for 2015, 2016 and 2017 seasons. There were non-significant differences between bulk densities recorded in URMD and SMD for the three seasons. The respective reductions in bulk densities of BRMD when compared to those of control for the seasons are 5, 6, and 6%. Although the bulk densities increased after the first season, there was a non-significant difference among the seasons except for BRMD and control. Generally, the order of increase in the bulk densities in the three seasons were 2015 < 2016 < 2017 while the order of increase in bulk densities among the amendments was URMD < BRMD < SMD < Control.

The significantly lower bulk densities under amendments relative to control attest to attenuation effect of agro-wastes on soil compaction. These wastes reduced soil bulk density and improved structural tendency. Uguru *et al.* (2015) and Ohaekweiro (2016) respectively noted that agro-wastes significantly reduced bulk densities of soil and improved both structure and soil productivity. The agro-wastes did not affect reductions in bulk densities after the first season but rather marginal increments in the second year of the amendment and residual season. The increase in bulk densities after the first season could be due to tillage effect (Anikwe *et al.*, 2003). Marginal differences in bulk densities among amendments in 2015 except in BRMD and control compared to other seasons indicate that the agro wastes encouraged low structural dynamics for the seasons. Bulk densities under amendments compared to control were below critical limit of 1.63 Mgm^{-3} recommended for root penetration in sandy loam (Arshed *et al., 1996*) and the non-limiting standard value of 1.50 Mgm^{-3} to promote good structure (Obi, 2000) for high soil productivity. Beyond the improvement of soil structural index, the agro-wastes contributed minimally to structural sustainability through residual effect.

Table 4. Effect of Agrowastes on Bulk Density

Treatment	**2015**	**2016**	**2017**
Control	1.60	1.68	1.68
Burnt rice mill dust	1.53	1.55	1.55
Unburnt rice mill dust	1.57	1.58	1.58
Saw mill dust	1.58	1.58	1.58
FLSD ($P<0.05$)	0.02	0.02	0.02

FLSD -Fisher’s least significant difference

3.5 Total Porosity

Total porosity (Table 5) showed that plots that received agro-wastes amendment were significantly (P<0.05) higher than those of control in the three seasons. There were marginal variations in total porosities across treatments and seasons. Generally, total porosities diminished after the first season giving the least values with a range of 37.15 – 41.22 % in the second season of the amendment and residual study. The higher total porosities obtained under BRMD agro-waste amendment implies that materials released from mineralization of the waste enhanced porosity dynamics but was not sustainable as seasons progressed. This is supported by the report of Adeleyeye *et al.* (2010). According to Nnabude and Mbagwu (2001), agro-wastes of rice mill significantly increased total porosity in comparison to control, but the effect was transient. Burnt rice mill dust recorded significantly higher total porosity when compared to their counterparts, and this could be attributed to its higher calcium content (Table 1). Calcium is a divalent cation and possesses the capacity to cement soil particles together to form aggregates of good structure (Obi, 2000). The marginal reductions observed in total porosities after the first season could be adduced to the effect of tillage, which masked the positive impact of agro-wastes on soil porosity.

On the other hand, bulk density has an inverse relationship with total porosity and could have impacted negatively on porosity dynamics, as evidenced in the trend obtained across the seasons (Table 4 and 5). Comparable values of total porosities both in seasons of amendments and residual study could be traced to the fact that materials that have low mineralization have a long positive residual effect (Ohaekweiro, 2016; Uguru *et al.,* 2015) on soil properties. The total porosities obtained under the agro wastes amendment and control are within low values (Obi, 2000) and ranged from critical to non-limiting values for root penetration, aeration, water transmission and soil productivity (Obi, 2000).

Table 5. Effect of Agro-wastes on Total Porosity

	Total Porosity%		
Treatment	**2015**	**2016**	**2017**
Control	39.32	37.15	37.15
Burnt rice mill dust	42.06	41.22	41.22
Unburnt rice mill dust	40.55	40.08	40.08
Saw mill dust	40.18	39.90	39.90
FLSD (0.05)	0.92	1.54	1.54

FLSD – Fisher's least significant difference

3.6 Aggregate Stability

Table 6 shows the effect of agro-wastes on aggregate stability across the seasons. Except in 2016, the aggregate stabilities obtained under agro wastes amendment for 2015 and 2017 were significantly (P<0.05) higher than those of control for the seasons. The order of increase in aggregate stability in 2015 and 2016 was Control < SMD < URMD < BRMD. Whereas in 2017 the Control also recorded the lowest aggregate stability value of 48.4% whereas that of amendment ranged between 49.1 – 56.7%. Generally, the order of decrease in aggregate stability in the three seasons was 2017 > 2016 > 2015. Higher aggregate stabilities obtained under agro wastes amendment in 2015, 2016 and 2017 could be linked to materials released from the burnt rice mill dust, unburnt rice mill dust and sawmill dust which promoted formation and stabilization of aggregates. Organic wastes mineralize useful materials which improve soil aggregation through binding of its particles (Asadu *et al.,* 2008). Aggregate stability has a positive effect on bulk density, total porosity, reduction of both erosivity of soil and erodibility of water, encourage water retention, nutrient supply capacity of soil and aeration all of which culminate in higher soil productivity (Obi, 2000). Impact of tillage implements destabilize and weaken formation and stabilization of soil aggregates (Anikwe, 2006; Nwite and Okolo, 2017). Aggregate stabilities in 2015 and 2016 apart from 2017 were above 60 % recommended as ideal or standard (Anikwe, 2006) for sustainable productivity. Poor formation and stabilization of aggregates in 2017 imply that the wastes have a low residual effect on soil aggregation. Generally, the aggregate stabilities in 2015 and 2016 are described as strongly developed (Obi, 2000), but those of 2017 are poorly developed.

Table 6. Effect of agro-wastes on aggregate stability

	Aggregate stability%		
Treatment	**2015**	**2016**	**2017**
Control	65.7	65.0	48.4
Burnt rice mill dust	71.0	70.2	55.3
Unburnt rice mill dust	70.8	69.6	56.7
Saw mill dust	70.1	69.4	49.1
FLSD(P<0.05)	2.9	NS	3.0

FLSD = Fisher's least significant difference, NS = Not significant

3.7 *Mean Weight Diameter*

Table 7 indicates significantly ($P<0.05$) higher mean weight diameter in plots receiving BRMD waste across seasons when compared to control as well as their counterparts of URMD and SMD amendments. The lowest mean weight diameter of 2.66 mm was obtained in Control in 2015, and 2016 while mean weight diameter in amended plots ranged between 2.79 – 3.21 and 2.70 – 3.15, respectively with BRMD recording the highest value and SMD recording the lowest value. In the residual year (2017), Control recorded the lowest value of 2.53mm. This observed mean weight diameter in control was smaller than the mean weight diameter in BRMD, URMD, and SMD by 25, 9, and 8%, respectively. Generally, the order of decrease in mean weight in the three seasons was 2015 > 2016 >2017.

Burnt rice mill dust generally significantly affected mean weight diameter positively demonstrating that it can cause structural dynamics through its influence on studied structural index more than other agro-wastes. This is attributable to its higher calcium content (Table 2) compared to other wastes. Presence of calcium as a divalent cation in soil has been noted (Mbah and Nwite, 2013); Obi, 2000) to induce flocculation or aggregation of soil particles and structural stabilization. Mean weight diameter is an index of soil stability, and so its high value indicates structural stabilization and higher productivity. Low and non-significant variations across seasons among the treatments imply that season or time lapse in terms of the amendment does not impact on structural dynamics significantly. However, non-significant changes across seasons indicate that they have the potential for long residual sustenance of structural stabilization (Mbah *et al.,* 2009). The values of mean weight diameter recorded for control and agro wastes amended plots except for BRMD were low (Anikwe, 2006; Obi, 2000) for ideal soil structure to ensure structural stability and sustainable productivity.

Table 7: Effect of agro wastes on mean weight diameter

Treatment	Mean weight diameter (mm) 2015	2016	2017
Control	2.66	2.66	2.53
Burnt rice mill dust	3.21	3.15	3.15
Unburnt rice mill dust	2.85	2.85	2.75
Saw mill dust	2.79	2.70	2.70
FLSD (P<0.05)	0.15	0.41	0.41
Standard	3.5	3.5	3.5

3.8 Maize grain yield

Maize seed yield as affected by agro-wastes amendment is shown in Table 8. Maize grain yields for the amended plots were significantly ($P < 0.05$) higher than yields in control for the seasons. There were no significant differences in maize seed yields among the agro-waste treatments across the seasons except marginal variations. Generally, yields in first cropping season for the agro-wastes (2.21–2.27 t ha^{-1}) amended plots and control (2.08 t ha^{-1}) were higher relative to yields obtained in other subsequent seasons. The grain yield obtained in 2015 from the amended plots ranged from 2.21-2.25 t ha^{-1}. These values were higher than the value of 2.08 t ha^{-1} recorded for the control in the same year. Furthermore, yields recorded for second and residual seasons did not vary. The significantly higher maize grain yields under the amendments compared to control imply that nutrients were boosted by decomposition and mineralization of the wastes (Table 4-7). It could further be linked to improved structural dynamics as exemplified in low bulk density, enhanced aeration occasioned by moderate total porosity, robust aggregate stability and mean weight diameter (Table 4-7) in those plots receiving the agro-wastes amendment. These findings are supported by the reports of Anikwe (2015); Obi (2000) and Aulakh *et al*. (2007) that nutrients released into the soil through waste amendment as well as excellent structural dynamics increased and sustained soil productivity.

Table 8.Effect of agro-wastes on maize seed yields

Treatment	Maize Seed yield t ha^{-1} 2015	2016	2017
Control	2.09	2.08	2.07
Burnt rice mill dust	2.27	2.24	2.23
unburnt rice mill dust	2.25	2.24	2.23
Sawmill dust	2.21	2.20	2.19
FLSD(P<0.05)	0.06	0.10	0.08
Standard	2.50	2.50	2.50

FLSD – Fisher's least significant

4 **Conclusion**

Evidence from this study has shown that agro-wastes namely burnt rice mill dust, unburnt rice mill dust, and sawmill dust when added to the soil are significantly low in inducing structural dynamics, but they increased maize yield productivity when compared to control. The structural indices evaluated were robust under the treatments but plummeted in control in 2015, 2016, and 2017 cropping seasons. Burnt rice mill dust showed superiority over other agro-wastes in the enhancement of soil structural dynamics and productivity all the three seasons. The agro-wastes such as burnt rice mill dust, unburnt rice mill dust, and sawmill dust had a minimal positive residual effect on the sustainability of soil structure as well as productivity. Burnt rice mill dust could be recommended for treatment of soil for higher and sustainable structural stabilization to elicit economic maize seed yield.

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