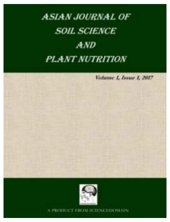

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Effects of Topsoil Removal and Amendments on Soil Bulk Density and Maize Yield in the Southern Guinea Savanna of Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author AOA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors FKS and JOA managed the analyses of the study. Author MTA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Effects of topsoil removal and amendments on soil bulk density and maize production in the Southern Guinea Savanna of Nigeria were studied during 2012 and 2013 cropping seasons. A split-split plot experiment in a Randomized Complete Block Design, with three replications was conducted. The factors were topsoil removal; cropping systems and amendments. Soil physical and chemical properties were analyzed before planting and after harvest. Maize (*Zea mays L.*) growth and yield parameters were evaluated. Bulk density increased significantly (P = .05) at Otobi from 1.39 to 1.58 g cm^{-3} in 2012 and from 1.40 to 1.54 g cm^{-3} in 2013, as topsoil removal increased from 0 to 20 cm. There were significant relationships between topsoil removal and the organic matter (OM) content of the soil. For every centimeter (cm) of topsoil removal, OM decreased by 0.04 g kg^{-1} in 2012 and 0.10 g kg^{-1} in 2013 at Makurdi. Meanwhile, at Otobi, the loss of 0 – 1 cm depth of topsoil resulted in the decrease in OM content by 0.06 g kg^{-1} (2012) and 0.07 g kg^{-1} (2013).The application of poultry manure (PM) significantly improved maize grain yield at Makurdi (2868 and 2804 kg ha^{-1})and Otobi (2836 and 2393 kg ha^{-1}) in 2012 and 2013 seasons. The

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interaction between topsoil removal and soil amendments suggests that at higher depth, application of either PM or inorganic fertilizer may not differ significantly in maize grain yield after first season cropping. The yield advantage of PM relative to other treatments suggested the efficacy of PM as a better soil management option that enhances the restoration of the productivity of an eroded soil.

Keywords: Artificial desurfacing; poultry manure; soil rehabilitation maize performance.

1. INTRODUCTION

Loss of topsoil is a potential danger to food security, as topsoil remains the store house for plant nutrients, and the medium through which such nutrients are made available for plant growth and development. Soilerosionis responsible for the extensive losses of topsoil and agricultural productivity worldwide. It is a consequence of prolonged exposure of the soil to rain drops impact and other erosive agents that caused detachment and transport of materials including plant nutrients from one location to another [1].

Topsoil removal by any process has destructive effects on soil productive capacity for crops and the ecological wellbeing [1]. Researchers have made efforts to quantify the relationship between soil degradation and soil productivity principally, in the United States and to some extent in India and Nigeria [2,3,4,5,6,7,8]. Simulated erosion (artificial desurfacing) is one of several approaches that have been used to estimate natural erosion on soil productivity [4,6,8,9] and quantify relationships between soil quality elements and soil productivity. Besides providing a means of quantifying erosion-productivity relationships, removal of topsoil using artificial desurfacing technique could be used to evaluate the contributions of different soil amendments in the restoration of the productivity of the soil [10,11,6,8]. This can be used to evaluate the resilience of the soil after degradation. Soil resilience which is the intrinsic capacity of the soil to regain or restore its productive potentials following degradation is an important phenomenon in soil conservation. This is because, different soils respond differently to applied stresses, therefore resilience may be specific to each soil which could depend largely on complex interaction between physical, chemical and biological processes within the soil systems [12].

1.1 Objectives

The objectives of this study were to evaluate the effect of simulated erosion through topsoil removal on soil bulk density and maize performance, and to assess the restorative ability of poultry manure and inorganic fertilizer (NPK + urea) on eroded soils.

2. MATERIALS AND METHODS

2.1 Site Description/Experimental Design

Experiments were carried out during 2012 and 2013 cropping seasons at two sites with different geological formations. The first location was Teaching and Research Farm of the University of Agriculture Makurdi, underlain by Makurdi sandstone formation, located between latitude 7°40'N to 7°53'N and longitude 8°22'E to 8°35'E at an elevation of 97 m above mean sea level, the soils were classified as *Aquic Arenic Haplustalf* [13]. The second location was the National Root Crops Research Institute (NRCRI) out-post at Otobi,Nigeria, which is underlain by more of consolidated shale located between latitude 7°07'N to 07°46'N and longitude 08°06'E and 08°34'E at elevation of 143 m above mean sea level, the soils were classified as *Typic Kanhaplustalf* [13].

Benue state has a hot climate typical of the Middle Belt area of Nigeria. There are two major seasons in the year- the rainy season and the dry season. The rainy season usually begins from April through to October in most parts of the state and the dry season from November to March. The total annual rainfalls were 1492.80 mm in 2012 and 1287.80 mm in 2013 meanwhile, the annual maximum temperatures for the periods were 32.90℃ for 2012 and 33.16℃ for 2013.

The experimental design was a 5x2x3 split-split plot experiment laid out in a Randomized Complete Block Design (RCBD), with three replications. The factors were topsoil removal (0 cm, 5 cm, 10 cm, 15 cm and 20 cm); cropping systemssole maize (SM) and maize/soybean intercrop (MSI); and soil amendments (poultry manure, inorganic fertilizer and zero application).

2.2 Land Preparation and Planting of Crops

The experimental sites were soils that were under fallow for over four years that have not been cultivated to ridges before. The sites were cleared manually using cutlass in July 2012 and the land mapped out into blocks and plots. A meter rule was used to ascertain the required depths on each of the plots and topsoil of the plow layer was excavated manually using spade to depths of 5,10,15 and 20 cm in each replication; while the un-desurfaced plot (0 cm depth) was left as control. There were a total of 135 sub-sub plots measuring 3 m x 3 m each with an alley of 1 m between replicates and 2 m between blocks in each of the locations. The plots were later cultivated to ridges using the traditional hoes at 75 cm apart. The second year (2013) experiment was carried on the same piece of land using the same plots.

2.3 Application of Soil Amendments

The poultry manure (PM) was sourced from layers' litters in a deep litter system from a private farm at Otobi, this was analyzed for nutritional quality (Table 1) and applied at the rate of 9 t ha^{-1}. [8] reported application 10 t ha^{-1} of poultry manure in southwest Nigeria. The PM was incorporated into the soil three weeks before planting to allow curing. For the inorganic fertilizer, N P K (15:15:15) + urea fertilizers were applied to obtain 120:60:60 kg ha^{-1} ($N:P_2O_5:K_2O$), this was by band placement at 5 cm away from the plant and 3 cm deep into the soil. Fertilizer was applied in split form; the compound (NPK) was applied at 2 weeks after planting (WAP) and urea was later top dressed at 4 WAP. Weed control was done manually with hand held hoe at 3 and 7 weeks after planting to reduce weed competition with the crop.

2.3.1 Chemical properties of poultry manure applied

The chemical properties of the poultry (PM) manure applied had pH (H_2O) of 6.90, while organic carbon content and total nitrogen were 18.30 and 1.67 g kg^{-1} Exchangeable K and Ca were 2.72 and 11.60 cmol kg^{-1} while available P was 4.88 mg kg^{-1}.

2.4 Planting

Maize (*Zea mays* L) variety *Oba super II* which served as the test crops was planted on the ridges in August for 2012 and 2013 seasons. Three seeds of maize were planted at the spacing of 75 (inter row) cm x 50 cm (intra row) and later thinned to two plants per stand; giving a total plants population of about 53,333 plants per hectare.

2.5 Soil Sampling/Analysis

A cylindrical core sampler (homemade instrument) with height of 5 cm and a diameter of 5 cm was used to collect undisturbed soil sample from each plot for bulk density determination as described by [14]. Soil bulk density (BD) was determined at 4, 6 and 8 weeks after planting (WAP). Disturbed soil samples were also taken from each plot for routine analysis. The bulk samples were air-dried and gently crushed using mortar and pestle. The samples were then passed through 2 mm sieve, collected and packed for laboratory analysis. Particle size distribution was determined by Bouyoucos hydrometer as described by [15]. Soil pH in KCl (1:1) was determined by electrometric method. The wet oxidation method of [16] was used to determine the organic carbon content. Bray-1 method was used to determine the extractable phosphorus [17].

2.6 Crop Data Collection

The plant height of maize was measured from the basal node to the node before the flag leaf using measuring tape at 4, 7 and 10 weeks after planting (WAP).Grain yield was determined by harvesting the net plot, that is, the two middle rows manually and cobs were dried to constant weight and later shelled to determine the seed weight and grain yield.

2.7 Data Analysis

Data generated were subjected to analysis of variance (ANOVA) test, using GENSTAT release 12.1 (VSN International Ltd) Software and means were separated using Least Significant Difference (LSD) at 5% level of probability.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Physicochemical properties of the soil after topsoil removal and before planting

The particle size distribution (PSD) of the soil before planting indicated a decrease in the sand fraction with increase in the depth of topsoil removal with consequent increase in the clay content at Makurdi (Table 1). The sand fraction ranged between 758 g kg^{-1} at 0 cm depth to 690 g kg^{-1}, while clay content increased from 122 g kg^{-1} at 0 cm to 187 g kg^{-1} at 20 cm depth. At Otobi, sand ranged between 735 – 658 g kg^{-1} at 0 – 20 cm depths while the highest clay content (192 g kg^{-1}) was observed at 20 cm depth. The textural class of the two locations was sandyloam (Table 1). Bulk density (BD) increased with soil depth from 1.42 g cm^{-3} at 0 cm depth to 1.48 g cm^{-3} at 20 cm depth at Makurdi while at Otobi it ranged between 1.39 to 1.52 g cm^{-3} at 0 – 20 cm depth (Table 1). The pH of the soil at 0 – 20 cm depth of topsoil removal ranged between 6.30 to 6.12 at Makurdi, and 6.25 to 6.05 at Otobi, (Table 1). Organic matter and total nitrogen were highest on the control plot (no topsoil removal) with value of1.93 and 0.11 g kg^{-1} at Makurdi and (2.63 and 0.12 g kg^{-1}) at Otobi while the lowest values for organic matter and total nitrogen were recorded at the 20 cm depths (0.17 and 0.08 g kg^{-1}) for Makurdi and (0.35 and 0.08 g kg^{-1}) for Otobi (Table 1). At Makurdi, the CEC decreased from 8.80 at 5 cm depth to 6.10 cmol kg^{-1} at 20 cm depth while at Otobi the highest value (9.10 cmol kg^{-1}) was observed at 0 cm depth with lowest (5.80 cmol kg^{-1}) recorded at 20 cm depth (Table 1).

Topsoil removal significantly (P = .05) increased soil bulk density (BD) at different growth stages of the maize during the 2012 and 2013 cropping seasons at Makurdi and Otobi (Tables 2). At 4 WAP, BD increased significantly from 1.37 g cm^{-3} at 0 cm to 1.49 g cm^{-3} at 20 cm depth in 2012 and 1.35 g cm^{-3} at 0 cm to 1.46 g cm^{-3} in2013 at 20 cm depth (Table 2). At Otobi, soil bulk density also significantly increased from 1.22 g cm^{-3} at 0 cm to 1.31 g cm^{-3} at 20 cm depth at 8 WAP in 2012. The interaction between depth of topsoil removal and soil amendments significantly affected soil bulk density during 2012 and 2013 cropping seasons at Makurdi and Otobi (Fig. 1). The mean values of soil bulk density indicate a significant reduction at each depth due to application of poultry manure compared with values obtained where inorganic fertilizer was applied and also the zero application (control). Zero application at 20 cm depths gave the highest values of soil bulk density at Makurdi. Also, at Otobi the interaction caused significant changes on soil BD (Fig. 1). Application of PM on the 0 cm depth significantly (Fig. 1) reduced the BD while the highest value was observed on the plots treated with IF at the 20 cm depth in 2012.

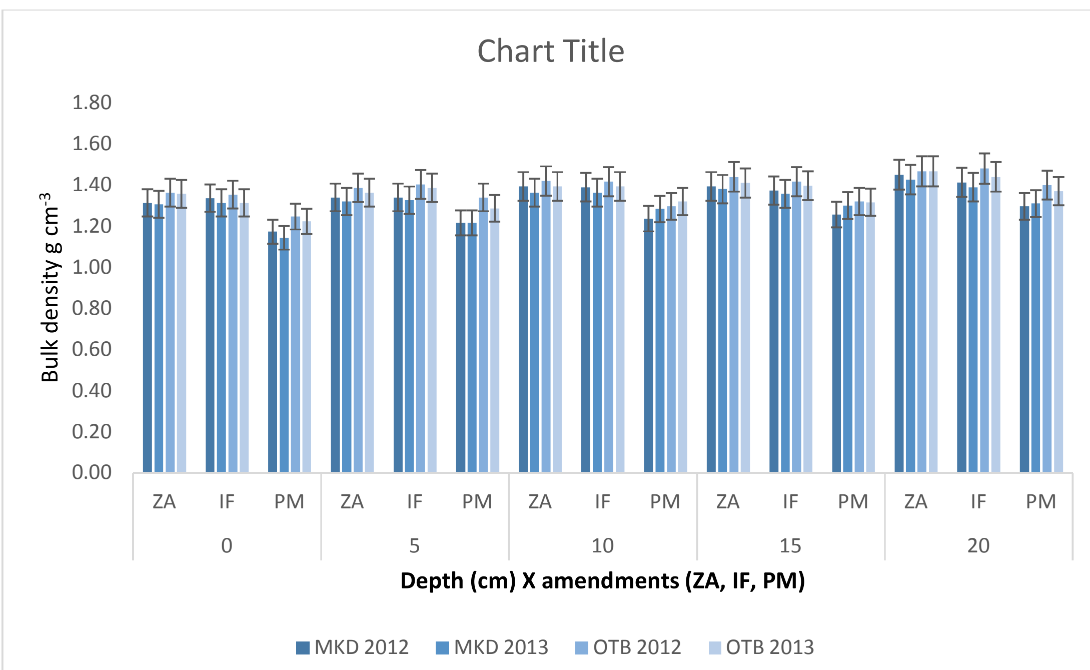

Fig. 1. Interaction effects of topsoil removal and soil amendments on bulk density Amendments

(ZA= zero application, IF=inorganic fertilizers, PM=poultry manure) MKD = Makurdi OTB = Otobi

Table 1. Physicochemical properties of the soil before planting at Makurdi and Otobi

Depths (cm)	Sand	Silt	Clay	Text class	BD ($g\ cm^{-3}$)	Porosity (%)	pH (KCl)	N ($g\ kg^{-1}$)	Ca (cmol/kg)	K (cmol/kg)	Mg (cmol/kg)	CEC (cmol/kg)	Avai. P ($mg\ kg^{-1}$)
	PSD ($g\ kg^{-1}$)												
Makurdi													
0	758	120	122	Sandyloam	1.42	46.41	6.30	0.11	4.00	1.96	0.44	8.77	5.22
5	751	114	135	Sandyloam	1.45	45.28	6.20	0.10	3.70	1.8	0.38	8.80	4.88
10	734	113	153	Sandyloam	1.44	45.70	6.15	0.10	3.90	1.62	0.35	7.40	4.71
15	724	125	151	Sandyloam	1.46	44.90	6.15	0.08	3.60	1.74	0.33	6.30	4.51
20	690	133	187	Sandyloam	1.48	44.15	6.12	0.08	3.10	1.56	0.29	6.10	4.42
Otobi													
0	735	133	132	Sandyloam	1.39	47.40	6.25	0.12	4.60	1.88	0.38	9.10	5.85
5	722	141	137	Sandyloam	1.43	46.03	6.22	0.11	3.00	1.93	0.41	7.90	5.77
10	670	142	188	Sandyloam	1.48	44.90	6.20	0.10	3.50	1.77	0.36	7.74	4.82
15	699	136	165	Sandyloam	1.46	44.15	6.10	0.08	3.40	1.62	0.32	6.30	4.15
20	658	150	192	Sandyloam	1.52	44.53	6.05	0.08	1.80	1.55	0.30	5.80	3.96

PSD= Particle size distribution, Text class=Textural class, BD= Bulk density

Table 2. Effects of topsoil removal, cropping systems and soil amendments on soil bulk density and Makurdi and Otobi

Depth	Bulk density ($g\ cm^{-3}$)											
	Makurdi						Otobi					
	2012			2013			2012			2013		
	4 WAP	6 WAP	8 WAP	4 WAP	6 WAP	8 WAP	4 WAP	6 WAP	8 WAP	4 WAP	6 WAP	8 WAP
Topsoil depth removal (cm)												
0	1.37	1.31	1.15	1.35	1.31	1.1	1.39	1.35	1.22	1.4	1.33	1.18
5	1.39	1.32	1.18	1.37	1.31	1.19	1.5	1.37	1.25	1.45	1.36	1.23
10	1.44	1.34	1.23	1.4	1.34	1.28	1.54	1.36	1.23	1.49	1.36	1.25
15	1.44	1.34	1.24	1.43	1.32	1.29	1.52	1.38	1.26	1.48	1.38	1.26
20	1.49	1.36	1.31	1.46	1.35	1.32	1.58	1.46	1.31	1.54	1.43	1.31
LSD (P<0.05)	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.05	0.02	0.01	0.04

	Bulk density (g cm^{-3})											
Depth	**Makurdi**						**Otobi**					
	2012			**2013**			**2012**			**2013**		
	4 WAP	**6 WAP**	**8 WAP**	**4 WAP**	**6 WAP**	**8 WAP**	**4 WAP**	**6 WAP**	**8 WAP**	**4 WAP**	**6 WAP**	**8 WAP**
	Cropping systems											
SM	1.44	1.34	1.25	1.43	1.33	1.25	1.51	1.4	1.25	1.47	1.39	1.24
MSI	1.43	1.33	1.19	1.4	1.33	1.22	1.5	1.38	1.23	1.47	1.36	1.21
SS	1.4	1.33	1.23	1.37	1.32	1.24	1.52	1.37	1.29	1.46	1.36	1.28
LSD (P<0.05)	0.03	0.02	0.02	0.02	NS	0.02	0.02	0.01	0.04	NS	0.02	0.02
	Soil amendments											
ZA	1.47	1.39	1.28	1.44	1.35	1.28	1.51	1.4	1.25	1.47	1.39	1.24
IF	1.44	1.37	1.3	1.42	1.34	1.3	1.5	1.38	1.23	1.47	1.36	1.21
PM	1.37	1.25	1.09	1.35	1.28	1.13	1.52	1.37	1.29	1.46	1.36	1.28
LSD (P<0.05)	0.03	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.04	NS	0.02	0.02

LSD= Least significant difference, CRS= Cropping systems, SM= Sole Maize, MSI= Maize soybean intercrop, SS= Sole soybean, ZA= Zero application, IF= Inorganic fertilizer, PM= Poultry manure, Amd= Amendments. NS = Not significant, WAP= Weeks after planting

The soil bulk density was significantly higher on sole soybean plots at 8 WAP in 2012 and 2013 compared with sole maize plots, while maize soybean intercrop plots had the lowest values at Makurdi (Table 2). The application of poultry manure significantly reduced the soil BD during the 2012 and 2013 cropping seasons compared with plots that were treated with NPK + urea fertilizer, while the control (zero application plots) had the highest values of BD for the two seasons at Otobi (Table 2).

3.2.1 Effect of topsoil removal on soil organic matter (OM) content

There were significant relationships between topsoil removal and the organic matter (OM) content of the soil for the two cropping seasons (2012 and 2011) in the two locations (Fig. 2.). For every centimeter (cm) of topsoil removal, OM decreased by 0.04 g kg^{-1} in 2012 and 0.10 g kg^{-1} in 2013 at Makurdi. Meanwhile, at Otobi, the loss of 0 – 1 cm depth of topsoil resulted in the decrease in OM content by 0.06 g kg^{-1} in 2012 and 0.07 g kg^{-1}in 2013.

3.3 Effect of Topsoil Removal and Amendments on the Performance of Maize

3.3.1 Maize plant height

The removal of topsoil caused significant reduction in the vegetative growth of maize in this study. At 7 and 10 WAP, plant height of maize was significantly (P = .05) higher at 0 cm and decreased with increase in topsoil removal in 2012 and 2013 (Table 3) at Makurdi. At Otobi, topsoil removal also caused a significant reduction in the plant height of maize in 2012 and 2013. Sole maize plots were significantly higher in height compared with maize soybean intercrop plots at Otobi during the 2012 and 2013 cropping seasons (Table 3). Cropping systems had no significant effect on maize plant height during the 2012 cropping season at Makurdi, however, in 2013, sole maize plots significantly gave higher plant height compared with the intercrop plots at 4, 7 and 10 WAP at Makurdi (Table 3).

The application of poultry manure gave consistent and significant higher values of maize plant height than the plots that were treated with inorganic fertilizer in 2012 and 2013 both at Makurdi and Otobi (Table 3). At 10 WAP for instance, maize height was 158 cm in 2012 and 152 cm in 2013 for plots treated with PM while the plots treated with IF recorded 95 and 150 cm for the same period at Otobi.

3.3.2 Grain yield of maize

The removal of topsoil caused significant reduction in the grain yield of maize during the 2012 and 2013 cropping seasons in the two locations (Table 4). A yield reduction of 21% in 2012 and 26% in 2013 were recorded at 5 cm depth of soil removal compared with the values obtained where no topsoil was removed; whereas the decline in maize grain yield due to loss of 10 cm depth was equivalent to 25 and 33 % for the two seasons at Makurdi (Table 4). Furthermore, the removal of 15 cm depth of soil caused 29% yield reduction of maize in 2012 and 31% in 2013, while 38 and 68% yield reduction were recorded due to removal of 20 cm depth for 2012 and 2013 seasons at Makurdi. At Otobi (Table 4), the grain yield of maize for the 2012 and 2013 seasons was 2093 and 2225 kg ha^{-1} at 0 cm depth which was significantly higher than the values obtained at 5 to 20 cm topsoil removal.

Sole maize (SM) plots had significant higher grain yield (1765 kg ha^{-1}) than the maize soybean intercrop (MSI) plots (1565 kg ha^{-1}) (Table 4). Likewise, at Otobi, SM was higher (1694 and 1586 kg ha^{-1}) than MSI (1484 and 1468 kg ha^{-1}) for 2012 and 2013 cropping seasons respectively. The application of soil amendments significantly (P = .05) increased the grain yield of maize compared with other treatments in this study (Table 4).

A significant higher grain yield was obtained on the plots treated with poultry manure than those treated with inorganic fertilizers.

The interaction between Topsoil removal and soil amendments cause significant reduction in the grain yield of maizein this study. The mean of both locations, Makurdi and Otobi, and seasons 2012 and 2013, (n = 4) indicate the lowest yield reduction (17%) due to application of poultry manure at 5 cm depth of topsoil removal (Fig. 3). However, at 20 cm depth, application of poultry manure caused the highest maize grain yield reduction (59%). Likewise, the trio interactions of topsoil removal, cropping systems and soil amendments showed significant reductions in the grain yield of maize (Fig. 4). The highest percentage yield reduction (62%) was recorded at 20 cm depth for sole maize under zero application while, the lowest yield reduction (15%) in the interaction which translates to the

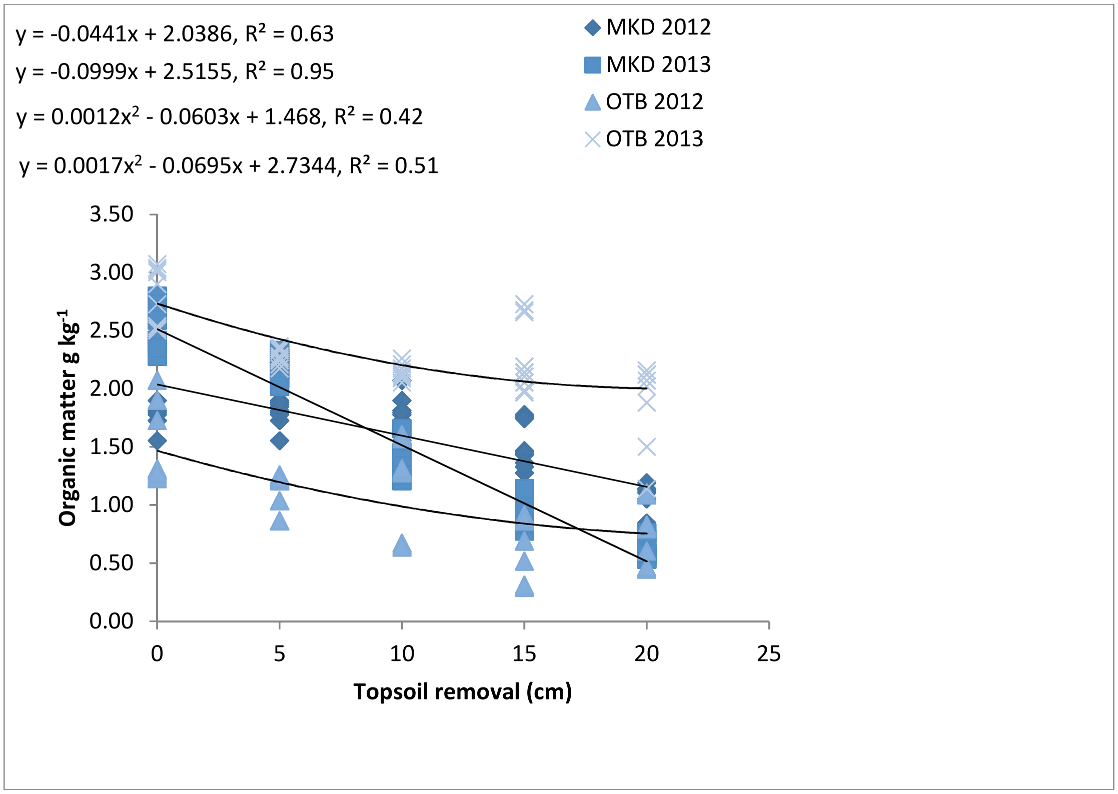

Fig. 2. Effect of topsoil removal on the organic matter content of the soil for 2012 and 2013 at Makurdi and Otobi

highest grain yield was observed at 5 cm depth under sole maize with the application of inorganic fertilizer (Fig. 4). A higher maize yield reduction was observed on maize soybean intercrop plots compared with the sole maize plots across the depths with the application of inorganic fertilizer. Whereas, application of poultry manure caused higher yield reduction under sole maize plots compared with maize soybean intercrop at 5 and 10 cm depths (Fig. 4).

4. DISCUSSION

4.1 Effect of Topsoil Removal and Amendments on Soil Properties

The soils of Makurdi and Otobi were predominantly sandy loam texture at 0 to 20 cm depth. Topsoil removal (simulated erosion) exposed soil layers with different particle size distribution (PSD) which were locations specific. Therefore, the variability in texture to be experienced even for the same soil group due to erosion would differ from one location to another. This has implication for heterogeneity of soils after erosion, and the need for location specific management. According to [4], the initial particle size distribution and time seemed to affect the texture of the exposed soil layer than by the depth of soil removal [7] observed a site–specific decrease in the magnitude of clay content of exposed subsoil.

The increase in soil bulk density with the depth of topsoil removal, at Makurdi and Otobi may be attributed to the compaction of the subsurface layer of the soil, because bulk density is an indicator of soil compaction and soil health. Topsoil removal caused increase in bulk density because soil organic matter which plays a vital role in lowering the soil BD was very low at the sub-soil compared with the topsoil, [7] reported that changes in bulk density affected 20% productivity of the soil in their two study sites, [6] reported increase in soil bulk density (BD) with depth of topsoil removal from a mean value of 1.38 g cm^{-3} under control to 1.55 g cm^{-3} at 20 cm depth of removal in Southwest Nigeria. The increase in the BD of the soil with increase in the depth of topsoil removal suggested that soil loss has declining effect on the productivity of the soil. Meanwhile, application of 9 ton ha^{-1} of poultry manure significantly (P = .05) reduced the bulk density of the soil compared with the application of inorganic fertilizer (120:60:60 kg ha^{-1} N: P_2O_5: K_2O) and the control plots. Several studies have established the significant role of the poultry manure in improving both the physical and chemical properties of the soil [18,19,20]. The poultry manure is believed to enhance soil organic matter, which in turn has stabilizing effect on soil aggregates thereby reducing the BD of the soil. In this study, the lower BD observed due to application of PM could be attributed to an increase in the organic matter from the PM. [21] found that soil physical properties were improved with the application of poultry manure. The interaction between depth of topsoil removal and soil amendments suggests that application of PM reduced BD compared with other treatments across the depth of topsoil removal.

In this study, the significant reduction in OM content of the soil due to 20 cm topsoil removal were equivalent to 43% in 2012 and 21% in 2013 at Makurdi; while that of Otobi was 49% in 2012 and 26% in 2013. The significant higher value of organic matter on the 0 cm could be due to the presence of litters and the accumulation of plants and animalresidue on the soil surface which have decomposed over time. The decrease in organic matter and consequent increase in soil bulk density observed was consistence with the findings of [22] who reported a negative correlation between organic matter content and soil bulk density. [7] observed 2 and 18% decreased in soil organic matter due to removal of 3 and 6 cm topsoil which also reduced soil productivity. Organic carbon was reported to be 9 to 16 times higher in poultry manure than the surface soil where no topsoil was removed [8]. [23] reported that the maintenance of soil organic matter through organic manuring accounts for about 80% of the CEC in tropical soils.

4.2 Effect of Topsoil Removal and Amendments on Maize Plant Height and Grain Yield

The significant higher height of maize observed at the 0 cm depth (control plot) could be attributed to higher nutrient status at soil surface compared with the subsoil as revealed by the results of the analyzed soil chemical properties before planting where nutrient elements decreased with increase in the depth of topsoil removal. Topsoil which was richer in soil organic matter and lower soil bulk density was more favourable for maize vegetative growth to produce taller plants compared with the desurfaced depths. At the higher depth of topsoil removal, maize roots growth and development might have been limited by higher bulk density and lower porosity coupled with low organic matter content which could have been responsible for the low agronomic performance compared with the surface soil. The growth and development of plant could be influenced by soil chemical properties as well as the concentration of various minerals at the end of cropping season [24].

The reduction in the grain yield of maize with increase in topsoil removal at the two locations (Table 4) may be attributed to the decline in soil quality indicators such as increase in soil BD with depth as well as the progressive decline in OM content of the soil with depth. This is consistent with the findings of [6], that maize yield significantly decreased in the first year from 3.2 t ha^{-1} on the control plot to 0.12 t ha^{-1} where 20 cm of topsoil was removed and correspondingly from 1.85 to 0.09 t ha^{-1} in the second year cropping. [8] observed 17% reduction in maize grain yield due to 15 cm topsoil removal and 67% due to 25 cm depth of soil removal. Likewise, [25] reported that the grain yield response was in the order of topsoil removal (3.1 Mg ha^{-1}) < undisturbed control (5.6 Mg ha^{-1}) < topsoil addition (7.8 Mg ha^{-1}). [9] reported 54.4% yield reduction in maize biomass due to 10 to 20 cm depth of soil removal. The general trend in the interactions between topsoil removal, cropping systems and soil amendments was that, application of inorganic fertilizer caused less maize grain yield reduction under sole maize system whereas application poultry manure caused less maize grain yield reduction under maize intercrop system across the depth of topsoil removal (Fig. 4). This implied that while inorganic fertilizer would improve the grain yield of maize grown as sole under topsoil loss condition, the grain would be better enhanced with the application of poultry under maize intercrop system under topsoil loss condition.

The low grain yield of maize (generally< 1000 kg ha^{-1}) suggested very poor soil tolerance (Table 4). However, the comparative yield advantage of plots treated with Poultry manure relative to other treatments suggested that PM could better improve the performance of maize after erosion.

Table 3. Effects of topsoil removal, cropping systems and soil amendments on the plant height of maize at Makurdi and Otobi

Depth	Plant height (cm)											
	Makurdi						Otobi					
	2012			2013			2012			2013		
	4 WAP	6 WAP	8 WAP	4 WAP	6 WAP	8 WAP	4 WAP	6 WAP	8 WAP	4 WAP	6 WAP	8 WAP
Topsoil depth removal (cm)												
0	18	48	122	24	94	161	15	64	125	23	92	150
5	17	44	117	24	86	152	15	47	121	22	77	139
10	17	52	102	23	81	131	14	50	109	18	69	131
15	15	36	99	22	75	126	13	49	76	17	62	137
20	16	31	102	18	58	114	11	41	70	15	55	115
LSD (P = .05)	NS	13	17	2	9	6	2	7	15	1	8	8
Cropping systems												
SM	17	38	107	23	83	140	14	54	106	20	73	138
MSI	17	46	109	21	75	134	14	46	94	19	68	131
LSD (P = .05)	NS	NS	NS	2	5	2	NS	6	8	1	4	4
Soil amendments												
ZA	9	16	64	16	48	105	8	27	47	15	41	102
IF	10	29	89	17	70	147	10	39	95	14	69	149
PM	32	81	173	34	118	158	23	84	158	29	103	152
LSD (P = .05)	2	11	11	2	6	3	1	6	9	1	5	6

LSD= Least significant difference, CRS= Cropping systems, SM= Sole Maize, MSI= Maize soybean intercrop, SS= Sole soybean, ZA= Zero application, IF= Inorganic fertilizer, PM= Poultry manure, Amd= Amendments. NS = Not significant, WAP= Weeks after planting

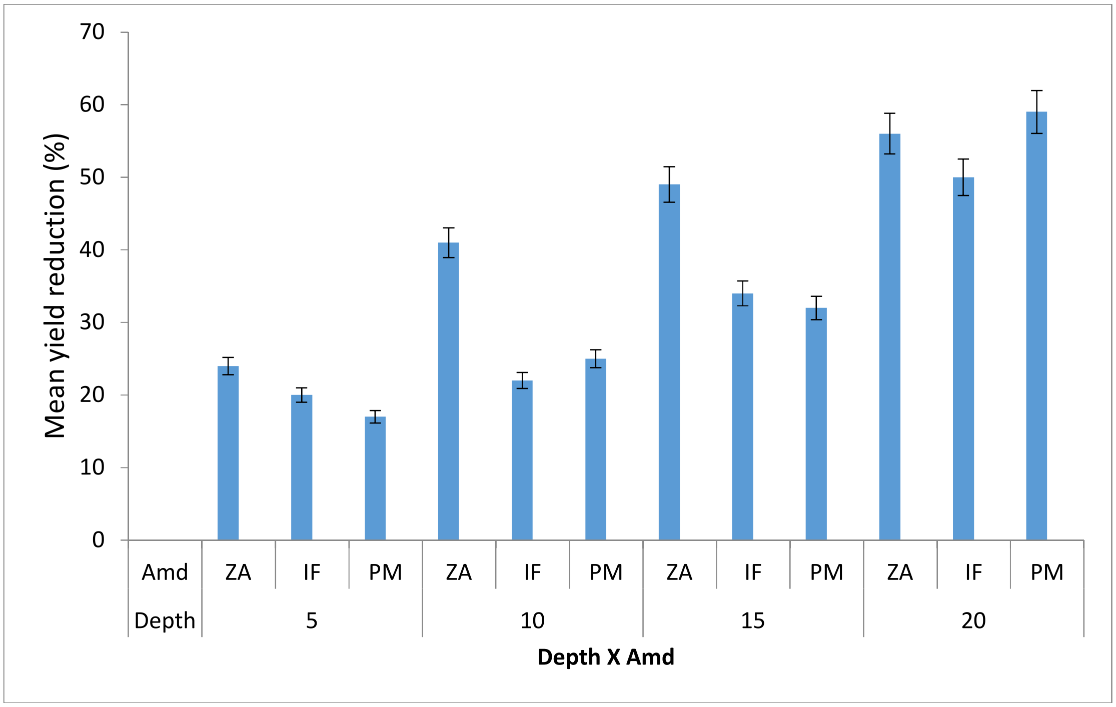

Fig. 3. Interaction effects of topsoil removal and soil amendments on maize grain yield.
Mean of both locations, Makurdi and Otobi,and seasons, 2012 and 2013, (n = 4); Error bars gives 95 % interval of confidence. Depth = depth of topsoil removal (cm) Amd = Amendments (ZA= zero application, IF = inorganic fertilizers, PM = poultry manure)

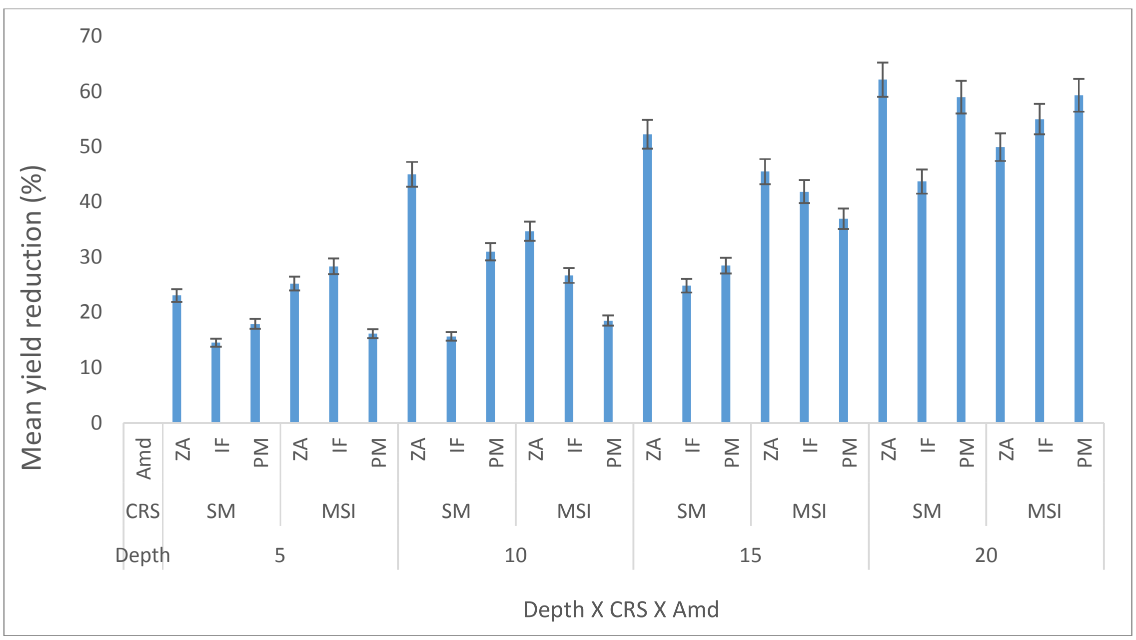

Fig. 4.Trio interaction effects of topsoil removal, cropping systems and soil amendments on maize grain yield
Mean of both locations, Makurdi and Otobi,and seasons, 2012 and 2013, (n = 4); Error bars gives 95% interval of confidence. Depth = Depth of topsoil removal (cm) CRS = Cropping systems; Amd = Amendments (ZA= Zero application, IF = Inorganic fertilizers, PM = Poultry manure)

Table 4. Main effect of depth of topsoil removal, cropping systems and soil amendments on grain yield of maize during 2012 and 2013 cropping season at Makurdi and Otobi

	Grain yield kg ha^{-1}			
	Makurdi		Otobi	
	2012	**2013**	**2012**	**2013**
Depth of topsoil soil removal (cm)				
0	2144	2352	2093	2225
5	1704	1843	1717	1872
10	1618	1580	1620	1694
15	1523	1623	1483	1082
20	1336	749	1033	764
LSD (P<0.05)	109	151	149	156
Cropping systems				
SM	1765	1623	1694	1586
MSI	1565	1636	1484	1468
LSD (P<0.05)	138	NS	40	62
Soil amendments				
ZA	568	641	557	604
IF	1558	1443	1374	1584
PM	2868	2804	2836	2393
LSD (P<0.05)	112	149	82	113

LSD= Least significant difference, CRS= Cropping systems, SM= Sole Maize, MSI= Maize soybean intercrop, SS= Sole soybean, ZA= Zero application, IF= Inorganic fertilizer, PM= Poultry manure, Amd = Amendments. NS = Not significant

5. CONCLUSION

The findings of this study revealed that both physical and chemical properties of the soil deteriorated with topsoil removal, resulting in significant poor performance of maize. The decrease in organic matter content and consequent increase in soil bulk density with increase in the depth of topsoil removal adversely affected maize performance in the two locations. The intercrop of maize and soybean significantly reduced the bulk density of the soil, likewise, the application of poultry manure. In the interaction between topsoil removal and soil amendments, application of poultry manure caused significant reduction in soil bulk density across the depths of topsoil removal. The growth and development of maize was better enhanced with reduced soil bulk density.

The percentage maize yield reduction during the 2012 and 2013 was lower (18 and 16%) and (23 and 24%) at Otobi compare with that of Makurdi (21 and 26%) and (25 and 33%) at 5 and 10 cm depths, whereas, at 15 and 20 cm depths, percentage yield reduction which suggested low soil tolerance was higher at Otobi (29 and 51%) and (51 and 66%) compared with Makurdi (29 and 31%) and (38 and 68%). Application of poultry manure gave a comparative yield advantage of maize relative to the other treatments, therefore, the restorative ability of an eroded soil could be better enhanced with the application of poultry manure compared with the use of inorganic fertilizer. However, the interaction between topsoil removal and soil amendments suggests that inorganic fertilizer would improve the grain yield of maize grown as sole under topsoil loss condition, while the grain would be better enhanced with the application of poultry under maize intercrop system under topsoil loss condition.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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