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Influence of Simulated Erosion on Soil Properties and Maize Yield in the Southern Guinea Savanah Zone of Nigeria I

Agada B.I. [a*], Agber, P.I. [a], Idoga S. [a] and Ugese F.D. [a]

[a] *Department of Soil Science, Federal University of Agriculture Makurdi, Benue State, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Long term studies were initiated to study topsoil loss and its effects on soil properties and crop yield. This study was conducted during the 2016 through 2019 cropping seasons to assess the influence of artificial topsoil loss on soil properties and grain yield of maize. Three geo- referenced sites within the Federal University of Agriculture Makurdi, Nigeria namely: Site 1, Site_2 and Site_3 were used for the experiment. Erosion levels were established in June 2016 only by the incremental removal of topsoil at various depths. The study of crop productivity using simulated erosion was conducted using Randomized Complete Block Design (RCBD) with desurfaced soil depths of 0cm (control), 5cm, 10cm, 15cm and 20cm as treatments. One profile pit was also dug in each of the three sites for soil characterization and soil type establishment. Data collected on soil physical and chemical properties as well as crop growth parameters and grain yield were subjected to Analysis of Variance (ANOVA) using R Statistical Software. Results of the study showed that the soils of the

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**Corresponding author: Email: blihotu81@gmail.com;*

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three sites were classified as Kandic Paleustepts for Site_1, Typic Plinthustalfs for Site_2 and Typic Hapluderts for Site_3. We report the effects of topsoil loss on soil characteristics in this paper for two years only.

Keywords: Simulated erosion; soil fertility; soil- crop productivity relations.

1. INTRODUCTION

The aim of soil conservation is to obtain the maximum sustained level of production from a given area of land whilst maintaining soil loss below a threshold level which permits the natural rate of soil formation to keep pace with the rate of erosion. Soil is dynamic and prone to rapid degradation with land misuse [1]. The management and conservation of soil and water resources are critical to human wellbeing as soil is a non- renewable resource over the human time scale [1]. Their prudent use and management are more important now than ever to meet the high demands for food production and to satisfy the needs of an increasing world population. The soil is the most fundamental and basic resource. Soil degradation by accelerated erosion is a serious problem, especially in developing countries of the tropics and sub-tropics [2]. Alfisols, the predominant soil of the sub-humid regions of West Africa, are easily degraded with continuous cultivation [3]. Pathak et al. [4] enumerated the problems of Alfisols as crusting and sealing, rapid drying of the soil surface, poor infiltration, low soil fertility, low soil moisture storage capacity, leaching and compacted sub-soil layer. Severe soil degradation in West Africa are due to land misuse and soil mismanagement, harsh climate, the susceptibility of the soil to degradation, and the predominance of resource-based and exploitative agricultural systems based on low external input and soil-mining systems [3]. Soil degradation implies long-term decline in soil's productivity and its environment moderating capacity [5,3]. In other words, it means decline in soil quality or reduction in attributes of the soil in relation to specific function of value to humans [6,3]. Soil erosion is widely considered the most serious form of soil degradation [7]. Soil erosion exacerbates soil degradation and vice versa. Various research and historical evidence show that soil loss can reduce the potential soil productivity of agricultural crops [8,9,10,11]. Soil loss above certain critical limits will lead to degradation of soil reserve, soil fertility and accelerate silting of dams and estuaries and, in some instance, burial of fertile agricultural soils by new sediments [12]. Neil et al [13] stated that, soil loss would lead to the soil profile being shortened, as well as to decreased rooting depth and water storage capacity. The question then arises, what limit of soil loss from an area is 'critical" or to what extent can soil loss be tolerated without loss of productivity? Soil loss tolerance is defined as the maximum acceptable level of soil loss from an area which will allow a high level of productivity to be maintained indefinitely [14]. Mannering [15] defines the term soil loss tolerance (T value) to denote the maximum level of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely.

The objective of this study was to assess soil physical and chemical properties of the study area and the effect of topsoil loss on soil properties and maize productivity amongst major soil types in Benue state.

2. MATERIALS AND METHODS

2.1 Field and Laboratory Methods

The experiment was carried out through 2016 to 2019 planting seasons at three geo referenced locations. At each location a 17m x 28 m plot was mapped and used for the experiment. A onetime artificial removal of the topsoil soil at five (5) depths was carried out in year 2016. The depths are 0 cm serving as the control, 5 cm, 10 cm, 15 cm and 20 cm topsoil removal respectively. Soil samples were collected from the various desurfaced depths in each plot, using free surveying technique to choose observation points. Profile pits were dug to characterize and establish the soil type of each location. Soil samples were collected from various points of the experimental site and bulked into a composite sample to determine the physical and chemical properties of the soil before planting.

The soil was tilled to the depth ranging from 18cm to 22cm using traditional hoes. Maize (Oba super VI hybrid variety) was used as a test crop.

2.2 Soil Physico-Chemical Properties

The particle size determination was by the Bouyoucous [16] hydrometer method. Available water capacity (AWC), was determined using a pressure plate apparatus at 0. l kPa (field capacity) and 1500 KPa (permanent wilting point) as described by IITA (1979). Undisturbed core samples, were used to determine the soil gravimetric water content and bulk density according to the method described by Blake and Harlage (1986). The total porosity was obtained from the bulk density value and assumed particle density of 2.65 g cm^{-3} as follows;

Total porosity (TP) = 100 X [1- ρ_b /ρ_p] …. (1), Where: TP = Total porosity; ρ_b = Bulk density;ρ_p = Particle density (2.65 g cm^{-3}). The soil penetrometer resistance was measured using a pocket penetrometer. The pH of the soil was determined in water using the glass electrode pH meter [18]. Organic carbon was determined by the Walkley and Black [17] method as modified by Allison [19]. The percentage organic matter was calculated by multiplying the value of organic carbon by the conventional Van Bemmler factor of 1.724, which is based on the assumption that in the tropics, soil organic matter contains 58% organic carbon.The total nitrogen was determined by the micro – Kjeldahl distillation method [20] using $CuS0_4$/Na_20_4 catalyst mixture. The ammonia from the digestion was distilled with 45% NaOH into 2.5% boric acid (H_3 $B0_4$) and determined by titrating with 0.05 N KCL. For the exchangeable bases, the complexometric titration method described by Chapman [21], was used for the determination of calcium and magnesium. Sodium and potassium were extracted using 1N ammonium acetate (NH_4 OAC) solution and then determined by flame photometry.

Available phosphorus was determined by the method of Bray and Kurtz, (1945). Exchangeable hydrogen and aluminum as exchangeable acidity, were extracted using the titrimetric method of Mclean [18]. The Cation Exchange Capacity (CEC) of the soil was obtained by the ammonium acetate method (NH_4 OAC), [22].

3. RESULTS AND DISCUSSION

3.1 Climatic Data of the Study Area

The rainfall distribution, relative humidity and temperature for the study location for both years during the growing season are shown in (Table 1). Growing season precipitation for the period was adequate. In 2016, the monthly rainfall recorded was 215.60 mm, 213.80 mm 268.90 mm and 116.10 mm for the months of July, August, September and October respectively (Table 1). In 2017, the amount of rainfall recorded in the months of July, August September and October was 95.7 mm, 224.3 mm, 158.7 mm and 73.9mm respectively. The total rainfall amount for each month in 2016 was higher than the amount of rainfall in 2017. The longest dry spells following rainfall pentad classification was seven days obtained in the month of October [23]. The temperature for the growing season period ranged from 30.9°C for July to 32.5 °C for October in 2016 while for the 2017 cropping season it ranged between 31 °C in July to 30.1 °C in October (Table 1). Sunshine hours were lowest in the months of July and August for both years. The relative humidity was above 80% during the growing season for both years.

3.2 Morphological Soil Properties of the Study Sites

A summary of the morphological properties of the soil is presented in Table 2. At Site_1, the soils were dark brown (5 YR3/2) at the surface but became lighter with depth it had no mottles. Texturally, the soils were sandy loam and had a crumb structure with water table at 57cm depth. Roots were few and had a clear, smooth boundary. Site_2, had a dark brown color (5YR 4/3) with no mottles a crumb structure and a gravelly sandy loam texture. The consistence when wet was non -sticky and non- plastic and was very friable when moist with clear smooth boundary at the surface horizon. For the subsurface horizon the color became lighter (7.5YR 5/6) and had few roots with water table at 71 cm depth.

For Site_3, surface color was 5YR2.5/1 texture was gravelly sandy clay loam had few fine faint mottles. Roots were fine and common; the soil was slightly sticky and had an abrupt but clear boundary. At the subsurface depth, the mottles were common fine and faint with a color of 5YR/5/8. The texture also varied from sandy clay loam to clay at the subsoil, the structure too changed from crumb to sub angular blocky few fine roots and a clear smooth boundary.

3.3 Soil Properties of the Study Sites

Some of the physical and chemical properties of the soil, at the start of the experiment at depths of 0 -30 cm for the study sites are presented in (Table 3). The percentage sand content at Site_1 was 75.9 %, Site_2 was 76.7 % while that of Site_3 was 70.9 %. Similarly, the silt content at Site_1 was 13.1 %, Site_2 was 12.8 % and

Site_3 was 13.3%. The percentage clay content was 13.1 %, 12.8 % and 15.8 % for Site_1 Site_2 and Site_3 respectively. The soils bulk density was high for the study locations, the distribution showed that values ranged between 1.43 to 1.53 Mg/m^3. These values were tending towards compacted soils. The penetration resistance values were 0.36 Kg cm^2 for Site_1, 0.68 Kg cm^2 for Site_2 and 0.65 Kg cm^2 for Site_3. The porosity had values of 46 %, 44 %, 45% respectively for the three sites. The value was lowest at Site_2 as compared to the other two locations. The permeability class for all the three locations were moderately slow with mean weight diameter (MWD) values of 0.65, 0.63 and 0.28 for Site_1 Site_2 and Site_3 respectively (Table 3). The soil pH was 6.6, 6.5 and 6.5 the pH was slightly acidic and close to neutral at all the locations. While the percentage organic carbon was 0.92, 1.07 and 1.04 for the sites in the order Site_1, Site_2 , Site_3 respectively. The percentage nitrogen was 0.16, 0.19 and 0.20 in the order Site_1 < Site_2 < Site_3. The physical and chemical properties of the soil at depths greater than 30 cm. (30 cm, 60 cm and 90 cm) are presented in (Table 4). The percentage sand content at Site_1 ranged between 75.9 – 68 %, that of Site_2 ranged between 76.7 – 66.1 % while that of Site_3 ranged between 70.9 – 60.1 %.

Agronomy Research farm (Site_3) at the surface, had the lowest sand content when compared to the other two sites. Similarly the silt content for Site_1 site ranged between 14 – 11.1 % , Site_2 ranged between 14.6 – 10.5 % and Site_3 ranged between 17 – 13.3 %. The percentage clay content range was 18- 13.1%, 19.3 – 12.8% and 23.9 -15.8% for Site_1, Site_2 and Site_3 respectively. The textural class changed from sandy loam (SL) to sandy clay loam (SCL) with increasing depth for Site_2 and Site_3.

The soil pH was 6.6, 6.5 and 6.5 while the percentage organic carbon was 0.92, 1.07 and 1.04 for the sites in the order Site_1, Site_2 and Site_3 respectively at the surface horizon.

3.4 Effect of Topsoil loss on Soil Physical and Chemical Properties

3.4.1 Effect of artificial top soil loss on soil physical properties

The physical properties of the desurfaced soils as affected by topsoil loss are presented in Tables 5-7. For the 2016 cropping season, the percentage sand and silt content decreased down the depths of the soil profile, while the clay content increased as depth of soil removal increased for the three sites respectively. In 2017, the percentage sand content decreased as the depth of soil loss increased. The percentage silt content showed a variable pattern while the percentage clay content increased for all the three sites respectively. The effects of desurfacing on soil bulk density for 2016 and 2017 cropping seasons at Site_1, Site_2 and Site_3 is presented in Fig. 1. The results showed that soil dry bulk density increased as the depth of top soil removal increased at all the sites in both cropping years. The bulk density was significantly ($P < 0.001$) affected by the removal of top soil. However, it was observed that higher bulk density values were obtained at Site_2 as compared to the other two sites for the year 2016. In 2017 cropping season, bulk density was highest in Site_1 and Site_2. The mean soil bulk density values ranged between 1.42 – 1.51 Mg/ m^3, 1.45 – 1.53 Mg /m^3 and 1.42 – 1.52 Mg /m^3 for Site_1, Site_2 and Site_3 respectively for the 2016 cropping year. In 2017, mean dry bulk density values were 1.44- 1.53 Mg/m^3, 1.44 – 1.53 Mg/m^3 and 1.42 -1.52 Mg/ m^3 respectively for the three sites.

The mean values of soil penetration resistance increased with increasing soil loss depth (Tables 5-7) for both years across the three locations. The soil total porosity decreased with increased incremental depth of desurfaced soil. The highest values were obtained in the 0 cm control plots.

3.4.2 Effect of top soil loss on soil chemical properties

The chemical properties of the soils as affected by artificial top soil loss is presented in (Tables 8-10). The soil pH increased with depth at Site_1 and at Site_2 but showed no definite pattern at Site_3. However, for the other soil properties, percentage organic carbon, total nitrogen(N), available phosphorus (P), potassium (K), Calcium (Ca), Magnesium (Mg) and Cation Exchange Capacity (CEC) they all decreased with increasing depth of topsoil removal for all the three locations and for both cropping seasons. Fig. 2 shows the relationship of organic carbon (OC) to depth of soil loss. The organic carbon ranged between 1.04 – 0.45 across the locations for both years for the depths of 0 cm and 20 cm respectively. Organic carbon was highest on the 0cm control plots.The same trend was observed for nitrogen, phosphorus, potassium, calcium, magnesium and Cation exchange capacity (CEC) Tables 8 -10.

Table 1. Meteorological Data at Makurdi In 2016 and 2017 Cropping Seasons

	2016				2017			
Month	**Rainfall Total frequency (mm)**	**Temperature(^{o}c).Max.**	**Relative humidity (%)**	**Sunshine (hrs.)**	**Rainfall Total frequency (mm)**	**Temperature (^{o}c) Max.**	**Relative humidity (%)**	**Sunshine (hrs.)**
Jan	0.00	35.4	27	7.50	0.00	36.40	49	7.20
Feb	0.00	38.4	29	6.90	0.00	38.10	31	5.70
Mar	47.60	35.7	73	6.00	0.00	39.50	59	8.20
April	91.10	34.0	73	7.10	88.3	36.30	70	6.40
May	23.80	33.4	79	7.70	24.58	33.20	78	6.70
June	49.40	31.8	80	6.20	123.9	32.10	80	6.60
July	215.60	30.9	84	4.70	95.7	31.00	84	5.10
Aug	213.80	30.6	84	3.50	224.3	30.10	86	3.50
Sept	268.90	30.9	85	4.40	158.7	31.10	82	4.50
Oct	116.10	32.5	81	6.90	73.9	30.10	83	6.60
Nov	0.00	35.3	71	8.50	0.6	34.60	69	5.80
Dec	0.00	35.4	52	7.50	0.00	36.00	51	6.90

***Source**: Nigerian Meteorological Agency, Headquarters, Tactical Air Command, Makurdi- Airport*

Table 2. Morphological Properties of the Soils of the Study Sites

Horizon/ Depth(cm)	Color (Moist)	Mottles	Texture	Structure	Consiste-nce	Inclusions	Remarks (boundary)
Site_1 0-57	5YR/3/2	None	SL	weak/fine/ crumb	NS/NP Friable	Roots/ Com/fine	WT@57cm /few/s.stones
Site_2 0-28	5YR/4/3	None	SL	weak/fine/ crumb	NS/NP VFriable	Roots/ few/Coarse	CS
28-71	7.5YR/5/6	None	Gravelly SL	Mod/f/m/c crumb	Sl.sticky/ Sl/plastic/Vfriable	Roots	WT@71cm
Site_3 0-30 (Ap)	5YR/2.5/1	Few/fine Faint	Gravelly/ Clayloam	weak/fine/ crumb	Sl.sticky/ Sl.plastic/ friable	Roots/ Com/Fine/medium	AC
30-69	7.5YR/4/6	Common/ Fine/Faint	Clay	Moderate/ Fine/ sbk	V.sticky/firm	Roots Few/fine	CS
69-100	10YR1.5/1	5YR/5/8 5YR4/6	Clay	Moderate/ fine/sbk	V.sticky/V.firm	-	WT@100 /Fe concretions

Determined at moist condition, note: symbols according to FAO 2006.
Structure:*0=Structureless,1=weeak,2=moderate,3=strong, sbk = sub angular blocky* ***Consistence:*** *V= very, V.friable =Very friable, Sl= Slightly Sticky/plastic.* ***Textur****e: SL=Sandy loam.* ***Roots:*** *1=few 2=moderate3=many, com=common.* ***Boundary:*** *A= Abrupt, C=clear, S=Smooth G=Gradual W= Wavy.* ***WT:*** *= Water table, S.stones= Sand stone, Mod= Moderate, NS= Non Sticky, NP= Non Plastic, f= fine, m=medium, c=coarse, Fe= iron.*

Table 3. Some selected physical and chemical properties of the study sites (0-30cm) at the start of the experiment

Soil property	Site_1	Site_2	Site_3
Sand(%)	75.9	76.7	70.9
Silt (%)	11.1	10.5	13.3
Clay(%)	13.1	12.8	15.8
Textural Class	Sandy loam	Sandy loam	Sandy loam
pH (in water)	6.6	6.5	6.5
Bulk Density (Mg /m^3)	1.44	1.48	1.45
Total Porosity (%)	46	44	45
Penetration Resistance (Kg/cm^2)	0.36	0.68	0.65
Hydraulic Conductivity (Cm/Sec) x 10^{-4}	5.09 x 10^{-4}	3.14 x 10^{-4}	3.53 x 10^{-4}
Permeability Class	Moderately slow	Moderately slow	Moderately slow
Aggregate Stability (MWD in mm)	0.65	0.63	0.28
Organic Matter (%)	1.82	1.62	1.72
Nitrogen (%)	0.16	0.19	0.20
Available P (mg Kg^{-1})	4.5	6.0	3.5
Potassium ($Cmol^{(+)}kg^{-1}$)	0.26	0.22	0.28
Base Saturation (%)	85.1	83.1	85
ECEC(Cmol $^{(+)}$ kg^{-1})	7.4	6.7	7.4

Table 4. Some selected soil physical and chemical properties of the study sites at lower depths

	Site_1	Site_2	Site_3
DEPTH/Soil Properties	**0-30**	**0-30**	**0-30**
Sand(%)	75.9	76.7	70.9
Silt(%)	11.1	10.5	13.3
Clay(%)	13.1	12.8	15.8
Textural Class	SL	SL	SL
pH (in water)	6.6	6.5	6.5
Bulk Density M(g /m^3)	1.44	1.48	1.45
Total Porosity (%)	46	44	45
Hydraulic Conductivity (Cm/Sec) x10^{-4}	2.09 x10^{-4}	3.14 x10^{-4}	3.53 x10^{-4}
Permeability Class	**Moderate**	**Moderately Slow**	**Moderately Slow**
Available Water Capacity (cm/cm)	0.28	0.17	0.18
Organic Carbon (%)	0.92	1.04	1.07
Nitrogen (%)	0.38	0.35	0.25
Sodium (Na) ($Cmol^{(+)}kg^{-1}$)	0.24	0.51	0.25
Potassium (K) ($Cmol^{(+)}kg^{-1}$)	0.26	0.22	0.28
Magnesium (Mg)($Cmol^{(+)}kg^{-1}$)	2.7	2.4	2.8
Calcium(Ca)($Cmol^{(+)}kg^{-1}$)	3.1	2.7	3.0
Available P.(mg kg^{-1})	4.5	6.0	3.5
ECEC(Cmol $^{(+)}$ kg^{-1})	7.4	6.7	7.4
P = Phosphorus			

Table 5. Mean effect of desurfacing on some soil physical properties at site_1, 2016 and 2017

Soil property/Depth (cm)	0	5	10	15	20
Year 2016					
Sand (%)	77.3a	77.2ab	76.9ab	76.4ab	76.0ab
Silt (%)	10.3a	10.4a	10.5ab	10.9ab	10.6ab
Clay (%)	12.6a	12.5a	12.9a	12.9a	13.4a
Bulk density (Mg /m^3)	1.42a	1.45b	1.47bc	1.49cd	1.51e
Total porosity (%)	46.2a	45.4ab	44.8ab	44.0c	42.9d
Penetrometer resistance (Kg cm^{-2})	0.36a	0.58a	0.72a	1.22ab	1.58bc

Year 2017					
Sand (%)	77.2a	76.9a	75.9ab	76.0abc	75.7bc
Silt (%)	10.36a	10.46a	10.95ab	10.99ab	10.71ab
Clay (%)	12.44a	12.48a	12.81ab	12.96abc	13.36abc
Bulk density (Mg /m^3)	1.44a	1.45b	1.48c	1.51d	1.53e
Total Porosity (%)	45.4a	44.9a	44.0ab	43.1b	41.9d
Penetrometer resistance (Kg m^{-2})	0.36a	0.45a	0.67a	1.18ab	1.45bc

Note: *Means with the same letters across the rows are not significantly different from each other($P<0.05$)*

Table 6. Mean Effect of Desurfacing on Some Soil Physical Properties at Site_2, 2016 and 2017

Soil property/Depth(cm)	**0**	**5**	**10**	**15**	**20**
Year 2016					
Sand (%)	76.4a	76.3b	75.9c	75.4d	75.1e
Silt (%)	10.8a	10.9a	11.0a	11.45a	11.18a
Clay (%)	12.8a	12.7a	13.1a	13.0a	13.5a
Bulk density (Mg /m^3)	1.45d	1.47e	1.49e	1.52f	1.54g
Total Porosity (%)	45.1a	44.3a	43.6b	42.9b	41.8c
Penetrometer resistance (Kg cm^{-2})	0.68a	0.91b	1.04b	1.55bc	1.91c
Year 2017					
Sand (%)	76.7a	76.5a	75.4ab	75.5abc	75.2bc
Silt (%)	10.75a	10.86a	11.35a	11.38a	11.11a
Clay (%)	12.64a	12.68a	13.00ab	13.16bc	13.56bc
Bulk density (Mg /m^3)	1.44a	1.46b	1.48c	1.51d	1.53e
Total Porosity (%)	45.6a	45.2a	44.3ab	43.4bc	42.2d
Penetrometer resistance (Kg m^{-2})	0.18a	0.28a	0.49a	1.01ab	1.28bc

Note: *Means with the same letters across the rows are not significantly different from each other($P<0.05$)*

Table 7. Mean effect of desurfacing on some soil physical properties at site_3 2016 and 2017

Soil property/Depth(cm)	**0**	**5**	**10**	**15**	**20**
Year 2016					
Sand (%)	76.3a	76.2a	75.9a	75.3ab	75.0b
Silt (%)	11.01a	11.1a	11.0a	11.6a	11.4a
Clay (%)	12.7a	12.6a	13a	13a	13.5a
Bulk density (Mg/m^3)	1.42a	1.45b	1.47bc	1.49cd	1.52e
Total Porosity (%)	46a	45a	44.6ab	43.8bc	42.7d
Penetration resistance (Kg cm^{-2})	0.65a	0.88a	1.01a	1.51ab	1.88bc
Year 2017					
Sand (%)	76.3a	76.2a	75.9a	75.3ab	75.0b
Silt (%)	11.01a	11.1a	11.0a	11.6a	11.4a
Clay (%)	12.7a	12.6a	13a	13a	13.5a
Bulk density (Mg /m^3)	1.42a	1.45b	1.47bc	1.49cd	1.52e
Total Porosity (%)	46.0a	45.4a	44.6ab	43.8bc	42.7d
Penetrometer resistance (Kg m^{-2})	0.65a	0.88a	1.01a	1.51ab	1.88bc

Note: *Means with the same letters across the rows are not significantly different from each other($P<0.05$)*

Table 8. Mean effect of desurfacing on some soil chemical properties at Site_1, 2016 and 2017

Soil Property/Depth (cm)	**0**	**5**	**10**	**15**	**20**
Year 2016					
pH (in water)	6.3a	6.5a	6.4a	6.7a	6.8a
N (%)	0.14b	0.09c	0.06d	0.04e	0.03f
Avail. P (mg kg^{-1})	3.6f	3.26ef	2.89bc	2.64ab	2.28a
K(Cmol(+) kg^{-1})	0.27a	0.23b	0.22c	0.20e	0.18f

Soil Property/Depth (cm)	0	5	10	15	20
Year 2016					
Organic Carbon (%)	0.92a	0.78b	0.66dc	0.43d	0.37d
Ca (Cmol(+) kg^{-1})	2.96a	2.71a	2.65a	2.72a	2.65a
Mg (Cmol(+) kg^{-1})	2.6a	2.4a	2.4a	2.4a	2.36a
ECEC (Cmol(+) kg^{-1})	7.9g	7.4g	6.6e	6.2e	6.0de
Year 2017.					
pH (in water)	6.49a	6.44a	6.15b	6.09bc	5.92cd
N (%)	0.32a	0.26b	0.22bc	0.16d	0.09e
Avail. P (mg kg^{-1})	4.05a	3.62a	3.0b	2.77bc	2.46bc
K (Cmol (+) kg^{-1})	0.29a	2.23b	0.17c	0.15d	0.14e
Organic Carbon (%)	1.08a	0.94b	0.80c	0.67d	0.53e
Ca (Cmol (+) kg^{-1})	3.09a	2.81a	2.67ab	2.57bc	2.52bc
Mg (Cmol (+) kg^{-1})	2.70a	2.50a	2.36b	2.22bc	2.21bc
ECEC (Cmol (+) kg^{-1})	7.83a	7.03b	6.49c	6.19cd	5.98de

Note: *Means with the same letters across the rows are not significantly different from each other ($P<0.05$)*

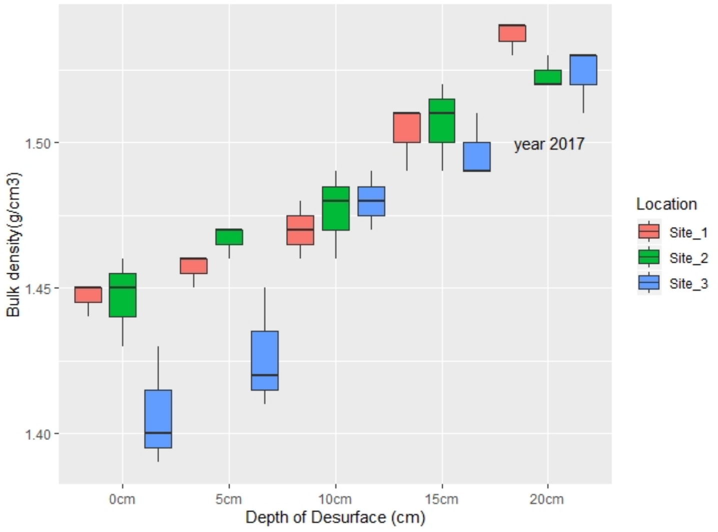

Fig. 1. Trend of Mean Effect of Top soil removal on Bulk Density across the Three Location for year 2017

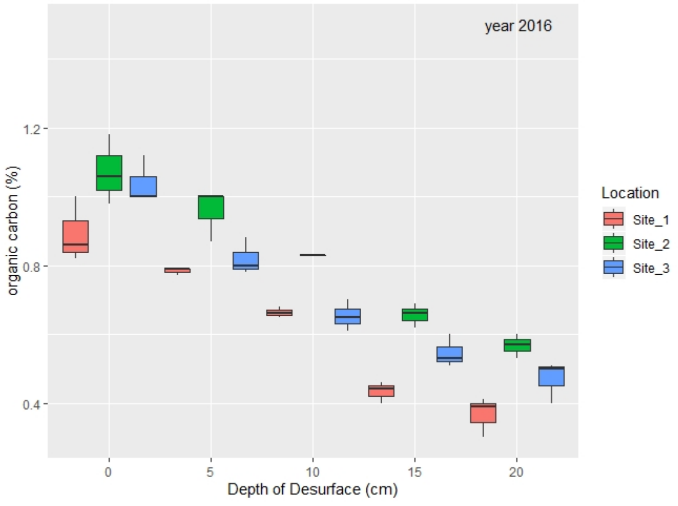

Fig. 2. The mean effect of depth of soil surface loss (cm) on organic carbon (%) for the study sites 2016

Table 9. Mean effect of desurfacing on some soil chemical properties at site_2, 2016 and 2017

Soil Property/Depth(cm)	0	5	10	15	20
Year 2016					
pH(in water)	6.5a	6.7a	6.7a	6.7a	6.7a
N (%)	0.15a	0.10b	0.08b	0.05d	0.05d
Avail. P (mg kg^{-1})	4.52a	4.19b	3.81b	3.57c	3.2c
K (Cmol(+) kg^{-1})	0.28a	0.24b	0.23d	0.22d	0.19f
Organic Carbon(%)	1.07a	0.9b	0.83c	0.66d	0.56d
Ca (Cmol(+) kg^{-1})	3.3a	3.1a	3.0b	3.0b	2.9b
Mg (Cmol(+) kg^{-1})	2.9a	2.7a	2.6a	2.4a	2.4a
ECEC (Cmol(+) kg^{-1})	8.2a	7.7a	6.9b	6.5bc	6.3bc
Year 2017					
pH (in water)	6.48a	6.44a	6.14b	6.08bc	5.92c
N (%)	0.35a	0.29b	0.24b	0.18d	0.11e
Avail. P (mg kg^{-1})	4.39a	3.96a	3.35b	3.12b	2.81b
K (Cmol(+) kg^{-1})	0.31a	0.26b	0.20c	0.18c	0.16c
Organic Carbon (%)	1.02a	0.87b	0.73c	0.60d	0.45e
Ca (Cmol(+) kg^{-1})	3.21a	2.93a	2.80a	2.69b	2.64b
Mg (Cmol(+) kg^{-1})	2.92a	2.72a	2.58b	2.44b	2.43b
ECEC (Cmol(+) kg^{-1})	8.18a	7.38b	6.83c	6.55c	6.34d

***Note:** Means with the same letters across the rows are not significantly different from each other ($P<0.05$)*

Table 10. Mean effect of desurfacing on some soil chemical properties, at Site_3, 2016 and 2017

Soil Property/Depth(cm)	0	5	10	15	20
Year 2016					
pH (in water)	6.3a	6.6a	6.5a	6.7a	6.5a
N (%)	0.16a	0.11b	0.09b	0.06c	0.05c
Avail. P (mg kg^{-1})	3.9a	3.6a	3.2b	3.0b	2.6c
K (Cmol (+) kg^{-1})	0.28a	0.23b	0.22c	0.2d	0.19e
Organic Carbon (%)	1.04a	0.82b	0.65c	0.54d	0.47de
Ca (Cmol (+) kg^{-1})	3.3a	3.0ab	3.0ab	3.0b	2.9ab
Mg (Cmol (+) kg^{-1})	3.0a	2.7a	2.7a	2.9a	2.7a
ECEC (Cmol (+) kg^{-1})	7.9a	7.4a	6.6b	6.2b	6.0c
Year 2017					
pH (in water)	6.49a	6.45a	6.15b	6.09bc	5.92d
N (%)	0.28a	0.22b	0.18b	0.12d	0.05e
Avail. P (mg kg^{-1})	4.22a	3.79a	3.18b	2.94bc	2.63c
K (Cmol (+) kg^{-1})	0.34a	0.28b	0.23c	0.19d	0.18e
Organic Carbon (%)	1.08a	0.93b	0.79c	0.66d	0.52e
Ca (Cmol (+) kg^{-1})	3.40a	3.12a	2.99b	2.88c	2.83c
Mg (Cmol (+) kg^{-1})	3.08a	2.86a	2.73a	2.60b	2.59b
ECEC (Cmol (+) kg^{-1})	7.82a	7.02b	6.48c	6.18cd	5.97e

***Note:** Means with the same letters across the rows are not significantly different from each other ($P<0.05$)*

3.4.3 Effect of artificial topsoil loss on soil properties

The soil pH (In water) was highest at Site_1. The pH of the soil also varied with depth although there was no definite pattern at Site_3, the pH increased as the depth of the topsoil removal increased across the locations. However, the increases were not statistically significant from the uneroded (0 cm) control plots. This contradicts earlier findings of Obi et al. [24], Oyedele and Aina, [25], Agber, [26], who reported decreasing pH with increased top soil removal. It however, agrees with those of Larney et al. [27], Gollany et al. [28], Tanaka and Aase, [29] who obtained increased pH as topsoil removal increased. This may be linked to higher $CaC0_3$ at lower depths within the soil profile. The removal of top soil significantly ($P < 0.001$) increased dry bulk density between the control (0cm) and all the treatment depths of 5 cm, 10 cm, 15 cm and 20 cm (Fig. 1). However, the difference between plots with 10cm, and 15cm, depth of top soil removal was not statistically significant (Table 5-7). The Bulk density (BD) values of the desurfaced plots were below critical values for root growth in sandy loam soils but still high to adversely affect crop performance [30]. The BD is a soil quality indicator used extensively to quantify the extent of soil compaction and is usually very influential to root growth and proliferations both of which are indices of soil productivity. Lal [31], reported a similar change in bulk density from a naturally eroded soil. Similarly, the removal of topsoil significantly increased the penetrometer resistance which serves as a function of the soil resistance to root proliferation and seedling emergence. Salako et al. [32] reported similar findings for penetration resistance on an Alfisol topo- sequence. The mean values at Site_1 ranged from 1.45 kg cm^{-2} at the 20 cm desurfaced plots to 0.36kg cm^{-2} for the uneroded (0 cm) plots. For Site_2 it was 1.25kg cm^{-2} to 0.18kg cm^{-2} and 1.88 kg cm^{-2} to 0.65kg cm^{-2} for Site_3 respectively. These soils which are inherently low in organic carbon coupled with high intensity rains could lead to loss of soil structure and compaction and may be the cause of the higher bulk density and penetration resistance values obtained for the study area. Increases in the bulk density also significantly lowered the soil total porosity as depth of topsoil loss increased for both cropping years and across the three locations. The lower B.D and Penetrometer resistance values at the (0cm) uneroded plot coupled with the higher aeration (high total porosity) and fertilizer application may be linked to higher yields obtained on the 0 cm no- desurface plots compared to the desurfaced plots.The organic carbon content of the soils were generally low, mostly less than 2% [33,26].The low organic matter at all the location may be partly due to rapid mineralization as a result of high temperatures and continuous cultivation. The percentage organic carbon (OC) decreased significantly ($p < 0.001$) as the depth of top soil removal increased at all locations for both years. The soil organic carbon was highest under the uneroded (0 cm) plots. In comparison to the uneroded check plots, the percentage organic carbon reduced by 60% when 20 cm of topsoil was removed at Site_1, 48% for Site_2 and 55% for Site_3 for year 2016. While for year 2017 it was 52%, 55%, and 51% respectively. The percentage OC increased relatively in 2017 over that of year 2016 for only Site_2, from 48% to 55 % while for Site_1 and Site_3, it decreased in 2017 as compared to 2016. Larney et al. [34], found that the removal of 20 cm of topsoil led to a loss of 71% OC at Hill Spring site and 47% at Lethbridge Dryland site in Alberta, Canada. Total nitrogen (N) was moderately high at the uneroded (0 cm) plots. This may be partly due to the fertilizer additions the percentage total N values obtained were more than 0.24 % [35]. The removal of topsoil significantly reduced total nitrogen across the varying depths of topsoil removal. The mean values for the uneroded (0 cm) plots across the three locations for the 2016 cropping season were 0.14 %, 0.16 %, and 0.15% for Site_1, Site_2 and Site_3 respectively. In contrast, the mean values for the 20 cm desurfaced plots for the three sites were 0.03 %, 0.05 %, and 0.05% respectively [36]. The Available P, exchangeable bases, CEC all decreased with increasing topsoil removal at the three sites and for the two- cropping season reported. The reductions were usually more drastic from the plots of 10 cm topsoil removal treatment when compared with 5 cm and the 0 cm (uneroded) control plots. The difference however, was not significant across the treatments for Mg and Ca in 2016 for the three sites, but in year 2017, there was significant difference at deeper topsoil removal treatments (Tables 8-10).

4. CONCLUSION

Careful observation and interpretation of the data obtained from this study revealed that, the study sites have sandy loam texture with low values of soil nutrients, organic matter values were 1.82, 1.62, 1.82, for percentage Nitrogen were 0.16, 0.20 for Site_1, Site_2 and Site_3 respectively, while soil PH was 6.6, 6.5, 6.5 for Site_1, Site_2 and Site_3 before the application of treatments.

Artificial top soil loss significantly ($p = 0.001$) caused a reduction in porosity, organic carbon (OC), Nitrogen(N) while it caused an increase in bulk density, soil pH and penetrometer resistance when the soils were desurfaced at 5 cm, 10 cm, 15 cm, 20 cm respectively in comparison to the 0 cm control plots. The study also finds that artificial top soil removal had profound impact on some soil physical properties (Bulk density porosity and clay and sand) and chemical (organic carbon, nitrogen and pH) while negligible effects were observed on calcium, magnesium and potassium.

The compensation for erosion by chemical fertilization alone cannot increase productivity: thus farmers should be taught the need for residue management on fields to improve soil structural properties and nutrition. The study underlines the need for site specific prioritization, conservation agriculture, should be encouraged too.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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