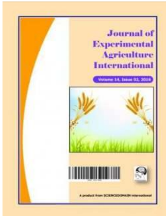

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Effects of Landscape Slope Position, Urban Refuse Compost and Sewage Sludge on Soil Properties and Cassava Yield in South Eastern Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors RAE and CLAA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors TEO and RSA managed the analyses of the study. Authors OJU, OA and ONU managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Understanding the effects of landscape slope position and organic waste residues on soil properties and cassava yield is a critical component of site-specific management. A field study was conducted in an Ultisol at Nsukka, southeastern Nigeria to investigate the effects of landscape slope positions and two organic waste residues (urban refuse compost and sewage sludge) on soil properties and cassava yield. The treatment consisted of two landscape slope positions, two organic waste residues, and a control; arranged in a split – plot design in RCBD. The two slope positions - mid slope (26%) and toe slope (5%) occupied the main–plot, while organic residues at the rate of 50% inorganic nitrogen fertilizer requirement of cassava and a control were the sub-plot treatment. The result obtained from this study showed that slope position significantly ($p<0.05$) influenced the soil

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properties after harvest. The toe-slope soil was significantly ($p<0.05$) higher in dry bulk density, water holding capacity, field capacity moisture content and more resistant to mound dispersion by rain drops. The mid-slope soil was significantly ($p<0.05$) higher in percent water stable aggregates. There was significant difference ($p<0.05$) between the non-amended plots and the organic wastes amended plots in respect of aggregate stability as measured by percent water stable aggregate (% WSA) index. Post-harvest soil analysis revealed that plots amended with urban refuse compost (UR) and sewage sludge (SS) did not differ significantly in their pH, total porosity, bulk density, water holding capacity, field capacity moisture content, saturated hydraulic conductivity and mound dispersion as measured by length of exposed nail. Weed infestation, fresh shoot and root yield were significantly ($p>0.05$) higher at the toe slope position. However, percent survival was significantly ($p>0.05$) higher at mid slope position. Significant interactions of the slope positions and organic residues were observed in bulk density, total porosity and fresh root yield. The highest fresh cassava root yield of 11.63 tha^{-1} of the study was obtained in plots amended with urban refuse compost under the toe slope position. Urban refuse compost had the least fresh root yield per hectare (1.32 tha^{-1}) when applied in midslope landscape position but highest (11.63 tha^{-1}) when applied in toe-slope landscape position.

Keywords: Landscape slope position; urban refuse; sewage sludge; ultisol; cassava.

1. INTRODUCTION

Cassava (*Manihot esculenta crantz*) is an important cash and food crop of resource-limited farmers in Africa, Asia, Latin America and the Caribbean. It offers many different alternative uses as processed food, animal feed, starch, alcohol, biofuel for vehicles etc. Nigeria produces over 45 million tons of cassava per annum, making her the largest producer of cassava in the world [1]. There is considerable pressure on farmers to increase cassava root yield per unit area to meet with the agricultural transformation agenda of the Federal government.

Increasing population and intensive cultivation has exerted tremendous pressure on available land leading to soil degradation. Low soil fertility is therefore, one of the bottlenecks to sustainable cassava production and productivity in Nigeria. Although cassava tolerates harsh environmental conditions such as low soil fertility, it is known to respond to applications of organic and inorganic fertilizers [2]. The cost of inorganic fertilizer has been enormously increasing to the extent that they are out of reach of the small and marginal farmers. It has become impracticable to apply such costly inputs for a crop of low marginal returns. Therefore, a search for an alternative fertilizer resource becomes increasingly important.

The application of organic wastes with a high organic matter content, such as sewage sludge [3] and urban refuse [4] to soil is a current environmental and agricultural practice for maintaining soil organic matter, reclaiming degraded soils, and supplying plant nutrients. Urban refuse and sewage sludge have shown positive effects on soil properties and on food and fiber production [5,6]. However, research information is quite scarce on response of cassava to the application of these wastes. Changes in physical condition and chemical composition of soils may be induced by application of these wastes and should be considered in the agricultural utilization of such materials.

The increased demand for cassava production has also induced farming of marginal lands on steep slopes previously held in pasture and wood lot. Landscape position is a key factor influencing soil properties under a hill slope and micro catchment scale. Slope defines flow patterns such as runoff generation, drainage, nutrient redistribution; contributes to spatial differences in soil properties and influence crop yield [7-10]. In a study, Tsui et al. [11] reported that slope factor involved in the transport and accumulation of solutes resulted in higher pH, exchangeable Ca and Mg in the depositional areas of foot slope, while higher organic carbon, exchangeable Na, available nitrogen, potassium and extractible Zn were highest on the summit. Gebeyaw, [12] also reported that clay fraction of lower slope soil was highest, followed by middle slope, intermediate slope and higher slope. Conversely, sand was highest at higher slope, followed by middle slope, intermediate slope and lower slope, respectively. The highest corn biomass production, nutrient uptake and grain yield were obtained in lower slope position than upper and middle slope positions [13].

Although, the influence of landscape position on soil properties are established, further studies are required to assess its effects on an Ultisol; amended with urban refuse , sewage sludge and fresh cassava root yield. Research findings in relation to influence of slope position can provide information on soil suitability for cassava production, diagnosing soil constraints and potentials as basis for recycling urban refuse and sewage sludge.

This study therefore intends to add new data on the potential effect of landscape position and organic residues (urban refuse and sewage sludge) on the root yield of cassava and properties of an Ultisol in Nsukka, Southeastern Nigeria.

2. MATERIALS AND METHODS

2.1 Description of Study Area

The research was carried out in the Laboratory and Research Farm of the Department of Soil Science and Land Resources Management, University of Nigeria, Nsukka. The site is located at Latitude 06°25′ N and Longitude 07°24′ E and altitude of approximately 400 m above sea level. Generally, the climate was characterized by mean annual total rainfall of about 1600 mm and mean annual evapotranspiration (ET) of about 1560 mm. The soils used for the study belong to the Nkpologu series classified as a typic kandic paleustult [14] that lie at two slope positions – mid slope (26%) and toe slope (9%). Urban refuse compost was collected from a refuse dump site at Nsukka while sewage sludge was collected from the University sewage treatment plant.

2.2 Field Study

The experimental design was a split- plot design in RCBD with three replications. Slope position (mid slope and toe slope) constituted the main plot treatment while organic residues (urban refuse compost and sewage sludge) and un-amended control, constituted the sub-plot treatment. The study was conducted in 147 m^2 (14 m x 10.5 m) block in each landscape slope position. The land was prepared by clearing, tilling and ridging manually because of the steep slope. The ridges were aligned across the slope direction. The size of each experimental plot was $12m^2$ (4m X 3m) with 50 and 100 cm paths separating adjacent plots and blocks, respectively. Each waste (Urban refuse, Sewage sludge) was applied at the rate that would supply half the mineral nitrogen fertilizer recommendation of 17 kg/ha for cassava [15], 3 weeks before the desired planting date and ploughed under immediately.

Cassava cuttings of TMS 30572 variety was planted at a spacing of 1 m X 1 m to give a plant population of 10, 000 stands/ha. Twenty – 6" nails were inserted into the topmost part of the ridges in each plot to assess soil loss due to soil detachment from ridges as determined by length of exposed nails at the end of farming season. Weeding was done by hand picking and the weight of weeds collected from each plot was dried and weighed. Harvesting was done after ten months of planting. At harvest, the number of survived plants was counted and their percentage computed. Then, their roots and shoots were harvested, weighed and recorded.

2.3 Laboratory Studies

Some chemical properties of the urban refuse and sewage sludge were determined using standard laboratory methods. Prior to land preparation, surface (0-20 cm) soil samples were collected using steel core (internal diameter of 5cm and height of 6 cm) over each slope position. Disturbed soil samples were also collected using an auger, air-dried and passed through 2 mm sieve for routine analysis. Core and auger soil samples were also collected from each treatment after harvest for analysis. Gravimetric moisture content and water retained at field capacity (FC) was determined using methods outlined by Obi [16]. Analysis of particle size distribution of the < 2mm fractions was done by the Bouyoucos hydrometer method as described by [17] using sodium hexametaphosphate. Soil bulk density was determined by the core method [18] using the formula,

$$BD\ (g\ cm^{-1}) = MS / V$$

Where,

BD = bulk density (Mgm^{-3})
MS= mass of dry soil sample (g)
V =Volume of sample (cm^3)

The soil volume is equivalent to the volume of the core.

$$V = \pi r^2 h$$

Where,

V = volume of core = volume of soil.
π= constant 3.142
r = radius of the core (2.5 cm)
h = height of the core (6 cm)

Aggregate stability was determined using wet sieving methods [19]. In this method, 25 g of the <4.75 mm soil sample was put in the topmost of a nest of four sieves of 2.00, 1.00, 0.50 and 0.25 mm sizes. Water-stable aggregates (WSA) on each sieve were estimated after wet sieving and oven drying and recorded as percentages of the original mass as shown:

$$WSA = (Mr/Mt) \times 100$$

Mr is mass of resistant aggregates and Mt is the total mass of wet-sieved soil. The WSA were then categorized into 4.75-2.00, 2.00-1.00, 1.00-0.50, 0.50-0.25 and <0.25 mm.

Saturated hydraulic conductivity was determined using steady-flow soil column method [20]. Total porosity was calculated from the relationship between bulk density and particle density. Particle density (ρp) was assumed 2.65 Mg m^{-3} for most mineral soils.

$$ST = (1 - \rho b / \rho p) \times 100$$

ST = Total porosity (%)
ρb = bulk density (Mg m^{-3})
ρp = particle density(Mg m^{-3})

Air porosity (space occupied by air when the sample is at field capacity i.e. at 0.1 bar suction for sandy soils) was expressed as percentage of the sample volume and calculated thus:

$$S = St - Qv\ (0.1)$$

S = air porosity (or macro porosity) (%)
ST = Total porosity (%)

Q V. (60cm) = percentage volume of water held at 60cm suction (that is field capacity, %)

Soil pH was determined in 1:2 soils to solution ratio in water (H_2O) using Beckman Zeromatic pH meter [21]. Soil organic carbon was determined by the Walkley-Black wet oxidation method [22], and later converted to soil organic matter (SOM) by multiplying by 1.724

2.4 Data Analysis

The experimental data collected were subjected to analysis of variance (ANOVA) to determine the statistical differences between treatments at 5%, using GENSAT Discovery Version [23]. Significant treatment means were compared using the Fisher's Least Significant Difference (F-LSD) at 5% probability.

3. RESULTS AND DISCUSSION

3.1 Soil Properties Prior to Treatment Application

The properties of mid slope and toe slope soils prior to treatment application are shown in Table 1. The two soils lie on different physciographic surface with 9% slope for toe slope soil and 26% for the mid slope soil. Their properties were similar in many aspects. Both soils were slightly acidic, sandy clay loam in texture, low in organic carbon and exchangeable cation content. The mid slope soil was higher in organic matter, nitrogen and C.E.C probably due to several years of grass fallow. The toe slope soil was however, higher in phosphorus and calcium which may have accounted for its higher pH value of 5.9. Most of their chemical nutrient elements were below the critical values [24]; which calls for supplementation with amendments such as urban refuse compost and sewage sludge.

Table 1. Selected physico-chemical properties of soils used for the study

Parameter	Mid slope	Toe slope
Slope position (%)	26	9
Sand (gkg^{-1})	740	760
Silt (gkg^{-1})	60	60
Clay (gkg^{-1})	200	180
Textural class	Sandy clay loam	Sandy clay loam
WSA (%)	60.4	44.9
pH H_20 (1:2.5)	5.6	5.9
pH KCl	4.9	5.0
Total N (gkg^{-1})	9.6	8.8
Na ($cmolkg^{-1}$)	0.12	0.10
K ($cmolkg^{-1}$)	0.13	0.12
Ca ($cmolkg^{-1}$)	0.7	1.6
Mg ($cmolkg^{-1}$)	0.5	0.9
C.E.C ($cmolkg^{-1}$)	5.0	4.0
Avail. P. (mg kg^{-1})	6.0	10.0
OC (gkg^{-1})	1.32	0.76

WSA = Water stable aggregate, OC = Organic carbon, C.E.C = Cation exchange capacity

Table 2 shows nutrient composition of urban refuse compost and sewage sludge used for the study. The urban refuse compost was higher in pH, but low in nitrogen while, sewage sludge was slightly acidic, high in organic carbon, magnesium and phosphorus. It is expected that test soils and cassava would benefit from added wastes since the soils are low in plant nutrients.

Table 2. Chemical properties of urban refuse and sewage sludge used for the studies

Parameter	Urban refuse compost	Sewage Sludge
pH (H_20)	7.7	6.4
Organic carbon (gkg^{-1})	5.5	24.7
Total N (gkg^{-1})	9.5	42.6
Avail. P ($mg\ kg^{-1}$))	600	800
Ca ($cmolkg^{-1}$)	2.4	1.34
Mg ($cmolkg^{-1}$)	2.0	4.08

3.2 Effect of Urban Refuse and Sewage Sludge on Soil Properties

Application of the urban refuse compost (UR) and sewage sludge (SS) at both landscape slope positions had non-significant effect on soil pH, total porosity, bulk density, water holding capacity, field capacity moisture content, saturated hydraulic conductivity and mound dispersion as measured by length of exposed nail (Table 3). However, there was significant difference ($p<0.05$) between non-amended plots and organic wastes amended plots in respect of aggregate stability, as measured by percent water stable aggregate (% WSA) index. The soil amended with UR had highest % WSA of 58.3 which did not differ significantly from sewage sludge treated soil. There was non–significant effect of urban refuse compost and sewage sludge on soil pH. However, pH generally decreased in all plots when compared with the pre-treatment status (Table 1). Ahmed et al. [25] reported similar decrease in soil pH. The addition of organic wastes to soil implies that organic matter also increases. Organic matter usually decreases soil pH by releasing hydrogen ions that are associated with organic anions or by nitrification in an open system [26]. The results indicate that use of these soil amendments as nutrient source may not impose pH related threats. This is of paramount importance as pH conditions mobility of heavy metals in soil and their subsequent absorption by plants [27,28] .The non-significant effect of these amendments on most soil physical properties may be ascribed to masked effect of long-term grass fallow on the added organic wastes. The result on total porosity disagrees with that of [29] who noted that sludge and composts improve soil porosity and water stability index of soil aggregates in a similar way to manure. Findings on aggregate stability agree with [30-32]. They noted that a good soil structure depended on the content and nature of organic matter added. Organic matter promotes flocculation of clay minerals, which is an essential condition for aggregation of soil particles. Ahmed et al. [25] reported that sludge derived organic matter contributes to formation of macro-aggregate through binding of pre-existing micro-aggregates. The variability in soil structural stability may be ascribed to differences in chemical nature of these organic wastes since the same amount was applied to the soil (Table 2). Increased structural stability in this study could not influence the soil aeration. Bulk density was not altered probably because quantity of these wastes applied was not enough to exert significant dilution effect on the denser soil mineral fraction.

Table 3. Mean values of soil properties as influenced by application of urban refuse compost and sewage sludge

Organic residues	pH	WSA (%)	Total porosity (%)	Bulk density (Mgm^{-3})	LEN (cm)	WHC (%)	FC (%)	SHC ($cmhr^{-1}$)
Urban refuse compost	4.38	58.3	45.6	1.27	1.86	25.19	22.41	54.2
Sewage sludge	4.33	55.3	48.1	1.22	1.57	28.65	22.82	56.2
No amendment	4.18	47.9	45.2	1.30	1.94	25.68	21.61	32.0
F-LSD $_{(0.05)}$	n.s	5.72	n.s	n.s	n.s	n.s	n.s	n.s

WSA = percent water stable aggregates, WHC=Water holding capacity, FC = Field capacity moisture content, SHC = Saturated hydraulic conductivity, LEN= Length of exposed nail, n.s = Non-significantly difference at 5% level of probability, F- LSD = Fisher's Least Significant difference at 5% level of probability

3.3 Effect of Landscape Slope Position on Soil Properties

Table 4 shows the mean values of pH , organic carbon, percent water stable aggregate, total porosity, dry bulk density, water holding capacity, field capacity moisture content and saturated hydraulic conductivity of soils and length of exposed nails, as influenced by slope position . The mid slope and toe slope soils did not differ significantly in their total porosity, saturated hydraulic conductivity and pH. Toe-slope soil was however, significantly ($p<0.05$) higher in dry bulk density, water holding capacity, field capacity moisture content and more resistant to mound dispersion by rain drops and runoff. On the other hand, mid-slope soil was significantly ($p<0.05$) higher in percent water stable aggregate. The higher structural stability of mid-slope soil may be attributed to its higher organic carbon content (Table 1). This agrees with [33] who noted that recently formed aggregates are likely to be only moderately stable, whereas old aggregates are usually more firmly cemented and longer lasting. The higher bulk density of toe-slope soil (Table 4) may be due to accumulation of finer clay-sized particles with their attendant close packing. This is contrary to findings of [34] that slope position was not a significant determinant for bulk density, due to site variability of natural and anthropogenic parameters. The toe-slope positions had greater soil organic carbon (SOC) concentration. This can be attributed to SOC distribution and losses due to soil erosion and deposition effects by slope position [35]. Majaliwa *et al.* [36] in the Lake Kivu Pilot Learning Site of Uganda made similar observation of variation of nutrients with landscape position.

3.4 Effect of Urban Refuse and Sewage Sludge on Weed Infestation, Survival and Yield of Cassava

Table 5 contains data on weed infestation, percentage plant survival and yield of cassava as influenced by application of urban refuse and sewage sludge. Urban refuse compost and sewage sludge, contrary to expectations did not influence weed infestation, percentage cassava stand survival, fresh shoot and root yield/ha. Although these amendments enriched the soil, their fertilization values were not enough to exert significant influence on weed infestation, fresh cassava shoot and root yield ha^{-1}. The non-significant influence may be attributed to innate soil fertility prior to amendment or due to cassava variety used. Odedina et al. [37] observed that cassava varieties bred for soils inherently low in nutrients do not respond to additional nutrient input. This is contrary to the report of [38] that cassava yields would drop without fertilizer since cassava is a nutrient exhauster. The results indicate that urban refuse compost at the rate applied was of equal quality in comparison to sewage sludge in terms of cassava yield.

Table 4. Mean values of soil properties as influenced by landscape slope position

Slope positions	OC (gKg^{-1})	WSA (%)	Total porosity (%)	Bulk density (Mgm^3)	pH	LEN (cm)	WHC (%)	FC (%)	SHC ($cmhr^{-1}$)
Mid slope	12.4	73.0	45.7	1.06	3.94	1.01	24.64	20.98	51.5
Toe-slope	23.2	34.7	46.9	1.46	3.95	2.57	28.37	23.58	43.5
F –$LSD_{(0.05)}$	2.68	8.09	n.s	0.070	n.s	0.572	3.150	2.369	n.s

WSA = percent water stable aggregates, WHC=Water holding capacity, FC = Field capacity moisture content, LEN= Length of exposed nail, SHC = Saturated hydraulic conductivity, F- LSD = Fisher' Least Significant difference at 5% level of probability, n.s = Non-significantly difference at 5% level of probability

Table 5. Mean value of cassava root yield and yield components as influenced by urban refuse and sewage sludge

Organic residue	Weed infestation	% survival	fresh shoot yield (tha^{-1})	Fresh root yield (tha^{-1})
Urban refuse compost	1.24	60.4	1.66	6.48
Sewage sludge	1.24	63.8	2.07	6.81
No amendment	1.30	63.3	1.62	4.93
F-LSD $_{(0.05)}$	n.s	n.s	n.s	n.s

F- LSD = Fisher' Least Significant difference at 5% level of probability, n.s = Non-significantly difference at 5% level of probability

3.5 Effect of Landscape Slope Position on Weed Infestation, Survival and Yield of Cassava

Landscape slope position significantly (p>0.05) influenced weed infestation, percent cassava stand survival, fresh shoot and root yield (Table 6). All the above parameters except percent cassava stand survival were significantly (p>0.05) higher at toe slope position. The fresh cassava root yield obtained at toe slope position was about 70% higher than mid slope position. The cassava grown on mid slope position may have induced erosion due to wide plant spacing used and crop's initial slow growth. This may have led to slow canopy formation, exposing the soil to rainfall splash and erosion with subsequent preferential loss of clay, organic matter and some nutrients, resulting to low yield. Similar observation were made by [39] who noted that lower slope positions; such as toe slope, typically have the greatest water and nutrient content and generally produce the highest crop yield. These findings imply that a more accurate assessment of the benefits of urban refuse and sewage sludge will be obtained with a landscape research approach.

3.6 Interactions between Landscape Slope Positions and Organic Residues (Urban Refuse and Sewage Sludge) on Soil Properties

There were significant interactions between slope position and organic residues with respect to total porosity, bulk density and dispersion of mound by rain drops (Table 7).The bulk density of toe slope soil differed significantly (p<0.05) in response to the type of amendment applied. However, such differences were not observed at mid-slope soil. This may be ascribed to higher organic carbon content of mid slope soil (Table 1) which may have resulted from lower rate of organic matter decomposition. Mound dispersion was highest in urban refuse treated plots at the mid-slope position and unaffected at toe slope. Variations in soil pH, water holding capacity, field capacity moisture content and saturated hydraulic conductivity were not significantly influenced by interactions between landscape slope positions.

Table 6. Means value of cassava root yield and yield components as influenced by slope positions

Slope position	Weed infestation (tha^{-1})	% plant stand survival	fresh shoot yield (tha^{-1})	Fresh root yield (tha^{-1})
Mid-slope	0.18	68.3	1.53	2.81
Toe-slope	2.14	56.7	2.03	9.33
F- LSD $_{(0.05)}$	0.855	7.59	0.387	1.67

F- LSD = Fisher' Least Significant difference at 5% level of probability

Table 7. Mean interaction of slope position and organic residues (UR and SS) on soil properties

Slope position	Mid slope			Toe slope			F- LSD $_{(0.05)}$
Organic residues	No amendment	Sewage sludge	Urban refuse compost	No amendment	Sewage sludge	Urban refuse compost	
pH	4.2	4.2	4.6	4.1	4.3	4.3	n.s
WSA (%)	64.9	77.0	76.9	30.8	33.5	39.7	n.s
Total porosity (%)	0.47	0.45	0.46	0.44	0.52	0.45	0.0432
Bulk density (Mgm^{-3})	1.05	1.07	1.08	1.55	1.36	1.46	0.1205
LEN (cm)	1.18	1.05	0.78	2.63	2.08	3.10	0.991
WHC (%)	24.98	25.79	23.16	26.38	31.51	27.22	n.s
FC (%)	19.12	22.82	21.0	24.1	22.58	23.8	n.s
SHC ($cmhr^{-1}$)	35.3	59.1	60.0	28.7	53.3	48.4	n.s

WSA = percent water stable aggregates, WHC=Water holding capacity, FC = Field capacity moisture content, LEN= Length of exposed nail, SHC = Saturated hydraulic conductivity, F- LSD = Fisher' Least Significant difference at, 5% level of probability, n.s = Non-significantly difference at 5% level of probability

Table 8. Mean interaction of slope position and organic residues (UR and SS) on weed infestation, cassava survival and yield

Slope position	Mid slope			Toe slope			F-LSD (0.05)
Organic residues	No amendment	Sewage sludge	Urban refuse compost	No amendment	Sewage sludge	Urban refuse compost	
Weed. Infestation.(t/ha)	0.28	0.17	0.09	2.31	2.31	1.79	n.s
% Survival	67.5	69.2	68.3	59.2	58.3	52.5	n.s
Fresh root yield (t/ha)	3.05	4.05	1.32	6.80	9.57	11.63	2.898
Fresh shoot yield (t/ha)	1.53	1.77	1.28	1.07	2.37	2.03	n.s

F- LSD = Fisher' Least Significant difference at 5% level of probability, n.s = Non-significantly difference at 5% level of probability

3.7 Interactions between Landscape Slope Positions and Organic Residues (Urban Refuse and Sewage Sludge) on Weed Infestation, Survival and Yield of Cassava

The result also indicated significant interactions between slope position and organic residues in influencing fresh root yield of cassava (Table 8). Urban refuse compost had least fresh root yield per hectare (1.32 tha^{-1}) when applied in mid-slope position but highest (11.63 tha^{-1}) when applied in toe-slope position. Organic residues increased cassava yield significantly ($p<0.05$) only at toe slope positions. This implies that crop response to manure application appear to be conditioned by slope position and nature of soil.

4. CONCLUSION

The study revealed that cassava crop response to applied organic manure (urban refuse compost and sewage sludge) is influenced by landscape slope positions. Urban refuse and sewage sludge at the applied rate increased cassava yield significantly ($p<0.05$) only at toe-slope position. In addition, applications of urban refuse compost and sewage sludge and cassava production tend to decrease soil pH. Total porosity, bulk density and mound dispersion by raindrop were significantly higher at the toe-slope position.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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