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Effects of Organic Amendments on Surface Runoff and Sediment Yield of Selected Erosion-prone Soils on Varying Geologic for-Mations at a Laboratory Scale

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ABSTRACT Soil erosion is a major constraint to agricultural productivity and environmental sustainability in humid tropics. However, the effectiveness of organic amendments in controlling runoff and sediment losses in soils of different geologic origins remains poorly understood. This study evaluated the effects of selected organic amendments on surface runoff and sediment yield under controlled laboratory conditions by using soils derived from four geologic formations: Asu River Group, Bende Ameki Group, Coastal Plain Sand, and False-Bedded Sandstone. Four types of organic amendments (poultry droppings, goat droppings, municipal solid waste, and a combination of amendment) were applied at different rates (10, 20, and 30 t ha^{-1}) to 10 kg of soil in a completely randomized design. After a 3-month incubation period, rainfall simulations were conducted under both air-dry and wet soil conditions representative of contrasting antecedent moisture states commonly observed in the area. Data were then analyzed through an analysis of variance, and treatment means were separated using least significance difference at a 5% probability level. The results indicated that increasing the amendment rates significantly reduced surface runoff and sediment yield across all soils, although the magnitude of response varied with geologic formation and moisture. Poultry droppings and combined amendments at 30 t ha^{-1} consistently produced the greatest erosion reductions, particularly under air-dry conditions. A negative correlation was observed between clay content and sediment yield ($r = -0.32$ and -0.21) in both moisture states, which highlights the role of soil texture in erosion resistance after amendment. In summary, this study demonstrates that organic amendments, especially poultry droppings and combined treatments, are effective in mitigating erosive losses and reducing the potential for sediment-bound nutrient transport. These findings underscore the value of amendment as a practical soil and water conservation strategy for minimizing sediment yield and supporting sustainable land practices in erosion-prone tropical environments.

Key Words: organic amendment, rainfall simulation, sediment yield, soil degradation, soil erosion, surface runoff

1. Introduction

The conservation and restoration of degraded soils are essential for building healthy and resilient communities, as emphasized by United Nations Sustainable Development Goals (SDGs) (UN,2015). In the humid tropics, soils experience severe degradation, driven mainly by water erosion and intensified by other degradative processes (Lal, 2009; Junge, 2008; European Commission, 2020).

Soil erosion remains a critical threat to global food security and ecosystem services.

This problem is particularly severe especially in regions where high-intensity rainfall meets highly weathered soils (Igwe, 2003).

Globally, soil erosion by water affects about 1.1 billion hectares, representing 56 % of degraded land (Humberto and Lal, 2008; Lal, 2020). The consequences include nutrient depletion, loss of soil organic carbon, reduced agricultural productivity (Igwe, 2003), water pollution (European Commission, 2020), and sedimentation of waterways (Worldwide Fund, 2025). Projections suggest that the combined impacts of soil degradation and climate change could displace 500-700 million people by 2050 (European Commission, 2020), underscoring the urgency of sustainable soil management strategies.

Geologic formation is a foundational factor governing soil properties, which strongly influences erosion processes (Vijayakumar et al., 2025). Soils developed on contrasting parent materials often show markedly different erosion susceptibilities, even under identical land use and rainfall conditions (Dong et al., 2025, Morgan, 2005). Soils derived from Coastal Plain Sands tend to have low structural stability and high erodibility, while soils from shale and limestone may have higher aggregation but may be susceptible under high rainfall events (Dong etal. 2025).

Despite this, many soil conservation studies treat soils as

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relatively homogeneous units with limited consideration of how geologic variability influences the effectiveness of erosion control measures

Among agronomic soil conservation measures, the application of organic amendments has received considerable attention due to their availability, low cost, and capacity to improve soil structure while supplying nutrients gradually for the soil (Rugendo et al. 2023, Junge et al. 2008,).

Studies have shown that organic amendments can reduce surface runoff and sediment yield, thereby lowering the transport of sediment bound nutrients and pollutants to downstream water bodies (Mohammadjavad et al. 2025, Rugendo et al. 2023, Sharpley et al. 1994). Organic amendments enhance soil aggregation (Yang et al., 2024) by introducing complex biochemical compounds that act as "soil glues", improving soil structure, porosity, infiltration capacity, and resistance to soil sealing (Gholamahmadi, etal., 2003, Gal et al. 1992, Six et al, 2002, Omokaro et al. 2024). These processes play an important role in soil restoration, especially in degraded soils. Organic amendments also promote microbial activity, humification, and vegetation growth, thereby sustaining soil health and ecosystem functionality (Rasoulzadeh & Yahhoubi, 2010). Nevertheless, an excessive and/or improperly managed rate of application could lead to increased nutrient losses, thus emphasizing the need for soil-specific management strategies (Sharpley et al., 2001; Agegnehu et al., 2017). Furthermore, the efficacy of organic amendments can be influenced by soil parent materials and types and amounts of organic matter applied. The global population, projected to exceed 10 billion by 2050, will put soil resources under unprecedented pressure.

However, little attention has been paid to the role of geologic parent materials in moderating the efficiency of soil conservation measures. This is particularly significant in tropical regions where soils with different geologic parent materials show considerable variability in texture, mineral composition, and structural stability. This study assessed the differential effects of localized organic amendments on surface runoff and sediment yield across soils derived from four distinct geologic groups.

By isolating these variables under controlled laboratory rainfall simulation, this research, which primarily focuses on physical erosion processes rather than chemical properties, provides insight into soil structural resilience and offers a basis for precision soil and water conservation in tropical landscapes.

The principal objective of this work was to determine the effects of organic amendments on surface runoff and sediment yield of soils on varying geologic formations at a laboratory scale.

Other specific objectives were to:

Characterize the amendments used.

Determine the organic amendment and rates that best suit the reduction of the parameters studied in the respective geologic formations.

Compare erosion losses under air-dry and wet antecedent moisture conditions following amendment applications Examine some relationships in existence among sediment yield, surface runoff, and selected soil properties.

2. Materials and Methods.

1. Study location, geology, climatic variables, land use and economic activities of the people.

The study covered four locations as presented in Table 1 and Figure 1, respectively. The Bende Ameki Group is of Eocene geological age. This group is composed of fine to coarse sandstone materials as well as calcareous and shelly limestone materials. False Bedded Sandstone (Ajali formation): This formation is composed of thick, unconsolidated, poorly sorted sandstone materials that range in color from white to pale green. However, it may sometimes show signs of ferrugination as it may be stained red, yellow, or brown. Coastal Plain Sand: This is of Pleistocene-Oligocene geological epoch. This formation is composed of yellow and white unconsolidated sand materials that may sometimes be cross-bedded with sandy clay as well as pebbles. The Asu River Group: This formation is composed of fine micaceous sandstone materials as well as sandy shale. This formation is also composed of blue shale as well as dense blue limestone of marine origin. This formation was first recorded. The study areas fall within the humid tropical climate, which is warm year-round (Agim, 2016). The two major seasons in the study area are the wet and dry seasons. Rainfall on an annual basis ranges from 2000 to 2500 mm, whereas humidity and temperature were between 80% and 90% and 26 and 29 °C, respectively (NIMET 2012).

Agriculture is the major occupation of the people, with food crops such as yams, rice, and cassava taking the lead. The farming system of shifting cultivation and bush fallow, which helps in soil conservation and fertility regeneration, has been hampered by the upsurge in the human population.

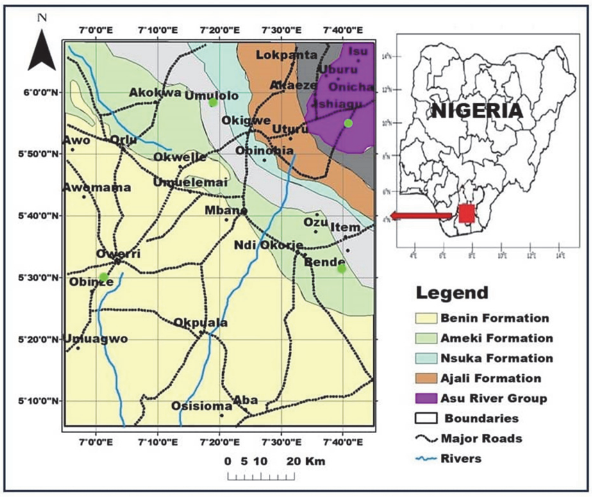

Fig.1 Map showing sample locations

Table 1 Geographical coordinates of the studied locations

S/No	location	Elevation	Geographical coordinates	Parent material
1	Ishiagu	89	$5^0$27'11'N and $7^0$31'5004"E	Asu River Group
2	Bende	118	5^0 33'35.6" N and 7^0 33'16.0" E	Bende Ameki group
3	Umulolo	121	$5^0$47'38.9 "N and $7^0$17'28.61"E	False-bedded Sandstone
4	Obinze	180	$5^0$22'23.3"N and $7^0$9'34"E	Coastal Plain Sand

2. Soil sampling and experimental design

A soil auger was used to collect soil samples at depths of 5-20 cm from each of the locations. The collected samples were bagged and labeled in preparation for organic amendment application in the Teaching and research farm of the Faculty of Agriculture, Federal University of Technology, Owerri. The samples used for routine laboratory analyses were air-dried, and sieved with a 2-mm sieve. All the samples were collected from oil palm plantations that have been in operation for more than 20 years from the respective geologic formations.

The experiment was factorially arranged in a Completely Randomised Design (CRD). The four locations, four organic amendments, and four organic amendment rates constituted the factors. Each experimental set was carried out in triplicate, resulting in 192 samples used.

3. Organic amendment applications

Organic amendments, viz, poultry droppings (PD), biodegradable municipal solid waste (MSW), goat droppings (GD), and combinations of amendments (COA), were applied at rates of 0, 10, 20, and 30 t ha^{-1}, respectively, in a sack bag containing 10 kg of sampled soil. Hand gloves were used in the process of mixing in order to ensure that there was a uniform and homogeneous distribution of soil and amendments. This process was repeated at weekly intervals over the incubation period, after which rainfall simulation was conducted. Organic amendments were cured and characterized in the laboratory in order to ascertain their nutrient composition, as shown in Table 2. The determined physical and chemical properties of the soils before amendment are presented in Table 3.

4. Rainfall simulation, surface runoff and sediment yield collection.

Rainfall simulation was carried out via a portable rainfall simulator similar to those used in the studies by Meyer and Harmon (1979), Igwe (2000), and Iserloh (2013). The simulator, with an average drop size of 2 mm, has an overhead tank mounted at a height of 2.5 m. The distance from the delivery pipe to the soil bin or microplot, whose dimensions were 30 cm * 10 cm * 12 cm, was 2 meters. Amended soil samples were packed in the bin following the procedures of Igwe (2000), Dimoyiannis et al. (2001), and Romkens et al. (2001). The soil bin was inclined at a slope between 1 and 2%, representing the field slope, which varied between 1 and 4%. Rainfall at an intensity of 25 mm hr^{-1} was allowed to fall on the soil for a maximum period of 30 minutes. The aim was to achieve near-modal rainfall intensity in the area under study. At five (5) minute intervals for a thirty (30) minute duration.

Surface runoff, collected in a bowl placed at the opening of the soil bin, was allowed to settle for 48 hours and was measured using a measuring cylinder. The sediment yield, which settled at the base of the cylinder, was air-dried and weighed. The experiment was conducted in two moisture categories of wet states (without allowing the soil to air-dry) and air-dry state (where the same sample used was allowed to air-dry for one week before simulation). The two states aimed to have a better understanding of changes in soil erosion with moisture content.

Fig.2 The Portable rainfall simulator used

5. Laboratory analyses

The hydrometer method of Gee and Or (2002) was used to determine particle size.

The Grossman and Reinsch (2002) method was used for the determination of bulk density. The procedures of Baver et al. (1972) and Brady and Weil (1999) were used for the determination of moisture content. Organic carbon was determined by the Nelson and Sommers (1982) wet oxidation method. Soil pH was determined in distilled water and 0.1N KCl solutions by a pH meter in a 1:2.5 soil-liquid suspension (Hendershot et al., 1993). The effective cation exchange capacity was carried out by the method given by Landon (1999).

6. Data analyses.

Data generated from the soils were analyzed using ANOVA. Mean separation was done using the least significant difference (LSD) at 5% probability.

Table 2 Characterization of amendments used

Property	Units	goat dropping	poultry dropping	municipal solid waste	combination of amendments
pH water		7.25	7.08	7.56	7.20
pH KCl		6.67	6.90	6.13	6.61
Organic carbon	g kg^{-1}	194.50	223.00	37.08	103.20
Total nitrogen	g kg^{-1}	18.70	21.10	4.60	13.90
Available phosphorus	mg kg^{-1}	1.87	2.10	0.46	1.39
C/N ratio		10.40	10.57	8.06	7.42
Calcium	cmol kg^{-1}	22.32	23.80	6.67	12.87
Magnesium	cmol kg^{-1}	15.41	24.41	7.33	13.33
Sodium	cmol kg^{-1}	2.18	1.17	0.65	1.39
Potassium	cmol kg^{-1}	10.03	3.88	1.73	5.28

3. Results and Discussions

1. Selected physical and chemical properties before and after amendments application

The resulst of the selected physical and chemical properties of the studied soils before and after applying the amendments are presented in Table 3. The result indicated that the application of organic amendments improved the properties of the soils in all study locations, although the degree of response was strongly influenced by the parent material. The noted reduction in sand fraction and corresponding increase in clay fractions following amendment application across all locations indicate enhanced aggregation rather than textural change. This observation is in line with Eshett (1985), who reported that soils of the humid tropics are predominantly loamy sand to sandy loam in surface horizons and that their texture cannot be easily altered Organic matter acting as a binding agent, promotes flocculation of fine particles and formation of stable aggregates (Six et al., 2002; Haynes and Naidu, 1998).

The increase in soil moisture content after amendment is attributed to an increase in soil organic carbon (SOC), which enhances water retention through increased micro porosity and aggregate stability (Six et al., 2002; Haynes & Naidu, 1998).

Similarly, the consistent reduction in bulk density across all soils confirms structural improvements induced by organic amendment (Lal, 2015). This improvement is particularly beneficial for root penetration and infiltration in compacted tropical soils (Brady and Weil, 2017). These findings are consistent with Nnabude and Mbagwu (2001), who reported reduced bulk density following organic amendment.

Following organic amendment application, soil pH increased to values ranging from 5.35 to 5.59 (water) and 4.95 to 5.18 (KCl), indicating partial amelioration of soil acidity.

Although these values fall within the moderately to slightly acidic range according to tropical soil rating standards (Sanchez, 2019; Brady and Weil, 2017), the increase represents an important improvement for highly weathered soils of southeastern Nigeria, where high rainfall promotes leaching and soil acidification (Adeoye and Agboola, 1985). The increase in soil pH reflects the buffering capacity of organic amendments through the release of basic cations and the complexation of exchangeable H^+ and Al^{3+} (Naramabuye & Haynes, 2006; Wong et al., 1998).

Soil organic carbon increased across all formations, confirming that organic amendments are an effective means of replenishing soil nutrients in degraded tropical soils. However, these values remain generally low (Landon, 1991), which is typical of soils of the region. The result revealed that the rate of accumulation of SOC depends on the initial status and mineralogical composition of the soils. Soil derived from False-bedded Sandstone and the Asu River Group recorded higher SOC gains likely due to the enhancement by clay minerals and Fe/Al oxides (Six et al., 2002; Cotrufo et al., 2013). Although coastal plain sand soils exhibited large proportional increases, their coarse texture suggests lower long-term SOC stability (Sanchez, 2019). The increase in SOC led to higher effective cation exchange capacity, improved nutrient retention and reduced mobility of soil nutrients.

The values of effective cation-exchanged capacity (ECEC), which increased across the studied soils after amendment, are below the critical limits for soils of Southeastern Nigeria (Landon 1991). The increase is closely linked to rising SOC levels and slight pH increases.

Effective cation exchange capacity (ECEC) increased across all studied soils following amendment application, but remained below the critical threshold for southeastern Nigeria soils (Landon 1991). The increase in ECEC is closely associated with rising SOC levels and slight increases in soil pH. Higher ECEC enhances the soil's ability to retain basic nutrients within the soil matrix, reducing their mobility into surface and downstream water bodies. In erosion-prone tropical soils known for rapid nutrient losses and very susceptible to non-point source pollution (Igwe 2003), improved ECEC is therefore critical.

The observed results explain the reduction in surface runoff and sediment yield values in Tables 4 and 5.

Table 3 Values of selected properties of studied soils before and after amendment

G. F	sand	Silt	Clay	TC	M.C	Bulk density	pH (H2O)	pH (KCl)	SOC	ECEC
		g kg^{-1}			g kg^{-1}	g cm^{-3}			g kg^{-1}	Cmol kg^{-1}
Before the amendment application										
ARG	602.07	255.66	142.27	SL	340.33	1.47	4.93	4.76	2.16	6.21
BAG	655.53	19.60	324.87	SL	470.00	1.62	5.48	5.13	8.43	5.85
CPS	874.67	12.79	112.54	LS	350.00	1.53	5.08	5.00	0.72	3.84
FBS	692.87	141.90	165.23	SL	390.00	1.59	4.74	4.31	10.32	9.24
LSD(*P<0.05*)	165.5*	7.21*	49.36*		10.23*	NS	0.39*	NS	0.68*	0.56*
After the amendment application										
ARG	524.27	310. 40	165.33	SL	376.78	1. 43	5.35	4.98	15.30	8.27
BAG	604.08	57.78	338.14	SL	570.89	1.53	5.59	5.18	12.10	9.01
CPS	839.70	19.50	140.80	LS	360.32	1. 48	5. 47	5.16	11.60	4.72
FBS	543. 40	217.30	239.30	SL	400.21	1. 42	5. 56	4.95	19.30	11.57
LSD(*P<0.05*)	115.5*	5.78*	23.98*		16.98*	NS	0.02*	NS	6.89*	1.76*

LSD=least significant difference, ARG=Asu River Group, SOC=Soil organic carbon, FBS=False bedded Sandstone, G. F=Geological formation, BAG= Bende AmekiGroup, CPS=Coastal Plain Sand, MC=Moisture content, ECEC=effective cation exchange capacity LS=Loamy sand, *=significant, P=probability, TC=Textural class

2. Effects of organic amendments on surface runoff of the respective geologic formation.

The effects of organic amendments on surface runoff are presented in Table 4. Surface runoff differed significantly (*P < 0.05) among treatments under both the air-dry and wet states. In the soil under the Asu River Group (ARG), poultry (PD) and goat droppings (GD) applied at 30 t ha^{-1} produced the lowest runoff values of 56.63 mm and 64.00 mm under air-dry and wet states, respectively. For soils derived from the Bende Ameki Group (BAG), the lowest runoff values were recorded with poultry dropping at 30 t ha^{-1} (19.63 mm) under air-dry conditions and with a combination of amendments (COA) at 20 t ha^{-1} (53.20 mm) under wet conditions (Table 4). In Coastal Plain Sand (CPS) and False bedded Sandstone (FBS), the lowest runoff values were obtained with PD at 20 t ha^{-1} (32.10 mm) and 30 t ha^{-1} (61.30 mm) and with municipal solid wastes (MSW) at 30 t ha^{-1} (64.20 mm) and 10 t ha^{-1} (70.80 mm) under air-dry and wet states, respectively. In all cases, runoff values were lower than those of the control (0 t ha^{-1}). Overall, poultry droppings were the most effective amendment, in reducing surface runoff, particularly under air-dry conditions. These findings agree with Giddens and Barnett (1980), who reported a substantial decrease in runoff and soil loss with the use of poultry litter applications. Similar reductions in runoff have been reported with organic mulches and manure application under simulated rainfall conditions (Ramon et al., 2018; Sadeghi et al., 2015). Although slight increases in surface runoff were observed at higher rates for some amendments, such as MSW at 30 t ha^{-1} in ARG and the COA in BAG, under wet conditions. These values remain lower than those of the control

Table 4 Effect of location, organic amendments and their rates on surface runoff of the studied soils

Geologic formation	Organic amendments	Rates of amendment (t ha^{-1}) application on runoff (mm) air-dry state				Rates of amendment (t ha^{-1}) application on runoff (mm) wet state			
		0	10	20	30	0	10	20	30
ARG	GD	106.90	96.20	90.90	90.63	105.07	111.30	106.70	64.00
	PD	107.00	86.50	75.40	56.63	105.06	103.00	103.00	104.00
	MSW	106.95	86.13	83.70	90.30	105.80	81.60	102.50	101.50
	COA	106.95	86.20	78.20	82.63	105.13	109.40	96.60	101.10
BAG	GD	39.20	30.00	36.70	36.40	87.11	86.10	85.00	85.40
	PD	39.20	25.00	22.10	19.63	75.49	72.00	63.00	69.00
	MSW	39.21	26.20	25.20	23.10	76.15	74.50	61.00	73.20
	COA	39.22	37.10	36.00	23.20	75.80	78.10	53.20	70.00
CPS	GD	79.21	52.70	44.87	59.10	87.40	83.20	85.00	69.50
	PD	79.23	42.10	32.10	41.00	88.40	81.50	70.90	61.30
	MSW	79.33	40.00	41.00	48.32	88.47	84.20	82.00	81.80
	COA	79.20	46.90	40.90	34.20	77.97	72.10	62.60	77.50
FBS	GD	72.70	65.13	71.00	64.73	84.03	82.30	80.80	82.50
	PD	72.70	70.20	69.70	67.70	84.55	82.00	81.50	84.20
	MSW	72.72	71.20	70.00	64.20	85.99	70.80	80.10	83.70
	COA	73.70	71.90	66.70	68.20	87.21	82.00	82.00	89.00
G x O.A x R		LSD (*P<0.05)= 10.3*, S.E=11.16				LSD (*P<0.05)= 10.3*, S.E=11.16,			

G x O.A x R= Interaction between geologic formation, organic amendment, and rate of application. GD =goat dropping, PD=poultry dropping, MSW= municipal solid waste, COA=combination of amendment, NS=not significant, *=significant, LSD=least significant difference, S. E=standard error.

(1) General effect of amendments on surface runoff irrespective of the geologic formations.

Across all soils, organic amendments significantly reduced surface run-off under both air-dry and wet states (Figure 3a). Decreased surface runoff values directly limit the transport of dissolved nutrients and fine particles to downstream water bodies. thereby mitigating non-point pollution (Ramon et al. 2018, Sharpley *et al.*1994), Poultry dropping consistently produced the greatest runoff reduction (Figure 3b), corroborating earlier findings by Mohammadjavad et al. (2025), Bushee et al. (1999), Westerman et al. (1983), Giddens and Barneth (1980). The considerable reduction in runoff from poultry manure-amended soils can be related to improved soil structural stability and aggregate cohesion. Poultry manure has readily decomposable organic matter that stimulates microbial activity and formation of stable organo-mineral complexes, hence enhancing aggregate stability and infiltration capacity thereby minimizing soil particle detachment and transportation during rainfall impact.

Increasing amendment application rates resulted in significant (*$P < 0.05$) reduction in surface runoff in both moisture states (Figure 3c). This trend is attributed to improved soil porosity, enhanced infiltration capacity (Sadeghi *et al.* 2015), and increased surface roughness induced by organic matter accumulation (Shi et al. 2017, Wu et al, 2010).

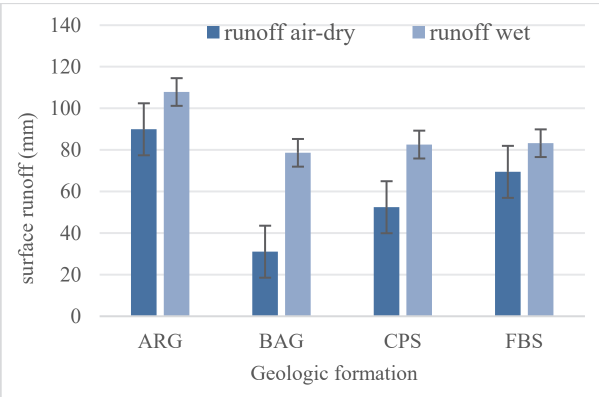

Fig.3a Effects of individual organic amendments on runoff of the studied soils

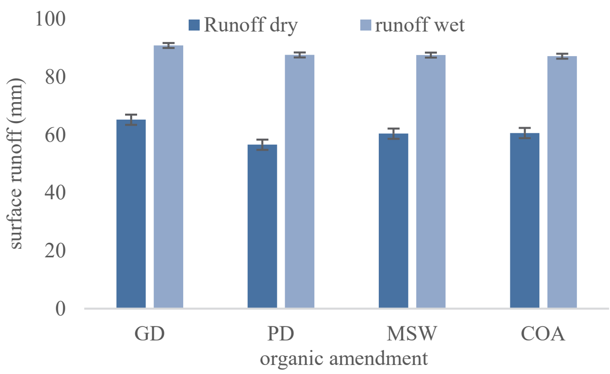

Fig.3b Effect of the individual organic amendments on runoff of studied soils

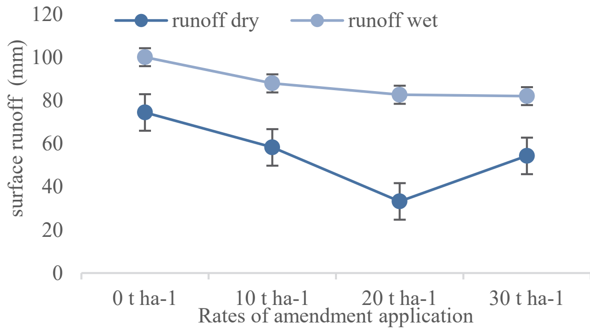

Fig.3c Reduction in runoff with respect to the rates of amendment

Organic amendments promote soil aggregation through cation bridging and sorption, reducing surface sealing and enhancing water intake (Nishimura et al. 2005). However, at excessively high rates, some amendments increased surface runoff, likely due to electrolyte-induced dispersion of soil particles (Haynes and Naidu, 1998, Erani et al, 2006). This highlights the importance of optimizing amendments rates to maximize conservation benefits while avoiding structural degradation.

3. Effects of organic amendments on sediment yield according to the respective geologic formations.

The effects of organic amendments on sediment yield are presented in Table 5. In the Asu River Group (ARG), the significantly (*$P<0.05$) lowest values of 2.00 and 2.07 kg m^{-2} hr^{-1} were recorded with COA at 20 t ha^{-1} under air-dry and wet conditions, respectively. In the Bende Ameki Group (BAG), the lowest values of 0.16 and 0.88 kg m^{-2} hr^{-1} were noted in the air-dry and wet states by the addition of 30 t ha^{-1} of goat droppings (GD). In Coastal Plain Sand (CPS), the use of municipal solid waste (MSW) at 30 t ha-1 resulted in the lowest sediment losses, whereas in FBS soils, the use of PD and GD at 20 t ha^{-1} and 30 t ha^{-1}, yield resulted in the lowest sediment yields. These results support the report of de Varennes et al. (2010) that a combination of amendments is often more effective than single amendments in soil reclamation.

(1) General effect of amendments on sediment yield irrespective of the geologic formation.

Figures 4a-c illustrate the general effects of the amendment and application rates on sediment yield in both states, irrespective of geologic formation. The presented results in Figure 4a showed that sediment yield varied from 3.39 to 2.72 kg m^{-2} hr^{-1} under dry and wet states in soil under Asu River Group (ARG), 1.74 and 2.35 kg m^{-2} hr^{-1} in the soil of the Bende Ameki Group (BAG), 1.77 and 2.28 kg m^{-2} hr^{-1} in the soil under Coastal Plain Sand (CPS), and 2.12 and 1.25 kg m^{-2} hr^{-1} in the soil of Falsebedded Sandstone (FBS), respectively. These results were consistent with to the studies of Yang et al. (2020), Wu et al. (2010) and Flanagan (2002). The variation sediment yields among the geologic formations may be related to differences in mineral composition, clay content, and structural stability of soils developed from these parent materials. Soils developed from Coastal Plain Sands, which are coarse-textured and contain small percentages of clay, have low aggregate stability and are more easily eroded. Soils developed from shale and sandstone may contain larger percentages of clay and iron oxides, which enhance aggregate stability and resistance to erosion.

Figures 4b and 4c show how the individual amendments and the rates of application affected sediment yield irrespective of the geologic formations. The following sequences for sediment yield were observed: PD> COA> MSW > GD (air-dry state) and PD> COA> GD > MSW (wet state).

Increasing amendment rates significantly (*$P<0.05$) reduced sediment yield, like trends reported for soil conditioners such as polyacrylamide (Wang et al., 2011; Kebede et al., 2020).

The observed reduction in sediment yield provides crucial initial protection against downstream pollution or degradation (Morgan, 2005). and reflects improvements in soil aggregation, cation exchange (Rahma et al. 2019) and infiltration capacity (Jordan, 2010, Biptubusa et al. 2008). Mamedov et al. (2010) and Yu et al. (2003) attributed such to enhanced porosity, infiltration, and increased soil strength. The efficacy of organic amendment, type of soil, concentration of ions, and clay mineralogy also contributed.

The higher sediment yield obtained under the wet state is attributed to the reduced infiltration capacity of the soils and aggregate breakdown at higher moisture contents. (Bot and Benites 2005).

Table 5 Effect of location, organic amendment and their rates of application on sediment yield result of the studied soils after simulation

Geologic formation	Organic amendments	Rates of amendment ($t\ ha^{-1}$) application on sediment yield ($k\ gm^{-2}\ hr^{-1}$) air-dry state				Rates of amendment ($t\ ha^{-1}$) application on sediment yield ($k\ gm^{-2}\ hr^{-1}$) wet state			
		0	10	20	30	0	10	20	30
ARG	GD	3.00	2.34	2.21	2.15	3.72	2.56	2.44	2.30
	PD	3.10	2.97	2.60	2.36	3.72	2.95	2.71	2.60
	MSW	3.12	3.01	2.69	2.24	3.74	2.38	2.21	2.10
	COA	3.00	2.52	2.00	1.92	3.72	2.28	2.07	2.17
BAG	GD	3.24	0.28	0.20	0.16	3.95	2.60	2.46	0.88
	PD	3.24	2.09	1.34	1.27	3.95	1.80	1.76	2.00
	MSW	3.22	1.18	0.93	1.08	3.97	1.26	1.05	1.16
	COA	3.25	2.17	2.12	2.06	3.95	2.25	2.40	2.16
CPS	GD	2.83	2.18	1.96	1.42	2.72	2.33	1.93	1.34
	PD	2.83	2.56	2.07	1.50	2.73	2.45	2.13	2.24
	MSW	2.85	1.00	0.82	0.79	2.74	2.36	2.25	2.01
	COA	2.82	0.95	0.90	1.00	2.72	2.18	2.07	2.23
FBS	GD	1.66	1.43	1.39	1.17	2.39	2.20	2.16	1.71
	PD	1.67	1.29	0.35	0.91	2.38	2.18	1.75	1.98
	MSW	1.65	1.48	1.20	1.28	2.41	2.08	2.17	2.03
	COA	1.66	1.38	0.66	0.82	2.39	2.29	1.82	2.09
G x O.A x R		*LSD ($P<0.05$) = 0.41**,		*S. E=0.25*,		LSD ($P<0.05$) = 0.56*, S. E=0.34.			

G x O.A x R= Interaction between geologic formation, organic amendment, and rate of application. GD =goat dropping, PD=poultry dropping, MSW= municipal solid waste, COA=combination of amendment, NS=not significant, *=significant, LSD=least significant difference, S. E=standard error.

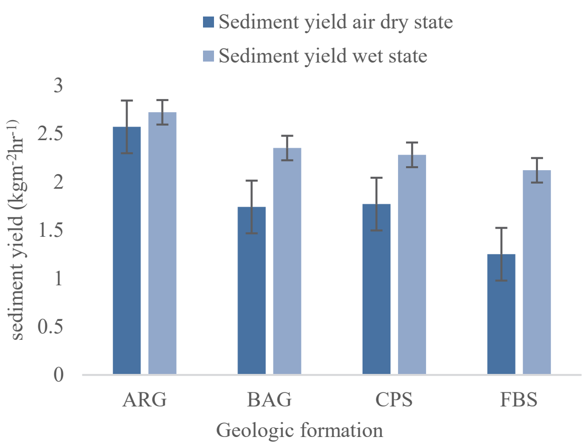

Fig.4a General performance of organic amendments on sediment yield according to the geologic formations

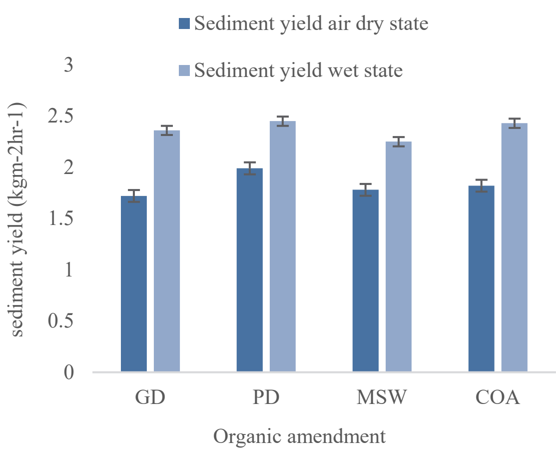

Fig.4b Effects of the individual organic amendments on sediment yield of studied soils

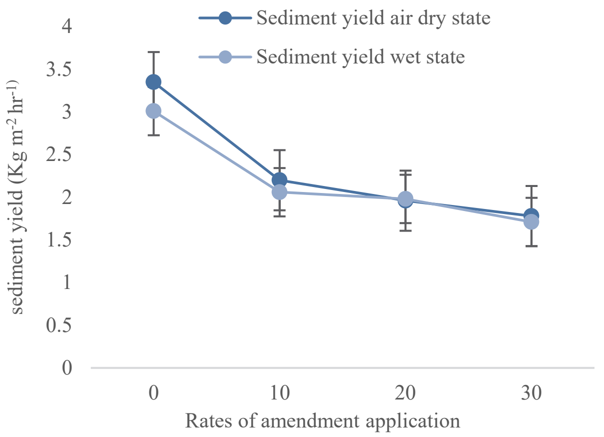

Fig.4c Effects of rates of amendment on sediment yield

4. Correlation between surface runoff, sediment yield and selected soil properties

Correlation analysis (Table 6). revealed significant negative relationship between clay content and sediment yield before and after amendment application (r = - 0.32, - 0.21). Similar negative correlations were observed between clay content and surface runoff, (r = - 0.40 and -0.46) as well as between soil organic carbon and both runoff and sediment yield (r = - 0.43 and - 0.21). These relationships indicate that increase in the clay fraction and organic carbon reduce erodibility by improving aggregation and infiltration capacity. of soil decreases sediment yield. These results agree with Feng-Ling et al. (2010), Igwe (2000). A similar negative relationship existed between the clay fraction and surface runoff under air-dry and wet states (r = - 0.40 and -0.46). Soil organic carbon is negatively related to sediment yield under air-dry and wet states (r = - 0.43 and - 0.21). Le Bissonnais and Singer (1993), who obtained a significant negative correlation between organic carbon, iron oxide, and infiltration rates.

Table 6 Relationship of some erosion parameters with selected soil properties.

Soil property	unit	Clay	SyD	SyW	Runoff wet	Runoff dry	SOC	BD
Clay	g kg^{-1}	1						
SyD	kg m^{-2} hr^{-1}	-0.32*NS*	1					
SyW	kg m^{-2} hr^{-1}	-0.21*NS*	0.32*	1				
Runoff wet	mm	-0.40*	0.93**	0.73*	1			
Runoff dry	mm	-0.46*	0.88**	0.33*	0.92**	1		
SOC	g kg-^{1}	0.52*	-0.43*	-0.21*NS*	- 0.03*NS*	-0.27*NS*	1	
BD	g cm-^{3}	0.02*NS*	-0.03*NS*	-0.55*	-0.03 *NS*	-0.03 *NS*	0.02*NS*	1

SyD and SyW=sediment yield under dry and wet state, SOC=Soil organic carbon, BD=Bulk density, *=Significant, **= Highly significant, NS=not significant

5. Conclusion

This study examined the effects of organic amendments on surface runoff and sediment yield of soils on varying geologic formations at the laboratory scale. Results revealed significantly lower (p<0.05) values of sediment yield and runoff following amendment under both air-dry and wet conditions. The magnitude of reduction depended on amendment type, application rate, and geologic formation. Poultry droppings produced the highest reduction in runoff, while goat droppings, municipal solid waste, and combined amendments were equally effective in minimizing sediment yield. The reduction in surface runoff and sediment yield were attributed to improvements in organic carbon, higher effective cation exchange capacity and reduced bulk density which likely enhanced aggregation and infiltration capacity of the soil.

Occasional increases in runoff at higher rates emphasize the need for site-specific and rate-controlled application to avoid structural dispersion, nutrient losses. The increased runoff and sediment yield under wet moisture conditions demonstrated how vulnerable tropical soils are to erosion when their pores are already filled with water. To minimize the risk of non-point source pollution and enhance field applicability, further studies involving field scale trials, nutrient transport assessment, and crop response evaluation are recommended. This research provides an effective soil and water conservation practice when applied judiciously and contributes towards achieving sustainable land management goals in line with the United Nations Sustainable Development Goals.

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7. Conflict of interest

There is no conflict of interest in this work.

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