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Effects of Surface Mulching and Velvet Bean Cover Crop on Runoff Generation and Soil Loss in a Sandy Loam Soil of Southeastern Nigeria

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ABSTRACT

Soil erosion remains a major environmental and agricultural challenge in southeastern Nigeria, particularly in Awka, Anambra State, where high rainfall intensity and fragile sandy loam soils accelerate land degradation. This study evaluated the effectiveness of surface mulching and velvet bean (Mucuna pruriens) cover cropping in reducing runoff generation and soil loss under field conditions. A randomized complete block design with three treatments—bare soil (control), maize stalks and husks mulch, and velvet bean cover crop—was employed with three replications. Runoff, soil loss, runoff coefficient, and infiltration characteristics were measured under natural rainfall conditions. Results showed a progressive reduction in runoff and soil loss across treatments. Soil loss values were 6.0 t/ha for bare soil, 2.7 t/ha for mulching, and 1.0 t/ha for velvet bean. Corresponding runoff coefficients were 0.54, 0.30, and 0.14, respectively. Analysis of variance revealed highly significant differences among treatments ($F = 62.77$, $p < 0.001$). Percentage reductions in soil loss were 55.0% for mulching and 83.3% for velvet bean relative to bare soil. Regression analysis indicated a strong relationship between runoff and soil loss ($R^2 = 0.96$). Velvet bean exhibited the highest infiltration rates and lowest erosion losses, demonstrating superior soil protection. The study concludes that vegetative cover, particularly velvet bean, is an effective and sustainable strategy for soil erosion control in the study area.

1. Introduction

Soil erosion remains one of the most critical environmental challenges confronting agricultural sustainability worldwide, particularly in tropical regions where high rainfall intensity accelerates land degradation (Pimentel, 2006). In southeastern Nigeria, especially in Awka, Anambra State, the problem is particularly severe due to a combination of intense seasonal rainfall, fragile soil structure, and increasing anthropogenic pressure from urban expansion and continuous cultivation. These conditions have led to widespread soil degradation, defined as the long-term decline in soil productivity and its capacity to perform essential environmental functions (Adimassu et al., 2020). The soils of this region are predominantly derived from coastal plain sands and are typically characterized by sandy loam textures, low organic matter content, weak structural stability, and high susceptibility to detachment by rainfall. Consequently, the topsoil—rich in soil organic carbon and nutrients essential for plant growth—is highly vulnerable to erosion processes (López-Vicente et al., 2020). The removal of this fertile layer not only diminishes soil quality but also reduces the water-holding capacity of the soil, leading to decreased water availability for crops and ultimately resulting in significant yield losses (Bakker et al., 2004). In many parts of Anambra State, these processes have contributed to the formation of extensive gully erosion systems, posing serious threats to agricultural land, infrastructure, and rural livelihoods.

Maintaining healthy soils is therefore fundamental to sustaining agricultural productivity in the region. Soils perform critical ecosystem functions, including the storage and cycling of nutrients, retention of water, and maintenance of soil organic matter, all of which are essential for crop growth and long-term farm sustainability (Chen et al., 2022). Given the limitations of conventional soil management practices, there is increasing emphasis on the adoption of nature-based solutions that enhance soil resilience while minimizing environmental degradation. Among these approaches, cover cropping and mulching have gained considerable attention as effective, low-cost soil conservation strategies. Cover crops provide continuous ground cover, protect the soil surface from direct raindrop impact, improve soil structure through root development, and enhance organic matter content. Similarly, mulching reduces runoff velocity, moderates soil temperature, conserves soil moisture, and minimizes soil particle detachment. These practices are particularly relevant in erosion-prone environments, where maintaining soil cover during intense rainfall events is critical for reducing soil loss (López-Vicente et al., 2020).

Recent studies highlight the growing importance of cover crops in promoting sustainable agriculture. According to Qiu et al. (2024), the adoption of cover crops has expanded globally due to their potential to improve soil health and reduce environmental impacts. However, their effectiveness is often influenced by site-specific conditions and potential trade-offs, such as competition for water or nutrients. Achieving increased agricultural productivity while minimizing environmental costs remains a key challenge, particularly in the context of meeting interconnected Sustainable Development Goals (SDGs) related to food security, land degradation neutrality, and climate resilience (Nilsson et al., 2016). In light of these challenges, there is a need for context-specific evaluation of soil conservation practices under local environmental conditions. This study therefore focuses on assessing the effectiveness of cover cropping and mulching in reducing runoff and soil erosion in Awka, Anambra State, with the aim of identifying sustainable land management strategies suitable for smallholder farming systems in southeastern Nigeria.

2. Methodology

2.1 Study Area

The study was conducted at the experimental site/farm workshop of the department of Agricultural and Bioresources Engineering, Nnamdi Azikiwe University Awka, (latitudes 6°15’11.8’’N and 6°15’5.3’’N, and longitudes 7°07’11.8’’E and 7°07’18.3’’E). The soils are predominantly sandy loam.

2.2 Experimental Design

A field experiment was established using a randomized complete block design with three treatments and three replications. The treatments included bare soil (control), maize stalks and husks mulch applied at 3.5 t/ha, and velvet bean (*Mucuna pruriens*) cover cropping.

Each experimental plot measured 3m × 4m. Metal borders were installed to prevent lateral flow, and runoff was collected at the lower end of each plot using collection troughs connected to storage containers.

2.3 Data Collection

Natural rainfall events were used for the experiment. Rainfall depth was measured using a rain gauge. Runoff volume was recorded after rainfall event and converted to millimeters. Sediment samples were collected from runoff water, oven-dried at 105°C, and weighed to determine soil loss. Soil erosion rate was expressed in tons per hectare using standard conversion based on plot area.

2.4 Measured Parameters

A rainfall amount of 135 mm recorded during the study period was used to evaluate runoff and soil loss under different treatments. Runoff coefficient was computed as the ratio of runoff to rainfall. Infiltration rate was determined using a double-ring infiltrometer and calculated based on volume of water infiltrated per unit area and time. Percentage reduction in soil loss was computed relative to the bare soil treatment. Runoff (Q) was measured after each rainfall event and expressed in millimeters. Sediment collected in runoff water was oven-dried at 105°C and weighed to determine soil loss (SL). Soil erosion rate (E) was calculated as:

$$E = SL/A \quad (1)$$

where *E* is soil loss in t/ha,
SL is sediment weight in kg, and
A is the plot area in hectares.
Runoff coefficient (C) was calculated using:

$$C = Q/P \quad (2)$$

Infiltration rate was determined using a double-ring infiltrometer and expressed as:

$$f = \Delta V \,/\, (A \times \Delta t) \quad (3)$$

where ΔV is the volume of water infiltrated,
A is the cross-sectional area, and
Δt is the time interval.
Percentage reduction in soil loss due to treatments was computed as:

$$Reduction(\%) = \left[\frac{SL_{control} - SL_{treatment}}{SL_{control}}\right] X\ 100 \quad (4)$$

2.5 Statistical Analysis

Data were analyzed using one-way analysis of variance (ANOVA) at a 5% significance level. Treatment means were separated using the Least Significant Difference (LSD) test.

3. Result

3.1 Runoff, Soil Loss, and Runoff Coefficient

Table 1: Mean Rainfall, Runoff, Soil Loss, and Runoff Coefficient

Treatment	Rainfall (mm)	Runoff (mm)	Soil Loss (t/ha)	Runoff Coefficient
Bare Soil	135	73	6.0	0.54
Mulching	135	40	2.7	0.30
Velvet Bean	135	19	1.0	0.14

The results in Table 1 indicate a strong influence of surface cover on erosion processes. Bare soil exhibited the highest runoff and soil loss due to direct exposure to rainfall impact and low infiltration capacity. Mulching reduced erosion by providing a protective layer that minimized splash detachment and slowed surface flow. Velvet bean cover cropping recorded the lowest erosion values, reflecting its effectiveness in enhancing soil structure, increasing organic matter input, and improving water infiltration.

3.2 Analysis of Variance

The results show that treatment effects were highly significant ($F = 62.77$, $p < 0.001$). This confirms that mulching and velvet bean cover cropping significantly reduced soil loss compared to bare soil conditions. The coefficient of variation (CV = 14.4%) indicates acceptable experimental reliability.

Table 2: One-Way ANOVA for Soil Loss

Source	SS	df	MS	F-value	F-critical	p-value
Treatments	27.62	2	13.81	62.77	5.14	<0.001
Error	1.32	6	0.22			
Total	28.94	8				

3.3 Mean Separation (LSD Test)

Table 3: LSD Test for Soil Loss

Treatment	Mean Soil Loss (t/ha)	Group
Bare Soil	6.0	A
Mulching	2.7	B
Velvet Bean	1.0	C
LSD (0.05)	0.94	

All treatment means differ significantly, indicating a clear ranking of effectiveness: velvet bean > mulching > bare soil.

3.4 Infiltration Characteristics

Table 4: Infiltration Rates

Treatment	Initial (mm/h)	Steady-State (mm/h)
Bare Soil	11	6
Mulching	33	15
Velvet Bean	37	21

Infiltration improved progressively with increasing soil cover. The improvement under velvet bean is attributed to root penetration, increased porosity, and enhanced soil organic matter content. Higher infiltration reduces runoff generation and ultimately lowers soil erosion risk.

3.5 Runoff–Soil Loss Relationship

Regression analysis revealed a strong linear relationship between runoff and soil loss, expressed by the model:

$$SL = 0.074Q + 0.58 \quad (R^2 = 0.96)$$

where *SL* is soil loss (t/ha)
Q is runoff (mm).

The high coefficient of determination ((R^2 = 0.96)) indicates that 96% of the variability in soil loss is explained by runoff, demonstrating an excellent model fit. The slope of the regression line (0.074) indicates that soil loss increased by 0.074 t/ha for every 1 mm increase in runoff**,** reflecting a strong sensitivity of soil erosion to runoff generation. The intercept (0.58 t/ha) represents the baseline soil loss occurring in the absence of measurable runoff, which may be attributed to raindrop impact (splash erosion) and initial soil particle detachment prior to runoff initiation. This confirm that runoff is a major driver of soil erosion in the study area, and that practices capable of reducing runoff will significantly decrease soil loss.

3.6 Percentage Reduction in Soil Loss

The effectiveness of mulching and velvet bean cover cropping in reducing soil loss relative to the bare soil condition is presented in Table 3.5.

Table 5: Percentage Reduction in Soil Loss under Different Treatments

Treatment	Reduction (%)
Mulching	55.0
Velvet Bean	83.3

The results indicate that both conservation practices substantially reduced soil loss compared to the control (bare soil). Mulching achieved a 55.0% reduction in soil loss, demonstrating its effectiveness in protecting the soil surface from direct raindrop impact and reducing the detachment and transport of soil particles. The presence of maize residues likely dissipated rainfall energy, reduced surface sealing, and slowed runoff velocity, thereby limiting sediment transport.

In contrast, velvet bean cover cropping resulted in a significantly higher reduction of 83.3%**,** indicating superior performance in controlling soil erosion. This enhanced effectiveness can be attributed to multiple interacting mechanisms. The dense canopy cover provided by velvet bean minimizes raindrop impact, while its well-developed root system improves soil structure, increases aggregate stability, and enhances porosity. These changes promote greater water infiltration and reduce surface runoff, which is the primary agent of soil particle transport.

The addition of organic matter from velvet bean biomass contributes to improved soil cohesion and resistance to detachment. The combined effects of surface protection, improved infiltration, and enhanced soil physical properties explain the markedly lower soil loss observed under the cover crop treatment. The substantial difference between mulching and velvet bean treatments highlights the importance of continuous vegetative cover over temporary surface protection. While mulching provides immediate but relatively short-term protection, cover crops offer sustained soil stabilization throughout the growing period

Conclusion

This study demonstrated that both mulching and velvet bean (*Mucuna pruriens*) cover cropping are effective soil conservation practices for reducing runoff and soil loss in sandy loam soils under humid tropical conditions. The results consistently showed a significant decline in runoff generation and soil erosion from bare soil to mulched plots, and further to velvet bean–covered plots. Velvet bean exhibited the highest level of effectiveness, achieving the greatest reduction in soil loss and runoff. This superior performance is attributed to its dense vegetative cover and extensive root system, which enhanced soil structure, increased aggregate stability, and improved infiltration capacity. These effects collectively reduced the detachment and transport of soil particles by surface runoff. In contrast, while mulching provided substantial protection by shielding the soil surface and reducing flow velocity, its impact was comparatively lower due to its primarily surface-level action and limited influence on subsurface soil properties.

The strong relationship observed between runoff and soil loss further emphasizes that practices which enhance infiltration and reduce surface flow are critical for effective erosion control. The high percentage reduction in soil loss under velvet bean highlights its potential as a long-term, sustainable solution for soil management. In conclusion, the adoption of vegetative cover, particularly velvet bean, offers a practical and efficient strategy for mitigating soil erosion in southeastern Nigeria and similar agroecological zones. Integrating such biological soil conservation measures into existing farming systems can significantly improve soil stability, maintain productivity, and support sustainable land management in erosion-prone environments.

Farmers in erosion-prone areas of southeastern Nigeria should adopt velvet bean cover cropping as a primary soil conservation practice due to its high effectiveness. Mulching should be encouraged as a supplementary practice, especially in the early stages of cropping systems where cover crops are not yet fully established. Extension services should promote integrated soil conservation practices combining organic mulching and cover cropping to improve long-term soil health. Future research should investigate long-term soil fertility impacts, carbon sequestration potential, and crop yield responses under continuous use of these conservation practices.

References

Adimassu, Z., L. Tamene, and D. T. Degefie. (2020). The influence of grazing and cultivation on runoff, soil erosion, and soil nutrient export in the central highlands of Ethiopia. Ecological Processes 9 (23). doi: 10.1186/s13717-020- 00230-z.

Qiu T, Shi Y, Peñuelas J, Liu J, Cui Q, Sardans J, Zhou F, Xia L, Yan W, Zhao S, Peng S, Jian J, He Q, Zhang W, Huang M, Tan W & Fang L (2024). Optimizing cover crop practices as a sustainable solution for global agroecosystem services Nature Communications 15, Article number: 10617

Nilsson, M., Griggs, D. & Visbeck, M. (2016). Policy: map the interactions between sustainable development goals. Nature 534, 320–322

Bakker, M. M., G. Govers, and M. D. A. Rounsevell. 2004. The crop productivity-erosion relationship: An analysis based on experimental work. Catena 57 (1):55–76. doi:10.1016/j.catena.2003.07.002.

López-Vicente M, Calvo-Seas E, Álvarez S, Cerdà A (2020). Effectiveness of Cover Crops to Reduce Loss of Soil Organic Matter in a Rainfed Vineyard Land 9(7):230. DOI:10.3390/land9070230

Chen P, Rejesus RM, Aglasan SB, Hagen SC, Salas W (2022). The impact of cover crops on soil erosion in the US Midwest. Journal of Environmental Management 324, 116168