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INFLUENCE OF SOIL PHYSICAL PROPERTIES ON SOIL LOSS DUE TO YAM HARVESTED ON A SANDY LOAM SOIL IN IWO, OSUN STATE, NIGERIA

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ABSTRACT

Soil loss due to crop harvesting (SLCH) has been established as an important soil erosion process that has contributed to soil degradation in many countries of the world. However, the quantification of SLCH, particularly concerning yam tubers, remains unstudied globally, despite yam being a crucial staple food in Nigeria. This research examines how soil physical properties affect soil loss during yam harvesting on sandy loam soil in Iwo, Osun State, Nigeria. Manual harvesting of yam tubers was conducted, measuring both their weight and the soil attached to them. The study analyzed the impact of soil properties such as aggregate stability, available water content, bulk density, and texture on soil loss. Results indicated sand content (671.00 g/kg), a bulk density of 1.30 g/cm³, saturated hydraulic conductivity of 7.37 cm/hr, and a moisture content of 15.70%. The infiltration rate averaged 12.5 units in 11 minutes. Manual mound tillage produced the highest soil loss (160.00 kg/ha/harvest), while Zai pit tillage resulted in the least (75.60 kg/ha/harvest). The study highlights the importance of adopting effective soil conservation practices and suggests developing yam harvesters that replicate the hand rubbing technique to reduce soil loss.

Keywords: Soil physical properties, Soil loss, Yam harvesting, Sandy loam soil, Tillage practices

INTRODUCTION

Soil is an essential natural resource that forms the foundation of agriculture and food production, yet it is often under threat from degradation processes such as erosion. In Nigeria, where agriculture remains the backbone of rural livelihoods, the issue of soil loss is particularly pressing. Among the many factors contributing to soil degradation, anthropogenic activities such as tillage and harvesting play a significant role, especially in areas where traditional, manual harvesting methods are common (Lal, 1998; Dada *et al*., 2016). Yam (*Dioscorea spp.*), a major staple crop in Nigeria, particularly in the southwestern states like Osun, is typically harvested by digging and uprooting, a process that can disturb soil structure and result in considerable soil displacement. Sandy loam soils, predominant in the Iwo region of Osun State, are favoured for yam cultivation due to their loose texture and ease of root penetration (Obi, 2020).

However, these same physical properties (low cohesion, high porosity, and moderate to low water-holding capacity) can make the soil more vulnerable to erosion during periods of disturbance, especially at harvest. The physical characteristics of soil, such as texture, bulk density, porosity, aggregate stability, and moisture content, are key determinants of how soil behaves under mechanical or manual disturbance (Brady and Weil, 2016). When harvesting yams, the act of digging disrupts the soil matrix, and depending on these properties, significant quantities of soil may be removed alongside the tubers.Research has shown that the rate of soil loss is not only a function of external forces like rainfall or slope but also heavily influenced by internal soil factors (Ezeaku and Iwuafor, 2020).

For example, a soil with higher bulk density may resist penetration more, leading to more forceful digging, which can exacerbate soil detachment. Similarly, a poorly aggregated soil may crumble easily during harvesting, contributing to greater soil loss. In areas with loose sandy loam soils and limited vegetation cover, the risks are even greater, as the protective layer that might otherwise reduce soil detachment is often absent.In Iwo, Osun State, where yam farming is widespread and frequently practised on sandy loam soils, the cumulative impact of repeated annual harvesting cycles could lead to long-term degradation if not properly managed. Understanding how specific soil physical properties influence the extent of soil loss during yam harvesting is, therefore, critical. Such knowledge can guide farmers and agricultural extension agents in adopting better harvesting practices, improving land use planning, and ultimately ensuring the sustainability of yam production systems in the region (Ojeniyi, 2022).Even though yam is a major staple food consumed and grown worldwide and it is prevalent in many parts of Nigeria, little has been known on influence of soil physical properties on soil loss due to yam harvesting on a sandy loam soil in Iwo, Osun State, Nigeria.

Therefore, this study reports the influence of soil physical properties on soil loss due to yam harvested on a sandy loam soil in Iwo, Osun State, Nigeria.

MATERIALS AND METHODS

Site description

The experiment was conducted at the Teaching and Research Farm of Offer Centre Institute of Agriculture, Oluponna, Iwo, Osun state, southwest, Nigeria {latitude 07° 55ʹ 30"N (7.5901245° N) longitude 04° 11ʹ 30"E (4.1816157° E)}. The annual rainfall is 1250 mm with a bimodal pattern and has a minimum temperature of 21.9°C and a maximum temperature of 35.5°C (NIMET, 2024).

Soil sampling, preparation, and analysis

Soil samples were collected randomly from 0-15cm topsoil before planting from the experimental plots which were analyzed for physical (aggregate stability, bulk density) and chemical properties (organic carbon, total nitrogen, etc). The soil samples collected were packed into well-labeled polythene bags and sealed for transportation to the laboratory to determine; bulk density by core-sampling method (Baruah and Barthakur, 1997), particle size distribution using hydrometer method (Bouyoucos, 1965), saturated hydraulic conductivity by core-sampling method (Soil Science Society of America, 2002; Oshunsanya, 2016), soil pH using pH meter (Udo and Ogunwale, 1986), organic carbon using Walkley Black wet oxidation method (Udo and Ogunwale, 1986), total nitrogen using khadjahl method (Kjeldahl, 1883; Fenton, *et. al*., 2016), available phosphorus with a spectrophotometer using Mehlich 111 as extractant (Mehlich, 1984) method, exchangeable bases (K, Ca, Na, and Mg) with atomic absorption spectrometer, exchangeable acidity and extractable Micronutrient (Fe, Mn, Cu, and Zn) with atomic absorption spectrometer. Post-planting soil was also collected as done before planting to determine the post-planting soil analysis after harvesting.

Experimental design and treatment

The experiment was laid out in a 3 x 3 factorial in a Randomized Complete Block Design (RCBD) with three replicates. Three cultivars of yam (*Dioscorea alata*, *Dioscorea cayenensis* and *Dioscorea rotundata*) and three tillage practices (manual mound, manual ridge and zai pit) were the treatments used in the experiment (Plate 1).

Source of yam setts

Yam setts were purchased from Iluju market in Oyo, state, Nigeria.

Determination of total soil loss due to yam harvesting specific (TSLYHspec) and crop (TSLYHcrop)

At harvesting, each of the harvested yam tubers was cleansed by hand rubbing to remove the soil particles loosely held unto the tubers during harvest (Plate 2) was weighed inside a well tagged nylon on the digital sensitive scale and recorded. Total soil loss due to yam harvesting specific (TSLYHspec) (using Equation 1) and total soil loss due to yam harvesting per area per harvest per year (TSLYHcrop) (Equation 2).

$$\text{Total SLYHspec}\left(\text{g}/\text{kg}\right) = \frac{M_{ds}}{M_{crop}} \quad (1)$$

Where:

M_{ds}= total mass of dry soil loss (g) obtained from hand rubbed yam; M_{crop} = yam mass (kg)

$$TSLCH_{crop}(kg/ha/harvest/year) = SLCH_{spec} \times M_{cy} \quad (2)$$

Where:

$SLCH_{spec}$= soil loss per unit root mass (g/kg);

M_{cy}= yam yield (kg/ha/harvest/yr),

Land preparation and crop establishment

The field was cleared and tilled manually with the use of matchet and hoe.The entire field was partitioned into nine (9) experimental plots each measuring 13m x 10m per replicate.Yam setts with an average weight of 260g were cut from yam tubers using knife, planted at a spacing of 1m x 1m and a depth of 15cm. Weeding was done manually as and when due. Yam tubers were harvested at eight (8) months after planting. Weight of freshly harvested tubers was determined using digital measuring scale.

Manual Mound Manual Ridge Zai pit

Plate 1: Tillage practices used for the experiment

Plate 2: Soil particles attached to the yam variety after harvest

Statistical Analysis

Data on aggregate stability, available water content, bulk density, yam yields and soil loss due to yam harvesting, were subjected to analysis of variance (ANOVA) using Genstat 5 release 3.2 (PC/Window 95). Means were compared using Duncan multiple range test (DMRT) at both 5% and 1% probability levels. Correlation coefficients and significance levels were determined.

RESULTS AND DISCUSSION

The pre-planting soil physical and chemical properties of the experimental sites are as presented in Table 1 and Figure 1. Soil particle distribution revealed a composition of 671 g/kg sand, 176 g/kg silt, and 153 g/kg clay, placing it in the sandy loam category. This type of soil is typically loose and drains well, making it particularly suitable for root crops like yam that require soft, easily penetrable ground for tuber growth and harvesting. However, the same loose structure and low cohesiveness also make sandy loam soils more prone to soil disturbance and loss during harvest (Obi, 2000).Bulk density of 1.30 g/cm³ falls within the standard range for cultivated soils, suggesting moderate compaction. This supports sufficient root penetration and water infiltration.

Nevertheless, the relatively low density may also make the soil more vulnerable to being physically disrupted during harvesting, potentially resulting in significant soil displacement (Lal, 1998). Similarly, the total porosity of 50.94% reflects ample pore space for air and water movement, but it may also lead to reduced soil structure stability when the soil is mechanically disturbed. Saturated hydraulic conductivity of 7.37 cm/hr indicated that the soil has high permeability, allowing water to pass through rapidly. This trend is consistent with the infiltration pattern shown in Figure 1, where water entered the soil quickly before leveling off. Such a pattern is common in sandy loam soils, which have larger pore spaces (Brady and Weil, 2016).

While rapid infiltration helps reduce surface runoff, it also means that soil particles are held together more loosely, increasing the likelihood of loss during root harvesting—especially in dry conditions when the soil is less cohesive.The moisture content at 15.7% signified a moderate level of water retention at the time of sampling. While this is sufficient to maintain some cohesion among soil particles, it may not provide enough moisture to prevent breakdown of soil structure during the physical strain of harvesting. The water stable aggregates (WSA) measured 59.53%, indicating moderate resistance to breakdown when wet. Similarly, the mean weight diameter (MWD) of 1.19 mm reflects average aggregate size and stability. These figures suggest that although the soil has some structural integrity, it remains vulnerable to disintegration under mechanical stress, a key concern during yam harvesting (Six *et al*., 2000).

The soil had a pH of 6.50, placing it in the slightly acidic range, which is favorable for yam growth and allows for effective nutrient uptake and microbial activity. The organic carbon content, measured at 26.93 g/kg, showed that the soil had a decent amount of organic matter. This can help improve both aggregate stability and water-holding capacity. However, despite this relatively healthy organic matter level, the moderate WSA and MWD values imply that the soil might still be structurally weak when subjected to mechanical harvesting (Ojeniyi, 2002).Levels of total nitrogen (2.80 g/kg) and available phosphorus (7.71 mg/kg) suggested a moderately fertile soil, capable of supporting vigorous yam growth. However, the development of strong yam roots can also result in intense soil disturbance during harvesting, increasing the risk of soil displacement. The concentrations of exchangeable cations—calcium (2.67 cmol/kg), magnesium (0.64 cmol/kg), potassium (0.33 cmol/kg), and sodium (0.31 cmol/kg) were within optimal ranges, indicating a balanced nutrient profile. Additionally, micronutrient levels, particularly iron (50.92 mg/kg) and manganese (43.33 mg/kg), were found to be abundant, contributing further to the favorable fertility conditions for yam cultivation.Altogether, the combination of a loose sandy loam texture, moderate moisture content, and average aggregate stability suggests that while the soil is agriculturally productive, it is also physically delicate. During yam harvesting, especially under dry conditions or when forceful extraction is required—there is a significant risk of soil disturbance and erosion. This observation is in line with findings from Ezeaku and Iwuafor (2010), who emphasized that mechanical interference in light-textured soils can lead to substantial topsoil loss, particularly in the absence of strong aggregate cohesion supported by organic matter or protective vegetation cover.

Table 1: Pre-planting soil physical and chemical properties of the experimental sites

Soil parameters	Content
Physical Properties	
Particle size distribution (g/kg)	
Sand	671.00
Silt	176.00
Clay	153.00
Textural class	Sandy Loam
Bulk density (g/cm^3)	1.30
Saturated hydraulic conductivity (cm/hr)	7.37
Moisture Content (%)	15.7
Water stability Aggregate (%)	59.53
Mean weight Diameter (mm)	1.19
Total Porosity (%)	50.94
Chemical Properties	
pH (H_2O)	6.50
Organic Carbon (g/kg)	26.93
Total Nitrogen (g/kg)	2.80
Available Phosphorus (mg/kg)	7.71
Exchangeable Acidity (cmol/kg)	0.31
Exchangeable Cations (cmol/kg)	
Ca	2.67
Mg	0.64
K	0.33
Na	0.31

Extractable Micronutrient (mg/kg)	
Mn	43.33
Fe	50.92
Cu	2.36
Zn	1.49

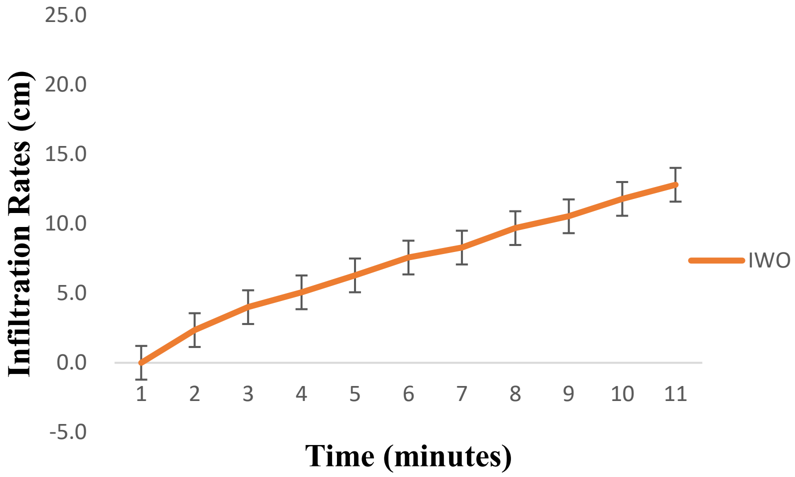

Figure 1: Infiltration rate over time (mins.) for Iwo experimental sites

Main and interactive effects (F- values) of tillage practices and yam varieties on total soil loss per land area per harvest per year (SLCHcrop (kg/ha/harvest)) and soil loss per unit root mass (SLCHspec (g/kg)) at Iwo are as presented in tables 2 and 3. Tillage practices, yam varieties, and their interaction significantly influenced soil loss per harvest (SLCHcrop) and soil loss per unit root mass (SLCHspec) across 2020–2022. Tillage had significant effects on both parameters each year ($p < 0.05$), while yam variety had highly significant effects in 2020 and 2022 ($p < 0.01$). The interaction (TP × YV) significantly affected SLCHcrop but not SLCHspec.Table 3 revealed that Zai pit tillage consistently minimized soil loss, with SLCHcrop values of 82.42, 94.91, and 75.60 kg/ha/harvest (2020–2022), significantly lower than manual mounding, which peaked at 160.00 kg/ha/harvest. SLCHspec followed the same trend, with Zai pit showing the lowest values (584.28–715.25 g/kg). These findings support the soil-conserving benefits of Zai pits (Ojeniyi, 2002; Brady and Weil, 2016). Among yam varieties, *Dioscorea alata* (Da) caused the least soil loss, with SLCHspec as low as 379.83 g/kg, compared to *D. cayenensis* (Dc), which recorded up to 1236.04 g/kg. *D. alata*’s smaller, shallower tubers likely reduce soil disturbance, corroborating Opara (2000) and Lal (1998), who linked root system architecture to erosion risk.

Table 2: Summary of ANOVA of Main and Interactive Effects (F- values) of Tillage Practices and Yam Varieties on Total Soil Loss per Land Area per Harvest per Year (SLCHcrop (kg/ha/Harvest)) and Soil Loss per Unit Root Mass (SLCHspec (g/kg)) at Iwo

Source of Variation	Degree of Freedom	2020		2021		2022	
		SLCHcrop	SLCHspec	SLCHcrop	SLCHspec	SLCHcrop	SLCHspec
Tillage practices	2	0.05**	0.05*	0.03*	0.03*	0.04*	0.05*
Yam varieties	2	<0.001**	<0.001**	0.05*	0.05*	<0.001**	<0.001**
TP X YV	4	0.01**	0.66ns	0.03*	0.73ns	0.03**	0.37ns

* = significant at 0.05 significance level; ** = highly significant at 0.01 significance level; ns = not significant at 0.05 significance level; TP = tillage practices; YV = yam varieties

Table 3: Main Effects of Tillage Practices, Sawdust Mulch and Yam Varieties on Total Soil Loss per Land Area per Harvest per Year (SLCHcrop (kg/ha/Harvest)) and Soil Loss per Unit Root Mass (SLCHspec (g/kg)) at Iwo

Treatment	2020		2021		2022	
	SLCHcrop	SLCHspec	SLCHcrop	SLCHspec	SLCHcrop	SLCHspec
Tillage practices						
Manual mound	132.39b	888.12b	160.00c	554.91b	111.64c	685.83b
Manual ridge	84.39a	747.54a	142.90b	438.92a	96.97b	655.19b
Zai pit	82.42a	715.25a	94.91a	417.03a	75.60a	584.28a
Yam varieties						
Da	70.79a	379.83a	94.69a	385.66a	72.99a	382.90a
Dc	90.99b	1236.04c	119.14b	511.09b	86.98b	1001.56b
Dr	89.35b	635.04b	110.14b	414.11a	78.09a	541.83a

Means followed by the same letter in each column for each parameter are not significantly different from each other by Duncan Multiple Range Test (DMRT) at 5% level of probability. Da = *Dioscorea alata*; Da = *Dioscorea cayenensis*; Da = *Dioscorea rotundata*

The ANOVA results (Table 4) revealed that tillage practices and yam varieties had highly significant effects ($p < 0.01$) on aggregate stability (AS) and bulk density (BD) across all years, while their effects on available water content (AwC) were not significant. However, the interaction between tillage and variety was significant for all parameters in 2021 and 2022 except for available water content in 2020. The result in table 5 shows that zai pit consistently resulted in the highest AS (74.09%, 74.04%, 73.61%) and lowest BD (1.21–1.22 g/cm³), indicating improved soil structure and porosity. Conversely, manual ridging led to higher BD values. Among yam varieties, *Dioscorea cayenensis* showed higher AS in 2020–2021, while *Dioscorea alata* performed better in 2022. Varietal differences in BD were also observed, with *Dioscorea rotundata* often associated with higher BD. AwC was not significantly influenced by either factor individually, though interaction effects were significant in later years, suggesting combined effects of tillage and yam type can influence water retention. These findings align with previous studies that highlight the benefits of conservation tillage (Obalum *et al*., 2012; Adekalu *et al*., 2006) and varietal influence on soil structure (Jaiyeoba and Olayemi, 2001; Ola *et al.,* 2018).

Table 4: Summary of ANOVA of Main Effects (F- Values) of Tillage Practices and Yam Varieties on Aggregate Stability (%) Available Water Content (cm^3) and Bulk Density (g/cm^3) at Iwo

IWO

SV	df	2020			2021			2022		
		AS	AwC	BD	AS	AwC	BD	AS	AwC	BD
Tillage practice	2	<0.001**	0.85ns	<0.001**	<0.001**	0.16ns	<0.001**	<0.001**	<0.001	<0.001**
Yam Varieties	2	<0.001**	0.88ns	<0.001**	<0.001**	0.13ns	<0.001**	<0.001**	0.35ns	<0.001**
TP X YV	4	<0.001**	0.95ns	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**

* = significant at 0.05 significance level; ** = highly significant at 0.01 significance level; ns = not significant at 0.05 significance level; TP = tillage practices; YV = yam varieties

Table 5: Main Effects of Tillage Practices and Yam Varieties on AS, AwC and BD at Iwo

Trts	2020			2021			2022		
	AS	AwC	BD	AS	AwC	BD	AS	AwC	BD
Tillage practice									
Manual Mound	67.33a	0.21a	1.39b	62.76a	0.23a	1.49a	58.40a	0.22b	1.45b
Manual ridge	69.81ab	0.21a	1.47c	73.18a	0.21a	1.51b	71.13b	0.17a	1.46b
Zai pit	74.09b	0.23a	1.21a	74.04b	0.24a	1.22a	73.61b	0.29c	1.22a
Yam Varieties									
Da	68.62a	0.22a	1.32a	67.67a	0.24a	1.42a	74.98b	0.22a	1.35a
Dc	77.10b	0.22a	1.37a	74.54b	0.21a	1.54b	64.77a	0.24a	1.35a
Dr	70.51a	0.22a	1.48b	67.74a	0.24a	1.37a	67.40a	0.22a	1.43b

Means followed by the same letter in each column for each parameter are not significantly different from each other by Duncan Multiple Range Test (DMRT) at 5% level of probability.
Da = *Dioscorea alata*; Da = *Dioscorea cayenensis*; Da = *Dioscorea rotundata*

Main effects of tillage practices and yam varieties on yield (t/ha) at Iwo is as presented in table 6. Over the three-year study at Iwo, manual mounding and ridging consistently produced higher yam yields than Zai pit tillage, with mean yields ranging from 1.31–1.76 t/ha compared to 1.13–1.51 t/ha for Zai pit. The lower yield under Zai pit may result from reduced soil volume for tuber expansion, despite its benefits for soil structure (*Adekalu et al., 2006*). Among varieties, *Dioscorea cayenensis* (Dc) significantly outperformed *Dioscorea alata* (Da) and *D. rotundata* (Dr) in all years, with yields up to 1.80 kg. This supports earlier findings that Dc is more adaptable and efficient in resource use (Ola *et al.,* 2018).

Table 6: Main Effects of Tillage Practices and Yam Varieties on Yield (kg) at Iwo

Treatment	Iwo 2020	Iwo 2021	Iwo 2022
Tillage practices			
Manual mound	1.32b	1.76b	1.47b
Manual ridge	1.31b	1.73b	1.39b
Zai pit	1.19a	1.51a	1.13a
Yam varieties			
Da	1.07a	1.60a	1.31a
Dc	1.79c	1.80b	1.57b
Dr	1.12a	1.71ab	1.41a

Means followed by the same letter in each column for each parameter are not significantly different from each other by Duncan Multiple Range Test (DMRT) at 5% level of probability. Da = *Dioscorea alata*; Da = *Dioscorea cayenensis*; Da = *Dioscorea rotundata*

Correlation matrix among the soil loss due to yam harvesting specific (SLCHspec.), soil loss due to yam harvesting per area per harvest per year (SLCHcrop), yam yield (RY), sand, silt, clay, bulk density (BD), organic matter (OM) and moisture content (MC) variables at Iwo is as presented in table 7. The correlation analysis showed strong positive associations between yield and soil loss due to harvesting (r = 0.88 – 0.95**), likely reflecting greater soil disturbance with larger tubers. Yield also correlated negatively with sand (r = -0.85*) and positively with clay (r = 0.75*) and organic matter (r = 0.38), suggesting that loamier, nutrient-rich soils favor yam growth (*Brady & Weil, 2008*).

Table 7: Correlation Matrix Among the Soil Loss due to Yam Harvesting Specific (SLCHspec.), Soil Loss due to Yam Harvesting Per Area Per Harvest Per Year (SLCHcrop), Yam Yield (RY), Sand, Silt, Clay, Bulk Density (BD), Organic Matter (OM) and Moisture Content (MC) Variables at Iwo

	SLCHspec	SLCHcrop	YY	Sand	Silt	Clay	BD	O.M
SLCHspec	1							
SLCHcrop	0.98**	1						
YY	0.88**	0.95**	1					
Sand	-0.94**	-0.94**	-0.85*	1				
Silt	-0.23	-0.26	-0.25	0.19	1			
Clay	0.66	0.75	0.75*	-0.85*	-0.68*	1		
BD	-0.44	-0.44	-0.26	0.37	-0.19	-0.19	1	
O.M	0.50*	0.48*	0.38	-0.54	0.02	0.38	-0.13	1
MC	0.36	0.35	0.33	-0.31	0.08	0.27	0.05	-0.06

∗ Indicates correlation is significant at $p<0.05$.
∗∗ Indicates correlation is significant at $p<0.01$.

CONCLUSION

Soil loss due to yam harvesting was quantified and soil physical properties that influence the huge amount of soil loss were investigated. It can be concluded that a significant amount of soil is lost from yam harvesting especially when the soils have high clay content. The main factors responsible for the large amount of soil loss during yam harvesting at both fields were soil moisture content and clay content. Additional factors are size and shape of crop. The high soil loss from yam harvesting and other tuber crops should not be ignored when assessing soil erosion on agricultural lands. Therefore, thorough hand rubbing of harvested tubers on the farm is suggested for small scale yam farms because the method removed about 96% of soil adhering to tubers. Fabricating yam harvesters that can mimic hand rubbing process is suggested for large scale yam farms especially in the studied area.

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