EVALUATION OF SOIL AND NUTRIENT LOSSES FROM CASSAVA MANUALLY HARVESTED IN ODEDA LOCAL GOVERNMENT AREA, OGUN STATE, NIGERIA

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ABSTRACT

Soil loss is a growing problem worldwide because the fertile top layer of the soil available for food production is reduced. Most research on soil erosion have focused on the negative effects of moving agents such as water and wind. However, soil loss due to harvesting of root/tuber crops like yam and cassava on the farms has received less attention. This study investigated the amount of soil and nutrients lost during tuber harvesting and the factors contributing to their losses based on representative sampling area per location using Oju-Ogun and Rolu-Osaara as study areas. Soil physical properties: Moisture Content (MC), Bulk Density (BD), soil particle distribution, soil loss due to crop harvesting (SLCHcrop) and Soil loss specific (SLCHspec); Soil macro nutrient status: Nitrogen (N), Phosphorus (P), Potassium (K) and Organic Carbon (OC) and Agronomic characteristics: Gross Weight (GW), Net Weight (NW), Average Crop Yield (ACY), and Mass of Crop Yield (MCY) were investigated. Data obtained were analyzed using descriptive statistics, t-test and correlation analysis. Average GW, NW, ACY, MCY, MC, BD, Soil and Micro nutrients lost for cassava fields in Oju-Ogun and Rolu-Osaara were 26.96kg, 25.20kg, 0.61kg, 13684.73kg/ha/har, 10.40%, 1.28g/cm^3, 885.19kg/ha/har, (12.09 N, 0.058 P, 0.65 K, 23.22 OC) kg/ha/har and 25.55kg, 24.45kg, 0.60kg, 13546.50kg/ha/har, 6.40%, 1.41g/cm^3, 576.99kg/ha/har, (22.67 N, 0.077 P, 0.42 K, 14.12 OC)kg/ha/har respectively. Agronomic characteristics, moisture content, and bulk density did not significantly affect SLCHcrop on the cassava fields ($P<0.05$). Silt content played a significant role in SLCH for cassava fields in Oju-Ogun ($P<0.05$), while Sand and Clay content did not play any significant role in SLCHcrop and SLCHspec in Rolu-Osaara. Soil loss in cassava fields in Oju-Ogun were significantly ($p<0.05$) higher than that of Rolu- Osaara fields. Consequently, since the soil and nutrient losses were significant, soil loss due to crop harvesting should not be ignored when assessing soil erosion on agricultural lands.

INTRODUCTION

Soil loss is a growing problem worldwide because it reduces the fertile top layer of the soil available for food production. As more than 99% of the world's food comes from the land, it is therefore of great importance to understand the mechanism of soil erosion and to be able to predict its effects in order to preserve human food availability and natural environment (Ruysschaert *et al.*, 2009).
Although, majority of soil erosion research work are focused on soil loss caused by moving agents like water, wind or tillage, large amount of soil are also lost when harvesting roots and tuber crops such as yam, cassava, potato, carrot etc. (Auersawald *et al.*, 2006; Dada *et al.*, 2016).

The soil sticking to the harvested crops that is exported from the farmland, and that is rarely returned to the farmland is known as soil loss due to crop harvesting (SLCH) (Mwango *et al.*, 2014; Oldeman *et al.*, 1990; UNEP 2000). Soil loss due to crop harvesting (SLCH) may vary from few to tens of tones of soil per hectare per harvest which may be the same order of magnitude as water and tillage erosion values, some studies have actually incorporated SLCH as a soil erosion process. Ruysschaert *et al.*, 2005 showed that mean SLCH values for sugar beet calculated from soil tare data measured in sugar factories were 6t ha^{-1} harvest for the Netherlands, 14t ha^{-1} harvest for France, 9t ha^{-1} harvest for Belgium and 5t ha^{-1} harvest for Germany between 1978 and 2000 and 3.8t ha^{-1}harvest for Turkey (Oruc *et al.*, 2000; Oztas *et al.*, 2002).

Soil loss due to crop harvesting (SLCH) may vary from few to tens of tones of soil per hectare per harvest which may be the same order of magnitude as water and tillage erosion values, some studies have actually incorporated SLCH as a soil erosion process. On the other hand, some traditional farmers intentionally leave the soil adhering to yams and cassava because they believe it makes their produce look bigger in the eyes of their customers (consumers) meaning they will be able to sell such yams and cassava at a higher cost. And some of the farmers who are using beam or spring balance believed the soil adhering to yams or cassava especially the ones with branches will add more weight for financial gains. They are ignorant of the fact that nutrients are lost as a result of soil adhering to the yams and cassava which will eventually lead to poor harvesting during the following harvesting season and a loss at long-run. Furthermore, some of the farmers do not want additional work of removing soil attached to the yams and cassava (Dada *et al*., 2016). Soil material is retained on the storage roots and its amount is related to the shape of the root, the amount of lateral roots, depth of rooting, the composition of soil and the amount of water in it as well from the technique of harvesting. Soil mass taken out from the field depends also on the adhesive properties of soil and its water capacity, increasing with the increase of clay fraction and water contents in soil during the harvesting (Larymers, and Stratz, 2003).The engineering approach to soil and water conservation problems involves the physical integration of soil, water and plants in the design of a coordinated water management and execute measures that curtails or minimizes the effects of factors that accelerate or aggravate the processes of Soil loss and flood. Despite the assessment of soil losses in tuber and root crops in many parts of the world, there is very little information on soil losses during manual yam harvesting, hence this study to evaluate losses of soil from harvested yam fields and investigate the soil physical properties influencing the losses.

MATERIALS AND METHODS

Site description

The studies were carried out in two villages: Oju-Ogun, Olodo (Latitude-N070^0 19^1; Longitude-E030^0 35'), and Rolu/Osaara (latitude-N070^0 12'; longitude-E0030^0 24^1) in Odeda Local Government Area, Ogun State, Nigeria.

Methods of Sample Collection

Soil samples were taken from cassava fields in the mornings when they were manually harvested in the two villages (Oju-Ogun and Rolu/Osaara) in Odeda Local Government Area of Ogun State, Nigeria. The cassava fields were selected in such a way that they represent a range of soil texture.

In each location, ten farms were selected based on the crop type. At each farm, the experimental plot area where harvesting took place was 4m^2 for cassava per sample per plot which were randomly selected. Cassava roots were carefully dug out of the heaps using small cutlasses and hands after cutting off the Cassava roots. In each farm plot, cassava roots were randomly selected in separate plastic bags and measured in the field immediately after harvesting by weighing gross mass of each crop (i.e. mass of crop plus mass of moist soil), thereafter the soil adhering to the roots is scraped off with a light stick removing the soil and weighing the individual crop again with spring balance. The total dry soil mass were determined after oven-drying overnight at 105°C.

In each location, crop samples from twenty experimental plots were collected making a total of 40 experimental plots from the two locations. At each sampling plot, one undisturbed top soil sample were collected with soil core rings (100cm^3) for determination of soil moisture content, soil texture, and bulk density using oven dry at 105°C. Composite top soil samples (from 10 sub samples randomly sampled at the farmers' plots at a depth between 0 and 30cm) were collected for soil fertility analysis. Average tuber yield (kg), plant density (ha^{-1}), and total soil loss due to crop harvesting specific (kg kg^{-1}) and soil loss due to crop harvest (kg ha^{-1} harvest^{-1}) were determined accordingly. Soil samples for physical and chemical analysis were air dried, milled, sieved and homogenized (ISO 11464).

PHYSICAL ANALYSIS

Determination of Gravimetric Moisture Content from the Heap

$$GMC = \frac{Mw}{Mds} \times 100 \quad (1)$$

Where GMC = Gravimetric moisture content(%), Mw = Mass of water (g) Mds = Mass of oven dried soil (g).

Determination of Bulk Density (BD):

$$BD = \frac{Mds}{Vc} \quad (2)$$

Where BD = Bulk density (gcm^{-3}), Mds = Mass of oven dried soil (g), Vc = Volume of soil core (cm^{-3})

Determination of Total Soil Loss Due to Specific Crop Harvesting (TSLCHS)

Total soil loss due to specific crop harvesting TSLCHspec is dimensionless and were calculated using the parameter described by Ruysschaert *et al.* (2004). The calculation is as shown below:

$$TSLCHspec = (Mds)/(Mcrop) \quad (3)$$

Where, Mds is the total mass of oven-dried soil (kg), Mcrop is the net crop mass (kg).

Measurement of plant density (PD) ha^{-1}

$$PD = \frac{Ncp}{EPA} \times 10{,}000 \quad (4)$$

Where PD = Plant density (ha^{-1}), Ncp = Number of plants, EPA = Experimental plot Area

Determination of Average Tuber Yield (ATY) kg.

$$ATY = \frac{Nwc}{Nc} \quad (5)$$

Where ATY = Average tuber yield (kg), Nwc = Net weight of cassava (kg), Nc = Number of cassava.

Determination of Mass of Tuber Yield (MTY) kg ha^{-1} har^{1}

This was calculated using equation 4 & 5 according to Ruysschaert *et al.* (2004). Therefore,

$$MTY = PD \times ATY \quad (6)$$

Where MTY = Mass of Tuber Yield ($kgha^{-1}har^{-1}$), PD = Plant Density (ha^{-1}), ATY = Average Tuber Yield (kg).

Determination of Soil Loss due to Crop Harvesting (SLCHcrop)

Soil loss due to crop harvesting is the total was calculated using equation 3 & 6 according to Ruysschaert *et al.* (2004).

SLCHcrop = $TSLCHspec * MTY$ 7

Where SLCHcrop = Soil Loss due to crop harvesting, ($kgha^{-1}har^{-1}$), TSCHspec = Total Soil loss due to crop harvesting specific ($kgkg^{-1}$), MTY = Mass of tuber yield ($kgha^{-1}har^{-1}$)

SOIL CHEMICAL ANALYSIS

Soil organic matter was determined by using the dichromatic oxidation method. It is measured by oxidation with potassium dichromate (Nelson and Sommers, 1982). The total nitrogen in the soil sample was determined by Kjedahl automatic analyzer using the Bremmer method. (Bremmer, 1982). The available phosphorus in the soil samples was determined by atomic absorption spectrophotometer method. The exchangeable potassium (K^+) in the soil sample was also determined by flame photometer method. The soil pH was determined by using normal laboratory pH meter in water.

Determination of Total Nutrient Loss

The nutrient content was expressed on oven-dry soil.

Total Nutrient loss $= Nutrient\ content\ soil\ (g/kg) * SLCHcrop\ (\frac{kg}{ha}/har)$ 8

Statistical Analysis

Data obtained were analyzed using descriptive statistics, t-test and correlation analysis.

Results and discussion

Soil physical properties

The soil physical properties revealed that the moisture content was generally low in the fields and this could be due to the harvesting of the crops done at the ending of the season when the soil was dry as a result of low or no rainfall. The particle size distribution showed that the soil textural class was sandy therefore, water retention was low while infiltration rate was high. The moisture content in Oju-Ogun and Rolu-Osaara villages cassava fields ranged from 2 to 17% with mean and standard deviation of (10.4%, 4.27) and (6.4%, 4.5) respectively. This variation in moisture content may be as a result of difference in their moisture distribution. The lowest moisture content value for cassava fields 2% were recorded in both Oju-Ogun and Rolu-Osaara fields while the highest value of 17% was recorded in Oju-Ogun field. The moisture content fell within the optimum range for the survival of cassava crops. The field in Oju-Ogun recorded the highest because the sample was collected 2 days after the rainfall while some fields in Oju-Ogun and Rolu-Osaara recorded the same lowest values because the samples were collected when the soil was very dry (peak dry season period) (Table 1). The moisture content for cassava and fields had low influence on total soil loss specific (TSLCHspec) and soil loss crop (SLCHcrop) in the studied villages (Table 2 & 3). This may be because the soil moisture content in the fields were generally low. In Rolu-Osaara, some of the cassava fields recorded the same moisture content value of 2%. Theoretically, the same amount of soil was expected to be lost but contrary to expectation they have different values of soil losses. This is an indication that soil loss does not depend on moisture content alone but also on other factors like side branches of the root tubers to which soil in the studied fields may stick to. This was also observed by Vermieulen in Smit *et al.,* (1998) as cited by Ruysschaert, (2006) that soil loss increases even when soil moisture content does not. A similar observation was reported by Mwango *et al,* .2014 stating that soil moisture content at harvest played only a minor role on the variability of SLCH for onion. They stated that this may be due to other factors such as structural changes of the soil, development of side branches, and skin roughness, to which soil could adhere during crop aging.This result was in contrast with findings that were reported by Nordstrom, 2000 and Isabirye *et al.,* 2007. Larymers *et al.,* 2003 and Dada *et al.,* 2015. They further stated that moisture content is positively correlated with soil loss due to yam harvesting and that soil loss increase with increasing moisture content.

The bulk density in Oju-Ogun and Rolu-Osaara village cassava fields ranged from 1.06 to 1.79g/cm^3 with mean variation of (1.28 ± 0.16g/cm3) and (1.41 ± 0.17g/cm3) respectively. The lowest bulk density value of 1.06g/cm^3 was recorded at Oju-Ogun village and the highest value of 1.79g/cm^3 was recorded in Rolu-Osaara village field respectively (Table 1) which fell within the range of soil-moisture density curves for a maximum bulk density of 1.77 to 1.99g/cm^3 for a moisture range of 7.6 to 14% as obtained by Sotona *et al.,* (2014). The mean variation obtained fell within the ideal bulk densities for plant growth (< 1.60g/cm3) for sandy soil (USDA, 2012) The bulk densities of both cassava fields were generally high because the soil were sandy in texture. USDA, 2012 also observed that sandy soils have relatively high bulk density since total pore space in sands is less than silt or clay soils. The bulk densities of both cassava fields also have low correlation with both the

TSLCHspec and SLCHcrop. Mwango *et al.,* 2014 also observed that bulk density had weak correlation with SLCH variabilities for onion. They also observed that bulk density has low correlation with SLCH for Potato at harvesting time. The low correlation may be explained by the lower soil moisture content at harvesting time and sandy texture of the soil in the fields.

The soil textural class was generally sandy for both cassava fields. This was because the clay content of the soil was low. Adeoye and Mohammed-Saleem, 1990; in Salako *et al*., 2002 also observed that the surface of the soil in their experimental field was low in clay content, as a result of which more silt was eroded causing increase in sand content. Sand, Clay and Silt in Oju-Ogun and Rolu-Osaara village Cassava fields ranged from 88.67 to 95.47%, 1.44 to 7.6% and 1.76 to 6.83% respectively. The mean were (91.50 and 92.61%), (3.52 and 3.78%) and (4.98 and 3.61%) respectively. While Sand, Clay and Silt in Agbetu-Iporo odofin village. It was observed that soil texture had low correlation with the soil loss in Cassava fields in both Oju-Ogun and Rolu-Osaara villages (Table 2 & 3). This may be as a result of the side branches of some of the roots. Isabirye *et al.,* (2007) also observed that correlation of SLCH with soil texture were significantly low in their cassava study. They stated that other factors would have likely had an influence an example could be root morphology such as the extent of rough, kinked branched roots. Similarly, Ruysschaert *et al.,* 2004, 2007 and Mwango *et al.,* 2014 observed that soil texture had poor correlation with SLCH variabilities. They stated that it may be partly due to the small variations of soil moisture content at harvest, sand, clay and silt contents because of the slight variations of landform of the farms sampled. The findings of Toscano (1999) states that for wet soil, soil loss increased with increasing clay content and decreasing with sand content. While in drier soils SLCH decreased with decreasing clay content and increasing with sand content. In contrast, Li *et al.,* (2006) in Aleksandra *et al.,* (2011) found out positive correlation between SLCH and sand percentage, and also negative correlation between SLCH and clay percentage.

Table 1: Descriptive statistics of soil physical properties and soil loss variables of cassava fields in Oju-Ogun and Rolu/Osaara villages.

					SOIL PARTICLE SIZE									
Fields	**Gravimetric moisture content (%)**		**Bulk density (g/cm3)**		**Sand (%)**		**Clay (%)**		**Silt (%)**		**Total soil loss specific (kg/kg)**		**Soil loss crop (kg/ha/harvest)**	
	Oju-ogun	**Rolu/Osaara**	**Oju-ogun**	**Rolu/Osaara**	**Oju-ogun**	**Rolu/Osaara**	**Oju-ogun**	**Rolu/Osaara**	**Oju-ogun**	**Rolu/Osaara**	**Oju-ogun**	**Rolu/Osaara**	**Oju-ogun**	**Rolu/Osaara**
Mean	10.40	6.40	1.28	1.41	91.50	92.61	3.52	3.78	4.98	3.61	0.066	0.043	885.19	576.99
Std Dev.	4.27	4.50	0.16	0.17	1.98	1.31	2.00	1.13	1.61	1.71	0.041	0.028	559.52	359.77
t-value	2.04		-1.75		-1.48		1.85		-0.36		1.44		1.47	
P-value	0.06		0.10		0.16		0.08		0.73		0.17		0 .16	

Table 2: Correlation of soil physical properties and soil losses of cassava fields in Oju-Ogun village.

Location		Moisture content (%)	Bulk density (g/cm³)	Sand (%)	Silt (%)	Clay (%)	Total soil loss specific (kg/kg)	Soil loss crop (kg/ha/harvest)
Oju-Ogun	Moisture content (%)	1						
	Bulk density (g/cm³)	-.655*	1					
	Sand (%)	-.524	.539	1				
	Silt (%)	.364	-.167	-.394	1			
	Clay (%)	.225	-.399	-.673*	-.415	1		
	Total soil loss specific (kg/kg)	-.387	.064	.312	-.526	.114	1	
	Soil loss crop (kg/ha/harvest)	-.417	.134	.227	.659*	.306	.960**	1

Table 3 Correlation of soil physical properties and soil losses of cassava fields in Rolu-Osaara village.

Location		Gravimetric moisture content (%)	Bulk density (g/cm³)	Sand (%)	Silk (%)	Clay (%)	Total Soil loss Specific (kg/kg)	Soil loss crop (kg/ha/harvest)
Rolu-Osaara	Gravimetric moisture content (%)	1						
	Bulk density (g/cm3)	.345	1					
	Sand (%)	-.098	-.177	1				
	Silt (%)	-.200	.090	-.748*	1			
	Clay (%)	.415	.071	-.034	-.638*	1		
	Total Soil loss Specific (kg/kg)	.039	.345	.094	.025	-.147	1	

Soil loss crop (kg/ha/harvest)	.078	.360	.020	-.048	.049	.928**	1

Soil micro-nutrient losses for cassava fields were higher in Oju-Ogun than Rolu-Osaara village fields with the order of magnitude such that Mn> Zn > Cu with mean losses values of 6.57, 2.05 and 0.68g/ha/harvest respectively. For cassava fields, soil macro-nutrient losses were higher in Oju-Ogun than Rolu-Osaara village fields and were in the order of OC > Total N> Ca > K > Mg > Na >P with the mean values of 23.22, 12.09, 0.67, 0.65, 0.16, 0.11 and 0.007 kg/ha/harvest respectively. Saku Lilanga, 2013 recorded soil nutrient losses for carrot as N = 29.1 kg/ha/harvest, P =0.085 kg/ha/harvest, K = 1.47 kg/ha/harvest , Mg = 3.87 kg/ha/harvest , Ca = 18.30 kg/ha/harvest , Na = 0.67 kg/ ha/harvest and for onion and sweet potato were N = 6.3 kg/ha/harvest, P = 0.039 kg/ha/harvest, K = 0.25 kg/ ha/harvest, Mg = 1.08 kg/ha/harvest , Ca = 3.90 kg/ha/harvest, Na = 0.17 kg/ ha/harvest and N = 2.8 kg/ha/harvest , P = 0.0088 kg/ha/harvest, K = 0.30kg/ha/harvest, Mg = 0.52kg/ha/harvest, Ca=1.70kg/ha/harvest, Na=0.11kg/ha/harvest respectively. Mwango *et al*., 2014, recorded soil nutrient losses OC, N, P, K, Ca, Mg and Na for Carrot as 365, 30, 0.1, 2, 19, 4 and 0.7 kg/ha/harvest respectively in Majulai and 423, 32, 0.1, 0.8, 16, 3 and 0.4 kg/ha/harvest in Migambo village. Dissimilarities in soil nutrient losses between crops and villages can be as a result of the variations in average crop yield and the inherent nutrient status of the top soil. These was also observed by Mwango *et al.,* (2014) who reported that differences in soil nutrient loss between crops was as a result of the differences in average crop yield and the inherent nutrient status of the top soil. Generally Rolu-Osaara village fields recorded the highest soil nutrient losses. It was also observed that nutrient losses in the fields was due to the fact that more soil was lost on Rolu-Osaara fields. Soil pH in Oju-Ogun village ranged from 5.92 to 6.97 with mean variation of 6.35 ± 0.32. While that of Rolu-Osaara village ranged from 5.96 to 7.34 with mean variation of 6.54 ± 0.42. Averagely, the soil pH was slightly acidic.

CONCLUSION AND RECOMMENDATION

Soil and nutrient losses from cassava fields were quantified and soil physical properties, crop agronomic characteristics and initial nutrients status of the soil that influence the huge amount of soil and nutrient losses were investigated. The average soil loss in cassava fields in Oju-Ogun and Rolu-Osaara villages were 885.19 and 576.99kg/ha/har. The average nutrient loss in kg/ha/har on cassava fields in Oju-Ogun and Rolu Osaara were (12.09 N, 0.058 P, 0.65 K, 23.22 OC) and (22.67 N, 0.0077 P, 0.42 K, 14.12 OC) respectively. Soil moisture content, bulk density, and root characteristics played a minor role in SLCH of cassava in the villages. Silt played a significant role in SLCH of cassava in Oju-Ogun. While clay played a minor role. Rolu-Osaara village had the highest rate of soil loss due to crop harvesting of the two villages studied.

Farmers should be educated on the effects of soil and nutrients losses on their farmlands. This study showed that average soil and nutrient loss due to harvesting for Cassava are enormous. Consequently, soil loss and nutrient losses due to crop harvesting should not be ignored when assessing soil erosion on agricultural lands.

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