Characterization of Soil Properties of Owner Managed Farms of Abia and Imo States, for Sustainable Crop Production in Southeastern Nigeria

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Abstract: This study investigated soil properties and cassava yield of 18 owner-managed farms in Abia and Imo States, Southeastern Nigeria. Transect studies were conducted on-farm and soil samples collected along the transects based on morphological differences. Results showed that soils of the area are very sandy (Total sand = 39-87%). Sulphur content was high (120 ppm). Exchangeable basic cations were generally low while soils were strongly acidic (pH water = 4.0-5.6). Principal component analysis of 12 variables studied showed that soil pH (PRIN 1) explained 28.5 percent of the total variance, followed by organic carbon (PRIN 2) which explained 27.3 percent of the total variance. Soil reaction and organic matter content of these soils become of paramount importance for sustainability. [The Journal of American Science. 2007;3(1):28-37].

Keywords*:* Farming Systems; Soil properties variability; Tropical soils, Sustainable crop; production, Southeastern Nigeria

Introduction

Human activities on land vary and may have differential impact on it. Physical land use, land use purposes and land use circumstances constitute three major interacting aspects of land use in many agro-ecosystems in West Africa (Van Duivenbooden et al., 1996). They defined biophysical land use as the human interference in the functioning of any given agro-ecosystem. Earlier, biophysical land use was described as land cover and the sequence of operations and their timing, implements and traction sources used, and the type and amount of inputs and outputs (Stomph et al., 1994). Mucher et al. (1993) observed that land use is related to vegetation and human constructions on land surface, water bodies and bare soils. In addition to the above, spatial structure of the landscape determines size, shape and orientation of fields (Huising, 1993).

Land use data are often insufficient or totally lacking and unreliable. Food and Agriculture Organization (1989) reported that actual data on land use are lacking or non-dependable because the results of agricultural surveys are often difficult to interpret owing to application of different techniques under a variety of natural conditions, cultural and national standards. Lal and Ragland (1993) observed that the available data are not problem solving. Complexity of language of delivery contributed substantially in the non-use of the available data (Akamigbo, 2002) and this could be why data are rarely used (Smith et al., 2004).

The farming system used in these areas (18 locations) is cassava- based. Due to the hardy nature of cassava and its lengthy period of stay of about 1 - 2½ years, the soil was characterized to evaluate the effect of this crop on the yield of owner-managed farms for sustainable soil and crop production in Imo and Abia States of Southeastern Nigeria.

Recently cassava has found itself in the international market of which Nigeria is making a lot of foreign exchange from its sale. In other to improve cassava production there is a presidential initiative on cassava production in all states of Nigeria.

The main aim of this study was to characterize land use, identifying the predominating variables in the study sites and evaluate the tuber yield of cassava for five years (2001-2005), with a view to understanding its productivity for sustainable soil and crop production.

Methods

Location: The study area, comprising Abia and Imo States is located between latitudes 4040 and 80 151 N and longitudes $6^{0}40'$ and $8^{0}15'$ E (Federal Department of Agricultural Land Resources, 1985). The major geological formations include Alluvium, Coastal plain sands (Benin formation), Shale (Bende Ameki formation), Lower coal measures (Mamu formation), Upper coal measures (Nsukka formation) and False-bedded sandstone (Orajaka, 1975). The study area is dominated by plains and lowlands (Ofomata, 1975). Abia and Imo States have humid climate, with wet season lasting for 9 months (lnyang, 1975). The vegetation of the study area is dominated by forests (Igbozuruike, 1975) and farming is a major socio-economic activity. Figure 1 is map showing the study area.

Field work

Eighteen owner-managed farms of the area, each less than one hectare were selected for the study. Farm size was measured using global positioning system (GPS). Three owner-managed farms were chosen to represent arable farms located on soils of the same parent material, resulting to a total of 18 farmers' foelds since 6 parent materials guided delineation of points.

The six farm delineations were Akwette, Oguta, and Owerrinta (farms on Alluvium); Okeikpe, Owerri and Umuahia (farms on Coastal plain sand); Arondizuogu, Bende and Nkporo (farms on Shale); Arochukwu, Ohafia and Uturu (farms on Lower coal measures); Abiriba, Item and Ihube (farms on Upper coal measures);Ezere Isikwuato, Okigwe and Umulolo (farms on False-bedded sandstones).

On each farm, a transect was run to capture the morphology of the farm as it affects soil conservation. Each farm was divided into eroded and non-eroded portions. Soil samples collected from all sections of the farm were bulked to form composite soil samples per location, which were later air-dried and sieved using 2mm mesh sieve for laboratory determinations. An average of 30 farmers were randomly selected from the study area and interviewed. These farmers were interviewed on the yield of their most cherished crop cassava for the years 2001 to 2005. This was recorded in the data sheet.

Laboratory analysis

Each soil sample was tested for pH, total nitrogen, available phosphorus, total suphur, exchangeable cations and particle size distribution. Soil pH was measured electrometrically by glass electrode in pH meter in both 0.1 normal KCI and distilled water suspension using a soil: liquid ratio of 1:2.5(International Institute for Tropical Agriculture, 1979). Exchangeable basic cations were extracted with ammonium acetate (NH_4OAC). Exchangeable calcium and magnesium were determined by ethylene diamine-tetra acetic acid titration method while exchangeable potassium and sodium were estimated by flame photometry (Jackson, 1962).

Exchangeable acidity was measured titrimetrically according to the procedure of Mclean (1982). Soil Organic carbon (SOC) was obtained by Walkley and Black digestion method (Nelson and Sommers, 1982). Total Nitrogen was estimated by microkjeldahl digestion method (Bremner and Mulvaney, 1982) while available phosphorus was determined by Bray II method (Olsen and Sommers, 1982). Total sulphur was got by potassium-nitrate/nitric acid digestion (Blauchar, 1986). Particle size distribution was obtained by hydrometer method (Gee and Bauder, 1986).

Statistical Analyses

Principal component analysis (PCA) was performed on the values of soil properties of the 18 owner-managed farms with the aid of SAS computer package (SAS, 2000) after values have been subjected to linear correlation analyses to produce a correlation matrix. The yied data was subjected to analysis of variance (ANOVA) as specified by Wahua (1999)

Results

Soil properties:

Table I shows soil properties of the studied farms. Soils were extremely acidic to slightly acidic (pH 4.0 5.6 in water) with low values of exchangeable basic cations. Moderate values of exchangeable magnesium were recorded on soils formed over Shale and Lower coal measures while the same status characterized exchangeable potassium determined on soils derived from Lower coal measures. Exchangeable calcium values were highest in soils of Arondizuogu, Bende and Nkporo being 3.00 cmol/kg, 3.80 cmol/kg and 3.50 cmol/kg, respectively. Exchangeable sodium was very low with the highest value 0.90 cmol/kg recorded at Akwete farm.

Organic carbon content was generally low in line with the report of Igwe and Stahr (2004), although moderate to high values were obtained at Akwete, Owerri, Nkporo, Bende and Oguta. With the exception of total sulphur, total nitrogen and available phosphorus, values recorded were low. Based on the ratings of Federal Ministry agriculture and natural Resources (1990), values of total sulphur (120 148 ppm) were very high.

Particle size distribution shows that sand-sized fractions dominated other particle sizes in most of the studied farms (% total sand = 39-87). Clay fraction followed percent total sand in abundance (% clay = 8 54%) while silt content was the least in occurrence. Similar findings have been made of soils of this agroecodogy (Igwe et al., 1995).

Relationship between soil properties

A correlation matrix of soil properties of the farms is shown in Table 2. Soil reaction (soil pH) showed varied correlation coefficients with soil properties as follows: Organic carbon (r=0.49, P=0.05, N=150) total nitrogen (r=0.78, P=0.05, n=150), available phosphorus (r=0.36, P=0.05, n=150 exchangeable sodium (r=0.47, P=0.05 n=150), total sulphur) (r=0.41, P=0.05, n=150) and sand (r=32, P=0.05, n=150). Organic carbon (OC) was significantly positively correlated with total nitrogen (r=0.77, P=0.05, n=150) and available phosphorus (r=0.44, P=0.05, n=150). Total nitrogen (TN) had significant positive correlation with available phosphorus (r=0.59, P=0.05, n=150) and total sulphur (r=0.49, P0.05, n=150. P=0.05 n=150 and total sulphur (r=0.49, P=0.05, n=150). Exchangeable potassium was significantly positively correlated with exchangeable calcium (r=0.63, P=05, n=150) and exchangeable magnesium (r=0.50, P=0.05, n=150). Total sand had a significant negative correlation with silt (r=-0.60, P=0.05, n=150).

The result on Table 3 shows that principal component analysis reduced 12 variables to 4 orthogonal components with eigenvalues greater than unity. These 4 components altogether explained 79.3% of the total variance within the variables. However, the pattern of the loading indicates that PRIN 1 explained 28.5% of the total variance. The fist component describes soil reaction. Component 2 (PRIN 2) explained 27.2% of the total variance and represents values of soil organic carbon, PRIN 3 describes values of total nitrogen and this third component explained 13.2% of the total variance. The fourth and final component explained only 10.3% of the total variance and describes variable phosphorus, which has been reported as a limiting factor in most tropical soils.

The yield of cassava in the 18 Locations of Owner managed farms (Table 4), showed variability in yield within locations and within years.

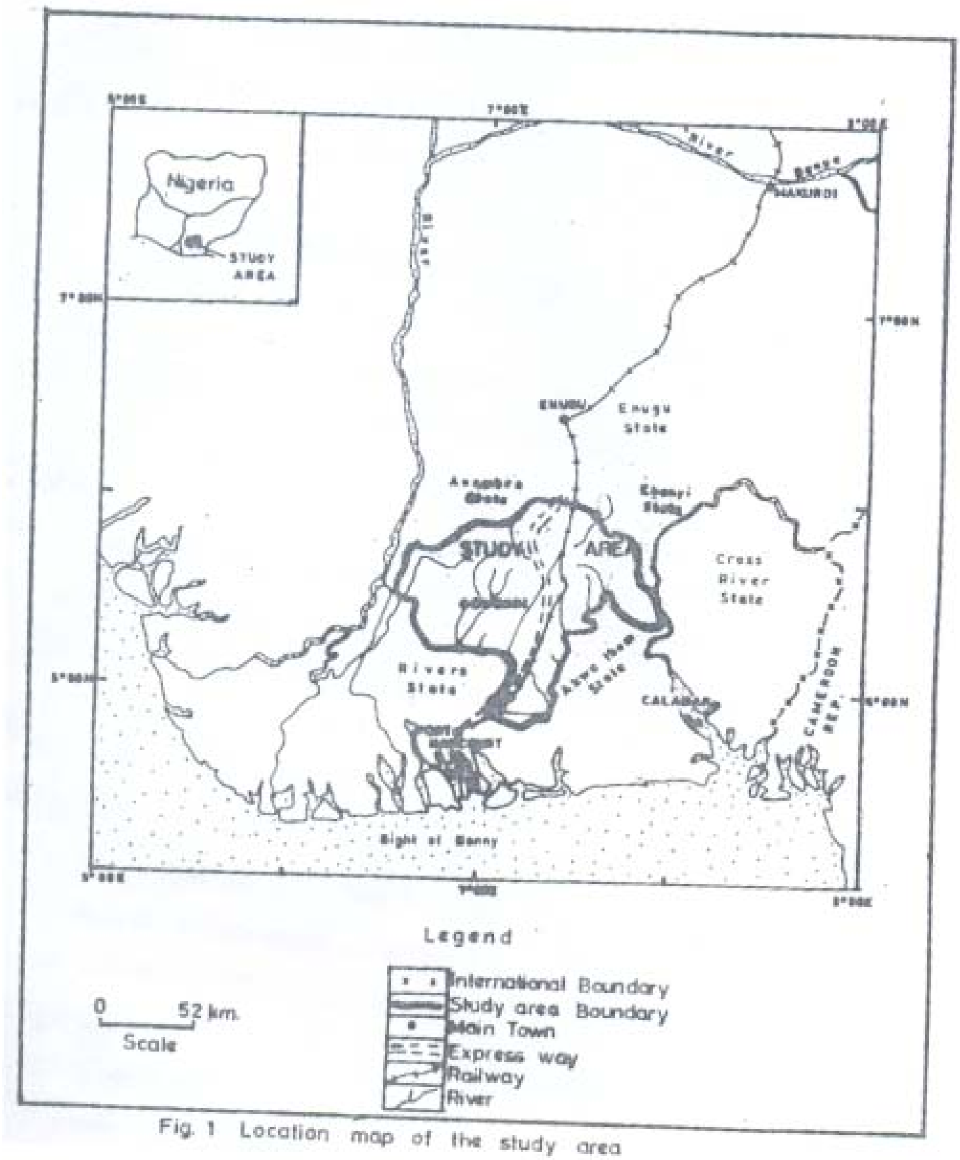

Figure1. Location map of the study area

Table 1. Variables Describing Soil Properties of 18 Farmers' Fields

S/No	Location			pH		OC.		T.N	Avail P.		Ca	Mg
	K	Na	S	Sand	Silt	Clay						
	(Cmol kg^{-1})		ppm			Water						
Akwette	**5.6**		**2.18**		**0.211**		**42**	**0.92**	**0.92**	**0.22**	**0.90**	**145**
		85	**3**	**12**								
Oguta		**5.1**		**1.92**		**0.212**		**6**	**0.60**	**0.70**	**.008**	**0.03**
		148	**87**	**4**	**9**							
Owerrinta		**5.0**		**1.15**		**0.096**		**10**	**0.80**	**0.72**	**0.18**	**0.30**
———		**136**	**86**	**6**	**8**							
Okeikpe		**4.9**		**2.12**		**0.200**		**44**	**0.90**	**0.44**	**0.40**	**0.10**
		128	**83**	**4**	**13**							
Owerri		**5.1**		**2.21**		**0.210**		**46**	**0.80**	**0.30**	**0.20**	**0.08**
		130	**84**	**5**	**11**							
Umuahia		**4.8**		**1.78**		**0.215**		**68**	**0.50**	**0.20**	**0.08**	**0.06**
		150	**72**	**7**	**21**							
Arondizuogu			**5.2**		**1.90**		**0.210**		**8**	**3.00**	**0.28**	**0.30**
		0.18	**125**	**62**	**10**	**28**						
Bende		**5.5**		**2.00**		**0.196**		**14**	**3.80**	**0.80**	**0.20**	**0.05**
		128	**39**	**7**	**54**							
Nkporo		**5.6**		**2.10**		**0.215**		**10**	**3.50**	**0.30**	**0.28**	**0.12**
		122	**60**	**10**	**30**							
Arochukwu			**4.6**		**1.80**		**0.126**		**7**	**2.00**	**1.20**	**0.50**
		0.09	**125**	**52**	**21**	**28**						
Ohafia		**4.8**		**1.50**		**0.116**		**5**	**1.10**	**0.80**	**0.30**	**0.07**
		124	**74**	**5**	**21**							
Uturu		**4.6**		**1.90**		**0.184**		**8**	**1.05**	**1.00**	**0.50**	**0.10**
		126	**82**	**5**	**13**							
Abiriba		**4.4**		**1.85**		**0.120**		**6**	**0.80**	**0.70**	**0.15**	**0.04**
		120	**83**	**4**	**13**							
Item		**4.2**		**1.55**		**0.114**		**5**	**0.30**	**0.20**	**0.10**	**0.06**
		121	**80**	**3**	**17**							
Ihube		**4.1**		**1.72**		**0.106**		**7**	**0.70**	**0.50**	**0.18**	**0.05**
		125	**78**	**8**	**14**							

Ezere Isikwu ato	**4.0**	**1.28**	**0.090**	**2**	**0.50**	**0.80**	**0.10**	**0.10**	**120**	**76**	**10**	**14**
Okigwe	**4.1**	**1.80**	**0.112**	**7**	**0.80**	**0.60**	**0.20**	**0.04**	**128**	**77**	**12**	**11**
Umulolo	**4.1**	**1.90**	**0.116**	**10**	**1.90**	**0.70**	**0.22**	**0.04**	**127**	**82**	**6**	**12**

Table 2. Correlation Coefficients of Soil Properties of 18 Farmers' Fields

	$_{p}HH_{2}0$	OC.	T.N	P.	Ca	Mg	K	Na	S	Sand	Silt	Clay
$_{p}HH_{2}0$	**1.00**											
OC	**0.49**	**1.00**										
TN	**0.78**	**0.77**	**1.00**									
P	**0.36**	**0.44**	**0.59**	**1.00**								
Ca	**0.13**	**0.23**	**0.25**	**-0.21**	**1.00**							
Mg	**0.09**	**-0.07**	**-0.08**	**-0.42**	**0.38**	**1.00**						
K	**0.14**	**0.28**	**0.13**	**-0.09**	**0.63**	**0.50**	**1.00**					
Na	**0.47**	**0.17**	**0.23**	**0.29**	**-0.07**	**0.26**	**0.04**	**1.00**				
S	**0.41**	**0.18**	**0.49**	**0.61**	**-0.20**	**-0.12**	**-0.31**	**0.40**	**1.00**			
Sand	**-0.32**	**-0.13**	**-0.17**	**0.14**	**-0.23**	**-0.28**	**-0.26**	**0.20**	**0.25**	**1.00**		
Silt	**-0.16**	**-0.11**	**-0.21**	**-0.26**	**0.07**	**0.39**	**0.39**	**-0.20**	**-0.26**	**-0.60**	**1.00**	
Clay	**0.43**	**0.19**	**0.28**	**-0.07**	**0.24**	**0.19**	**0.17**	**-0.16**	**-0.20**	**-0.95**	**0.33**	**1.00**

Table 3. Principal Component Analysis of Soil Properties of the 18 Farmers' Fields

	Prin1	Prin2	Prin3	Prin4
pH_{H20}	**0.429**	**0.195**	**-0.022**	**0.196**
OC	**0.380**	**1.160**	**0.024**	**-0.354**
TN	**0.488**	**0.143**	**-0.041**	**-0.169**
P	**0.412**	**-0.144**	**-0.123**	**-0.059**
Ca	**0.018**	**0.334**	**0.353**	**-0.394**
Mg	**-0.098**	**0.317**	**0.439**	**0.385**
K	**-0.009**	**0.376**	**0.409**	**-0.221**
Na	**0.269**	**-0.053**	**0.389**	**0.500**
S	**0.368**	**-0.194**	**0.027**	**0.303**
Sand	**-0.008**	**-0.464**	**0.394**	**0.175**
Silt	**-0.202**	**-0.323**	**-0.107**	**-0.257**
Clay	**0.067**	**0.426**	**0.422**	**0.112**
Eigenvalues	**3.42**	**3.27**	**1.59**	**1.23**
% variance	**28.5**	**27.2**	**13.2**	**10.3**
%Cum. Var.	**28.5**	**55.8**	**69.0**	**79.3**

Table 4. Cassava Yield in the 18 Owner Managed Farms in Abia and Imo States Southeastern Nigeria from 2001 – 2005.

Location	2001	2002	2003	2004	2005
Akwette	**18**	**16**	**19**	**22**	**24**
Oguta	**13**	**16**	**21**	**20**	**22**
Owerrinta	**15**	**21**	**20**	**21**	**24**
Okeikpe	**14**	**16**	**20**	**20**	**23**
Owerri	**19**	**18**	**22**	**23**	**23**
Umuahia	**18**	**17**	**21**	**24**	**24**
Arondizogu	**17**	**18**	**20**	**25**	**24**
Bende	**15**	**17**	**21**	**25**	**26**
Nkporo	**16**	**19**	**19**	**21**	**22**
Arochukwu	**14**	**18**	**20**	**21**	**23**
Ohafia	**15**	**20**	**20**	**22**	**24**
Uturu	**15**	**19**	**21**	**21**	**24**
Abiriba	**13**	**20**	**18**	**26**	**24**
Item	**19**	**21**	**17**	**24**	**25**
Ihube	**18**	**18**	**19**	**23**	**25**
Ezereisikwuato	**17**	**16**	**20**	**22**	**21**
Okigwe	**17**	**18**	**22**	**22**	**22**
Umulolo	**15**	**17**	**21**	**23**	**25**

SE. location	**=**	**0.55,**	**Year**	**=**	**0.15**
Sd Location	**=**	**5.22**	**Year**	**=**	**1.42**
LSD Location	**=**	**1.38**	**Year**	**=**	**2.61**

Discussion

Soil properties of the 18 owner-managed farms varied geospatially. Soil reactions as represented by soil pH values of soils have been attributed to the intensely leached unconsolidated sedimentary parent materials and the dominance of sesquioxdes in the exchange complex (Lekwa and Whiteside, 1986). But soils from the northernmost part of the study area were more acidic than those of the south. This could be attributed to the parent materials, namely Upper coal measures' and False-bedded Sandstones, which had earlier been reported (Orajaka, 1975). Bende, Nkporo, Arondizuogu and Arochukwu had higher pH values as they were derived from Shale parent materials having intercalations of limestone (Federal Department of Agricultural Land Resources, 1985). This same reason may have contributed to higher values as seen in exchangeable calcium. Values of exchangeable sodium were low except in soils of Akwette the latter probably due to marine influence in their pedogenesis. Available phosphorus was higher in soils lying at the southern part of the study area, which can be ascribed to high organic carbon content of soils. Higher organic carbon of the Southern parts of study area could be in response to the density of predominant vegetation as Igbozuruike (1975) has earlier classified the site into dense rainforest (south) and sparse forest (north). Generally, higher values of total sulphur were recorded in the Southern part due to greater release of the element from decomposed and decomposing litter. This contrasts an earlier report that variability of sulphur in the site is due to parent materials (Obasi *et al.,* 2003). However, Brady and Weil (1999) observed the release of sulphur from the microbial decomposition of organize carbon-bonded sulphur components and this tends to confirm the former reasoning.

In particle size distribution, sand-sized fractions predominated, followed by clay content. This is consistent with report of Igwe and Stahr (2004) while silt-sized particles were lower in content (Igwe *et al*., 1995). The clayey nature of soils from Arondizuogu, Bende, Nkporo and Arochukwu is attributable to Shale parent material from where they were derived.

The result (Table 2) indicates that there was a strong inverse relationship between sand and clay contents (r= -0.95, P=0.05, n=150), suggesting that an increase in sand leads to decrease in clay and this is not in harmony with sustainable crop production since clay minerals play important role in soil fertility status of a given location.. Sand is related with silt in that manner (r=-0.60, P=0.05, n=150). Percent sand was significantly high but negatively correlated with soil pH (r= 6.32, P=0.05, n=150). Ahn (1979) reported highest acidity in sand-sized fractions of tropical soils. This could be why soils of the area are popularly referred to as “acid sands” moreso, with over 60% of the geology being coastal plain sands, fluvial alluvium, lacustrine marine deposits.

In this study, soil pH had an over-riding influence on other 12 soil variables investigated. Earlier Osuji and Onojake (2004) described it as a master variable influencing nearly all soil physico-chemical cum biological properties. soil reaction becomes of major consideration in the sustainable management of soils of the area for high cassava yield. This is because most farms of the study site are owner-managed and farmers are resource-poor and hold tenaciously to the currently ineffective traditional soil conservation techniques which is stemmed on bush fallow, slash and burn system of farming, zero to minimum tillage and maize stump leftover (stubble mulching) in farm sites are practiced. However, the different locations had different fertility status as the farmer shifts from one farm location to the other and so was the cassava yield.

As a result of different fertility levels in different farm locations, the yield differed significantly within the locations. Also because of the different temperatures, rainfall and humidity in the different years the cassava yield in most of the owner managed farms differed significantly. In Table 1, for instance, between Arochukwu (No.10) to Okigwe (No.17) of the table the soil available P. is low while the same element is high between Owerrinta (No. 3) and Nkporo (No. 9). The cassava yield was high in 2004 and 2005 compared to the same locations in 2001 to 2003. This is noteworthy and could be attributed to a lot of factors since the farmers are always seeking ways and means of improving their farm output. The presidential initiative on cassava production coupled with the release of high yielding cassava varities by National Root Crops Research Institute Umudike and IITA Ibadan between 2003/2004 could be the reason for increase in cassava yield in 2004 and 2005 cropping seasons. There were high variation in the principal component analysis of soil properties of the 18 farmers field and the variables describing the soil properties showed a constant pH of 4.10 - 5.60. In agricultural production soil pH controls the availability and unavailability of most nutrient elements and governs the uptake of these nutrients for sustainable crop yield such as cassava.

Conclusion.

Soil properties varied among 18 owner-managed farms. Soils were dominated by sand-sized fractions. Soils were generally low in available phosphorus, organic carbon and exchangeable basic cations. Sulphur content was fairly high, while carbon and exchangeable cation were limiting factors in these farms. Soils were strongly acidic and soil pH is the principal component-determining variable out of 12 variables analyzed using PCA. Sustainable soil management for higher cassava and other crop yields in this study area requires a consideration of soil acidity as well as organic matter content of soils.

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Received: January 10, 2007

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