MERIT RESEARCH JOURNALS
www.meritresearchjournals.org

Merit Research Journal of Agricultural Science and Soil Sciences (ISSN: 2350-2274) Vol. 8(11) pp. 163-171, November, 2020
Available online http://meritresearchjournals.org/asss/index.htm

DOI: 10.5281/zenodo.4290992

Original Research Article

Nutrient build-up in an alfisol continuously grown to common crop mixtures for eight years before fallowing for thirteen years and current suitability for cassava, oil palm and plantain production in Southeastern, Nigeria

Asadu C.L.A[1*], A.G.O. Dixon[2] and H.C. Agu[1]

[1]Department of Soil Science, University of Nigeria, Nsukka

[2]International Institute of Tropical Agriculture (IITA), Ibadan Nigeria

***Corresponding Author E-mail: charles.asadu@unn.edu.ng**

Abstract

Evaluation of nutrient build-up in fallow land without the cropping history may not be very reliable because residual effects of previous activities on the land play vital roles in nutrient regeneration. This is particularly applicable to southeastern Nigeria where most of the farmers grow their crops in mixtures with various soil nutrient management techniques. A part of a virgin forest land was cleared in 1998 and continuously grown to sole crops of cassava (C), maize (M), pigeon pea (P) and C+P, M+P and C+M+P mixtures replicated thrice with three control (T) plots for seven years before fallowing for thirteen years. The experimental design was a randomized complete block design (RCBD). The current values of soil physico-chemical properties were compared and also with those obtained from an adjacent remaining forestland (F) and evaluated for cassava, oil palm and plantain production. The textural class (sandy clay loam) did not change over the years. The mean bulk density from T plots was significantly (p<.0.05) higher than that from P plots while microporosity and total porosity from C plots were significantly (p<.0.05) higher than those from F plots. The mean soil chemical values showed that the values across the plots previously grown to the crops (previous Land Utilization Types, pLUTs) were generally statistically similar in 2017. Fallowing a piece of agricultural land after years of continuous cultivation for long periods is highly recommended as this helps to regain its lost nutrients. The current aggregate suitability class for all the plots and the forest land irrespective of the variations in soil properties was "Highly Suitable" (S1) for all the three crops; cassava, oil palm and plantain production.

Keywords: Alfisols, Fallow, Cassava, Oil palm and plantain production, Soil nutrient

INTRODUCTION

Pressure mounted on available agricultural land due to increased population densities has affected agricultural development in Nigeria. According to Nweke (2015), more harm is being exerted on these lands by the introduction of mechanized farming systems with different tillage implements, all in a quest to increase agricultural productivity. These available lands are put into continuous cropping leading to severe depletion in their fertility status. Soil degradation and fertility depletion are the fundamental reasons for the decline of per-capita food production, hunger and malnutrition in Sub-Saharan Africa (Sanchez and Uehara, 1980). All these exert different impacts on soil productivity and soil properties.

Fallow system allows the accumulation of easily degradable organic matter (OM) and some dust to regenerate soil fertility (Gaiser, 1993). In this way, the cropping and fallow phases could take place simultaneously on the same land, allowing the land to be cropped for an extended period when long fallow periods are not feasible under the particular socioeconomic conditions (Oyedele *et al.*, 2009).

An abundant harvest is always obtained from a forested land when newly cleared, burnt and cultivated in the first few years. Recently, due to population growth, forest lands are degraded and converted to agricultural lands. The anthropogenic changes in land use have altered the characteristics of the forests land, leading to changes in soil physicochemical properties, soil fertility, soil erosion sensitivity and content of soil moisture (Jawad *et al.*, 2014).

The capacity of soil to function can be reflected by measured soil physical and chemical properties (Buol *et al.*, 2003). According to Oguike and Mbagwu, (2009), these properties, however, are largely affected by land use/management practices. Soil properties deteriorate with change in land use especially from forest to arable land. The cropping system may lead to erosion and leaching of soil nutrients which in turn adversely affect the physico-chemical properties of the soil. Soil structure can be affected by the intensity of land use and this has an effect on the distribution of microbial biomass as well as microbial processes within the aggregates (Gupta and Germida, 1988).

Cropping a land without nutrient replenishment adversely affects the physico-chemical properties of the soil (Awotoye *et al.*, 2011) which according to Asadu *et al.* (2002) contribute significantly to crop yield. Food crops grown on millions of hectares of soils all over the tropics no longer perform optimally well because most of the soils do not contain enough essential nutrients resulting in poor yields and subsequently the starvation of the people (Marler and Wallin, 2006). These yield reductions are mostly due to nutrient deficiencies resulting from decreases in soil organic matter content (Oguike and Mbagwu, 2009) and depletion of soil nutrients reserve during the cropping season. However, yield reductions are not only caused by poor nutrients status of the soils but also due to inappropriate land utilization types. Growing a crop on a land without due assessment of its suitability for such use leads to suboptimal soil productivity and low yield as crop requirements are not often related to the land's potential capacity (Ezeaku, 2011).

Oil palm (*Elaeis guinensis*) and plantain (*Musa paradisiaca*) belonging to the families of Arecaceae and Musaceae respectively are important plantation crops grown in Nigeria. Nigeria ranked 5th position in oil palm production. It is generally agreed that the Oil Palm (*Elaeis guinensis*) originated in the tropical rain forest region of West Africa. The main belt runs through the southern latitudes of Cameroon, Côte d'Ivoire, Ghana, Liberia, Nigeria, Sierra Leone, Togo and into the equatorial region of Angola and the Congo. Processing oil palm fruits for edible oil has been practiced in Africa for thousands of years, and the oil produced, highly coloured and flavored, is an essential ingredient in much of the traditional West African cuisine. The traditional process is simple, but tedious and inefficient (FAO, 2002).

Plantains are grown throughout the tropics, constitute a major source of carbohydrates for millions of people in Africa, the Caribbean, Latin America, Asia and the Pacific. Due to the perishable nature of the fruits, the rate of plantain post harvest losses varies from one country to another according to the organization of market chains and modes of consumption (FAO, 1999).

Many studies have addressed the effects of fallowing and/or continuous cultivation on soil physicochemical properties in Nsukka, Southeastern Nigeria (Asadu *et al.*, 2013; Asadu and Ekeleman, 2014). However, studies comparing the physicochemical properties of an alfisol under fallow and adjacent forest lands and their suitability for oil palm and plantain production in Nsukka, Southeastern Nigeria have not been fully examined.

Therefore, this study compared the physicochemical properties of an Alfisol under fallow and adjacent forest lands and their suitability for oil palm and plantain in Nsukka, Southeastern Nigeria with the following specific objectives:

- To compare the physicochemical properties of an Alfisol under fallow with that of the adjacent forest land.
- To evaluate their suitability for cassava, oil palm and plantain production.

MATERIALS AND METHODS

Location and background of study

The study area was at Amagu Edem-Nru, in Nsukka, Enugu State. It lies within the latitude 6º 52¹ N and longitude 7º 23¹ E in the Savannah zone of South Eastern Nigeria with an elevation of 447.2m above sea level.

According to Asadu *et al.*, (2013), some part of a forest in Amagu Edem-Nru, in Nsukka, was cleared in January 1998. The accumulated large debris and dry matter were burnt and the stumps were removed manually by digging them up. The cleared forest was partitioned into seven plots of 8m by 5m plot and each plot was replicated three times. Randomized Complete Block Design (RCBD) was used in establishing the trials. Three treatments were applied, they included solely cassava (*Manihot esculenta* Crantz) (SC), solely pigeon pea (*Cajanus cajan*) (SP), solely maize (*Zea mays*) (SM), their combination (M+P, C+P and C+M+P) and a control plot based on the prior knowledge of the most common staple food crops grown by the local farmers. The crops were planted at a spacing of 1m × 1m on ridges made with hoes.

The land was subsequently fallowed from 2005 after the seventh year of continuous cropping (1998-2004) to assess the soil fertility recovery till date and evaluate the various plots for their suitability for the production of common crops grown by the farmers in the area. Details of the general climate, geology and soils, agriculture and land use are already given in Asadu et al., 2013 and 2014.

Soil Sampling

Following the previous studies, seven (7) representative plots were selected from the fallow land which was replicated three times; triplicate samples were also collected from the adjacent forest lands. A total of twenty-four (24) soil samples were collected from 0-20cm depth using an auger. They were well-labeled and put into polythene bags. During the collection of samples; dead plants, furrows, areas near trees and compost pits were excluded. This was done to minimize differences, which may arise in the soil organic matter due to mixing through cultivation and other factors. The soil samples collected from the field were air-dried, mixed well and passed through a 2mm sieve for analysis of selected soil physicochemical properties. Separate soil core samples from the 0-20cm depth were taken with a sharp-edged steel cylinder (core sampler) forced manually into the soil for Bulk density and pore size distribution determination.

Laboratory Analysis

Soil physical properties

Soil particle size distribution was determined by the Bouyoucos hydrometric method (Van Reeuwijk, 1992) and dispersing the soil with sodium hydroxides (NaOH) in place of Calgon [sodium hexametaphosphate ($NaPO_3$)].
Soil bulk density was determined by the undisturbed core sampling method (Blake, 1965) after drying the soil samples in an oven at 105°C.

Pore size distribution was determined using the water retention data as follows: Macroporosity from the volume of water drained at 60cm of tension/volume of bulk soil; Microporosity from volume of water retained at 60cm of tension/volume of bulk soil; and Total porosity from the sum of macroporosity and microporosity (Brady and Weil, 2002).

Chemical properties

The pH of the soil was measured in water and potassium chloride (1N KCl) suspension in a 1:2.5 (soil: liquid ratio) potentiometrically using a Beckman's zeromatic glass electrode pH Meter (Rhoades, 1982)

Available Phosphorus (P) was extracted with Bray (II) solution (Bray and Kurtz; 1945) and measured using a colorimeter following the principles of light (Murphy and Riley method 1965).

Soil organic carbon content was determined using Walkley-Black's titration method (Jackson, 1973); the sample was digested with excess potassium dichromate and sulphuric acid and the residual unutilized dichromate black-titrated against standard ferrous ammonium sulphate solution.

Total Nitrogen (N) was determined using Kheldahl digestion, distillation and titration method as described by Bremner (1965) by oxidizing the organic matter in concentrated sulphuric acid (0.1N H_2SO_4).

Cation Exchange Capacity (CEC) and Exchangeable bases (Ca, Mg, K and Na) were determined after extracting the soil samples by ammonium acetate (1N NH_4OAc) at pH 7.0. Exchangeable Na and K in the extracts were analyzed by Flame photometer (Rhoades, 1982) while Exchangeable Ca and Mg in the extracts were determined by titration method using 0.1N EDTA (Chapman, 1965). Cation Exchange Capacity (CEC) was thereafter estimated titrimetrically using 0.1N NaOH (Chapman, 1965).

Exchangeable Acidity (EA) was determined by saturating samples with potassium chloride solution (1N KCl) and titrated with sodium hydroxide as described by Mclean (1965).

Percentage Base Saturation was determined by calculation as follows:

$\%BS = TEB/CEC \times 100$

Where; %BS: percentage base saturation; TEB: total exchangeable bases and CEC: cation exchange capacity.

Data Analysis

The soil fertility indicators were subjected to analysis of variance (ANOVA) using Statistical Analysis Systems (SAS), version 8 (1985) and the least significance difference (LSD) test was used to separate significant differences between treatment means at $p \leq 0.05$.

Land Suitability and its Classes

Land suitability is an approach in land evaluation that concerns the appraisal and grouping of specific areas of land in terms of their suitability for defined use (Ezeaku, 2011). FAO defined it as the fitness of a given type of land to support a defined use (FAO, 1976; 2007). The basic idea underlying the FAO approach on land suitability classification is that the land is rated based on a matching exercise between the crop growth (land utilization type) requirements and the land conditions.

According to the classification proposed by FAO (1976), five different classes, ranging from "Unsuitable" to "Highly Suitable", whose codes are recognized and

Table 1. Suitability Classes and their Description (FAO, 1976)

Suitability Class	Description
Class S1: Highly Suitable	Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.
Class S2: Moderately Suitable	Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land.
Class S3: Marginally Suitable	Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.
Class N1 Currently Not Suitable	Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.
Class N2: Permanently Not Suitable	Land having limitations which appear as severe as to preclude any possibilities of successful sustained use of the land in the given manner.

Table 2. Land and Soil Requirements for Cassava Production

	S1	S2	S3	N1	N2
Land Qualities					
Mean annual rainfall (mm)	1000 – 1800/ 1800 – 2400	750 – 600/ >2400	600 – 550	550 – 500	<500
Mean annual temperature (˚C)	20 – 30/20 – 18	>30/18 – 16	16 – 14	14 – 12	<12
Soil texture	L, SCL, CL, SL, SiCL, SiC	Cs, LFs, LS, LCS,Fs	CS, S, Cs	SC, Cm	Cm, S
Fertility (f)					
CEC (Cmol/kg)	>16	>10	<10	<5	<5
Base saturation (%)	>35	35 – 15	15 – 10	<10	<10
Organic matter (g/kg OC) (0-15cm)	>15	>8	>5	<3	<3

Source: Sys (1985)
Symbols used for soil texture and structures are defined as follows: Cs: structural clay; Cm: massive clay; SiC: silty clay; SiCL: silty clay loam; CL: clay loam; Si: silt; L: loam; SCL: sandy clay loam; SL: sandy loam; LFs: loam fine sand; LCS: loam coarse sand; Fs: fine sand; S: sand

constituted by a capital letter (indicating the order) and a number (indicating the class), identify land suitability for a certain purpose in Table 1.

Land Suitability Evaluation

The suitability of the soils for the production of cassava, oil palm and plantain was assessed using the principle of limiting condition (FAO, 1995). The soils were placed in suitability classes by matching their characteristics with the requirements of the crops and the overall suitability class of the soils was indicated by its most limiting characteristics for the conventional approach (FAO, 1995). The detailed land and soil requirements for cassava, plantain and oil palm are presented in Tables 2, 3 and 4 respectively

RESULTS AND DISCUSSION

Effect of Land utilization type (LUT) on Soil Physical Properties

From Table 5 even though the proportions of sand and clay fractions dominated the fine earth and appeared to

Table 3. Land quality requirements for the production of plantain

Land Qualities	S1	S2	S3	N
Climate				
Rainfall (mm)	2000 +	1450 – 2000	1250 – 1450	<1200
Dry season length	1 – 2	2 – 4	4 – 5	>5
Temp. °C	25 – 32	22 – 25	20 – 22	<20
Wetness				
Drainage	Well	Moderate	-	Imperfect
Flooding	F0	F1	-	F2
Soil physical characteristics (s)				
Soil depth (cm)	>100	50 – 100	20 – 50	<20
Texture	SL, SC, L, CL	LS	S	C
Topography (t)				
Slope (%)	0 – 8	8 – 16	16 – 30	30 – 50
Soil fertility (f)				
CEC, cmol/kg	>16	12 – 16	10 – 12	<10
Base Saturation (%)	>35	20 – 35	10 – 20	<10
Organic Matter	>1.8	1.2 – 1.8	0.8 – 1.2	<0.8
Soil pH	5.0 – 6.0	6.0 – 6.9	4.0 – 5.0	<4.0

Source: Sys *et al.,* (1991)
S1 = Highly Suitable, S2 = Moderately Suitable, S3 = Marginal Suitable, NS = Not Suitable, CL = clay loam, SC = sandy clay, SL = sandy loam, LS = loamy sand, S = Sand and C = Clay.

Table 4. Land quality requirements for the production of oil palm

Topography (t)						
	S1	**S2**	**S3**	**N1**	**N2**	
Land qualities						
Slope (%)	0 – 4	5 – 9	10 – 16	17 – 30	31 – 50	>50
Flooding	F_0	F_0	F_1	F_2	-	F_3
Drainage	Well drained	Moderately well drained	Imperfect. Drained	Poor (aeric) (easily drained	Poor (typic) difficult	Very poor
Physical Soil Characteristic						
Texture/Structure	CL, C_O, SC, C_S, SiC_S	L, SCL, SiCL	SL, LSf	LSm, LSc, Cm, SICm, Sf	Sm, Sc	LcS, S
Soil Depth (m)	>100	100 – 80	79 – 60	59 – 45	44 – 25	<25
Soil Fertility Characteristics (f)						
CEC (cmol(+)kg^{-1} soil	>16	<16 (-)	< 16(+)			
Base Saturation (%)	> 35	34 – 20	< 20			
Organic Carbon (%)	> 1.5	1.4 – 0.6	< 0.6			

Source: Sys *et al.,* (1991)
S1 = Highly Suitable, S2 = Moderately Suitable, S3 = Marginal Suitable, NS = Not Suitable, CL = clay loam, SC = sandy clay, SL = sandy loam, LS = loamy sand, S = Sand and C = Clay.

have been significantly influenced by the land uses the textural classes remained sandy clay loam (SCL) while that of silt was not significantly different. The highest average sand content was obtained from the plot earlier grown to sole maize and the lowest was recorded from the forest and the reverse was the case for clay. Parent material is the major factor influencing soil texture in the area (Akamigbo and Asadu, 1983; Akamigbo, 1984).

Previous land uses significantly ($p<0.05$) affected bulk density, microporosity and total porosity after thirteen years of fallow comparing with the original forestland (Table 4) and ranges of the parameters are within acceptable values for crop production (Asadu and Nweke, 1999). The transmission porosity (macroporosity and saturated hydraulic conductivity were not significantly influenced by the fallowing the plots with the different use histories. This is surprising as the two parameters are directly related. Li *et al*. (2007) and Ezeaku and Eze (2014) stated that fallow lands have higher bulk density when compared with the forest which may be associated

Table 5. Mean values of selected Physical properties of soil of the different fallowed plots and forest

Land Use	Sand	Silt	Clay	Textural class	BD	MaP	MiP	TP	Ksat
	(g/kg)	(g/kg)	(g/kg)		(g/cm^3)	(%)	(%)	(%)	(cm/hr)
SC	649.60	59.50	290.90	SCL	1.30	3.84	51.78	55.60	45.50
C+M+P	663.20	52.80	283.90	SCL	1.24	3.37	49.15	52.50	78.30
C+P	662.90	52.80	284.30	SCL	1.24	4.95	50.04	55.00	50.30
SM	676.30	66.10	257.60	SCL	1.27	3.77	47.77	51.50	31.50
M+P	656.30	66.10	277.60	SCL	1.21	5.08	48.13	53.20	33.70
SP	656.30	72.80	264.30	SCL	1.17	4.59	48.34	52.90	52.20
EP	656.30	59.50	284.30	SCL	1.33	3.45	48.51	52.00	73.20
Forest	642.90	59.50	297.60	SCL	1.23	4.61	41.92	46.50	56.90
$LSD_{(0.05)}$	25.55	NS	29.18		0.134	NS	7.882	8.80	NS

SC: Sole Cassava; C+M+P: Cassava, Maize and Pigeon pea; C+P: Cassava and pigeon pea: SM: Sole Maize; M+P: Maize and Pigeon pea; SP: Sole Pigeon pea; EP: Control Plot; TC: Textural Class; BD: Bulk Density; Map: Macroporosity; Mip: Microporosity; Tp: Total Porosity; Ks: Saturated hydraulic conductivity; SCL: Sandy Clay Loam.

Table 6. Mean values of pH, Organic Matter, Available Phosphorus and Total Nitrogen of the different fallowed plots and forest

Land Use	pH	pH	OM	AvP	TN
	(H_2O)	(KCl)	(g/kg)	(mg/kg)	(g/kg)
SC	4.17	3.43	22.65	8.70	0.17
C+M+P	3.93	3.50	17.78	8.70	0.09
C+P	4.00	3.43	19.59	6.53	0.16
SM	4.07	3.43	19.86	7.15	0.15
M+P	3.93	3.40	20.81	9.64	0.11
SP	4.17	3.47	22.24	7.77	0.16
EP	4.20	3.53	18.10	6.22	0.15
Forest	4.23	3.53	22.25	7.15	0.16
$LSD_{(0.05)}$	0.287	NS	NS	3.245	NS

SC: Sole Cassava; C+M+P: Cassava, Maize and Pigeon pea; C+P: Cassava and pigeon pea: SM: Sole Maize; M+P: Maize and Pigeon pea; SP: Sole Pigeon pea; EP: Control Plot; TC: Textural Class; BD: Bulk Density; Map: Macroporosity; Mip: Microporosity; Tp: Total Porosity; Ks: Saturated hydraulic conductivity; SCL: Sandy Clay Loam.

to low root density and OM accumulation. However, the bulk density of forest soil may increase as a result of the collapse of aggregates and clogging of voids by dispersed clay minerals, this consequently decreases the soil porosity and permeability (Certini, 2005).

Effect of Land utilization type (LUT) on Soil Chemical Properties

Only the mean pH value in H_2O from C+M+P and M+P (Table 6) were significantly lower than that obtained from the forest land. The other values from the plots formally grown to the LUTs were generally similar statistically. Similar trends in results applied to both SOM and total N an indication that the fallowed plots have recovered or caught up with the forest and the control (EP) plots after thirteen years of fallowing.

The mean values of available P from M+P plots was significantly higher than the value obtained from the EP. The other values were statistically similar to that from the forest land indicating also that after thirteen years of fallow available P from plots formally grown to the various LUTs had recovered to equivalent values obtained from EP and Forest (Table 6).

Generally, the low values (Landon, 1991) of soil pH, SOM, total N and available values obtained from the study area are characteristic of the soils of the study area (Asadu 1990) and could be attributed to different anthropogenic and natural activities including leaching of exchangeable bases, acid rains, decomposition of organic materials, application of mineral fertilizers and other farming practices (Rowell, 1994; Miller and Donahue, 1995; Tisdale *et al.*, 1995; Brady and Weil, 2002).

The mean values of exchangeable Ca, Mg, and TEB (Table 7) did not significantly differ from the mean values obtained from EP and forest land indicating that fallowing had made the plots formally under the various LUTs catch up the nutrient contents obtained from EP and Forest land. However, the mean exchangeable Ca obtained from SM plots was significantly higher than that

Table 7. Mean values of Exchangeable acidity, Exchangeable bases and Cation Exchange Capacity of the different fallowed plots and forest

Land Use	H^+	Al^{3+}	Ca^{2+}	Mg^{2+}	Na^+	K^+	CEC	TEA	TEB	BS
					(Cmol/kg)					(%)
SC	1.20	2.67	2.27	1.20	0.022	0.068	7.73	3.87	3.56	48.50
C+M+P	1.60	2.53	2.13	1.33	0.015	0.058	11.33	4.13	3.54	45.90
C+P	0.93	2.67	2.00	1.20	0.013	0.045	8.93	3.60	3.26	47.10
SM	1.87	2.40	2.53	1.73	0.012	0.050	8.40	4.27	4.21	50.40
M+P	1.73	2.00	1.33	2.27	0.013	0.043	8.53	3.73	3.66	49.60
SP	1.20	2.40	2.27	1.73	0.020	0.060	9.60	3.60	4.35	54.60
Ep	0.93	2.40	1.87	1.60	0.025	0.064	8.40	3.33	3.56	51.80
Forest	1.20	2.00	2.00	1.60	0.012	0.080	8.27	3.20	3.69	53.60
$LSD_{(0.05)}$	NS	NS	1.009	0.860	NS	0.023	NS	NS	0.997	NS

SC: Sole Cassava; C+M+P: Cassava, Maize and Pigeon pea; C+P: Cassava and pigeon pea: SM: Sole Maize; M+P: Maize and Pigeon pea; SP: Sole Pigeon pea; EP: Control Plot; TEA: Total Exchangeable Acidity; TEB: Total Exchangeable Bases, CEC: Cation Exchange Capacity %BS: Percentage Base Saturation; H^+: exchangeable hydrogen; Al^{3+}: exchangeable aluminum; Ca^{2+}: exchangeable calcium; Mg^{2+}: exchangeable magnesium; Na^+: exchangeable sodium; K^+: exchangeable potassium; NS: Not Significant.

Table 8. Suitability Class Scores And Aggregate Suitability Classification Of Soil For Cassava Production

Previous LUT	MAR (mm)	MAT (°C)	Texture	CEC (cmol/kg)	BS (%)	SOM (g/k)	ASC
SC	S1	S1	S1	S1	S2	S1	S1
C+M+P	S1	S1	S1	S1	S2	S1	S1
C+P	SI	SI	SI	SI	S3	SI	S1
SM	S1	S1	S1	S1	S1	S1	S1
M+P	S1	S1	S1	S1	S2	S1	S1
SP	S1	S1	S1	S1	S2	S1	S1
EP	S1	S1	S1	S1	S2	S1	S1
Forest	S1	S1	S1	S1	S2	S1	S1

SC= Sole Cassava; C+M+P = Cassava + Maize and Pigeon pea; C+P = Cassava + pigeon pea: SM = Sole Maize; M+P = Maize + Pigeon pea = SP: Sole Pigeon pea; EP = Control Plot; MAR= mean annual rainfall, MAT= mean annual temperature; BS = Base Saturation; Soil pH; ASC: Aggregate Suitability Class; S1: Highly suitable; S2: Moderately suitable; S3: Marginally suitable.

from M+P plots and the mean exchangeable Mg from M+ P plots was significantly higher than that from Sc plots (Table 6).

Exchangeable K recovery appeared to be more difficult as the mean value from the forest was significantly higher than those from SM, C+P and M+P plots even though Nweke (2015) reported high values of exchangeable potassium in fallow land. However, all the mean values were statistically similar to the mean value from the EP. All the mean values of TEB from the plots previously grown to all the LUTs were statistically similar to those values from forest land and EP indicating that within thirteen years of fallowing TEB has recovered to match up values obtained from the adjacent forest and EP. Apart from TEB from SP which was significantly higher than the value from C+P, other chemical parameters were statistically similar in the plots previously grown to the LUTs, the adjacent forest land and EP (Table 7) as reported in the previous year Asadu and Mirian (2016).

Land Suitability Evaluation

The various suitability classes for the production of cassava, oil palm and plantain given in tables 8, 9 and 10 were arrived at by matching the land qualities/ characteristics in tables 5, 6 and 7 with the requirements of both crops in tables 2, 3 and 4.

Table 8 shows the suitability classes for cassava production. All the fallow the plots previously grown to the various LUTs as well the Ep and forest land are currently highly suitable (S1)

Table 9 shows the suitability classes for oil palm production. All the fallow plots (SC, C + M+ P, C + P, SM, M + P, SP and Ep) and forest are currently highly suitable

Table 9. Suitability Class Scores of the Soils for Oil Palm Production

LAND USE	MAR (mm)	MAT (°C)	Texture	CEC (Cmol/kg)	BS (%)	OC (g/kg)	ASC
SC	S1	S1	S1	S2	S1	S1	S1
C+M+P	S1	S1	S1	S2	S1	S1	S1
C+P	SI	SI	S1	S2	S1	S1	S1
SM	S1	S1	S1	S2	S1	S1	S1
M+P	S1	S1	S1	S2	S1	S1	S1
SP	S1	S1	S1	S2	S1	S1	S1
EP	S1	S1	S1	S2	S1	S1	S1
Forest	S1	S1	S1	S2	S1	S1	S1

SC: Sole Cassava; C+M+P: Cassava, Maize and Pigeon pea; C+P: Cassava and pigeon pea: SM: Sole Maize; M+P: Maize and Pigeon pea; SP: Sole Pigeon pea; EP: Control Plot; BS: Base Saturation; Soil pH; ASC: Aggregate Suitability Class; S1: Highly suitable; S2: Moderately suitable; S3: Marginally suitable.

Table 10. Suitability Class Scores of the Soils for Plantain Production

Land use	MAR (mm)	MAT (°C)	Texture	CEC (Cmol/kg)	BS (%)	OM (g/kg)	ASC
SC	S1	S1	S1	NS	S1	S1	S1
C+M+P	S1	S1	S1	S3	S1	S1	S1
C+P	SI	SI	S1	NS	S1	S1	S1
SM	S1	S1	S1	NS	S1	S1	S1
M+P	S1	S1	S1	NS	S1	S1	S1
SP	S1	S1	S1	NS	S1	S1	S1
EP	S1	S1	S1	NS	S1	S1	S1
Forest	S1	S1	S1	NS	S1	S1	S1

SC: Sole Cassava; C+M+P: Cassava, Maize and Pigeon pea; C+P: Cassava and pigeon pea: SM: Sole Maize; M+P: Maize and Pigeon pea; SP: Sole Pigeon pea; EP: Control Plot; BS: Base Saturation; Soil pH; ASC: Aggregate Suitability Class; S1: Highly suitable; S2: Moderately suitable; S3: Marginally suitable; NS: Not Suitable

(S1) except for CEC that is moderately suitable for both fallow and forest plots.

Table 10 shows the suitability classes for plantain production. All the fallow plots (SC, C + M+ P, C + P, SM, M + P, SP and Ep) and forest land are currently highly suitable for the growth of plantain matching both texture and organic matter. The CEC of the soil is currently not suitable for both the fallow plots (SC, C + M+ P, C + P, SM, M + P, SP and Ep) and forest but the fallow plot C + M + P is marginally suitable.

Based on the ratings of Landon (1991) there is low available phosphorus and CEC in the soil as well as the pH which is extremely acidic in the year 2017. The availability of phosphorus in the soil depends on soil pH.

However, the soil can be amended by supplemental phosphorus application, liming, and other management factors that influence root growth

CONCLUSION

Long-term fallow of thirteen years was able to help recover most nutrients in comparison with the adjacent forest land and in some cases for example available P and exchangeable Ca higher values were obtained from some of the fallow lands than the forest land. Fallowing a piece of agricultural land after years of continuous cultivation for a long period is highly recommended as this helps to restore lost nutrients. There may be a net loss of nutrients from the topsoil due to runoff and rapid intake of nutrients as a result of increasing biomass. However, as the length of fallow period increases, litter fall adds more nutrients to the soil; thus the amount of nutrients in the topsoil is increased. Both the fallow and forest soils are currently highly suitable for the parameters measured for the production of cassava, plantain and oil palm.

REFERENCES

Akamigbo F.O.R, Asadu C.L.A., (1983). The influence of parent materials on soils of south eastern Nigeria. *East Afr. Agric. Forestry J.* 48: 81-91

Akamigbo, F.O.R., (1984). The accuracy of field textures in a humid tropical environment. Soil Survey and Land Evaluation. 4: 63-70.

Asadu CLA, A.G.O. Dixon, SC Eze (2014). Evaluation of cassava-based systems for adaptation to climatic variations in eastern Nigeria. Agro-Science. 13(2):37-42.

Asadu CLA, Ekeleman LD (2013). The effects of continuous cropping and fallowing on the chemical properties of an ultisol in Nsukka, Nigeria. Agro-Science; 12. 28-34.

Asadu CLA, Ugadu ME (2016). Comparison of the physicochemical properties of an Alfisol under Fallow and adjacent Forest lands and their suitability for Cocoyam, Pigeon pea and Sweet Potato production in Nsukka, Southeastern Nigeria. August 2016. Pp 41-46.

Asadu, C.L.A., (1990). A Comparative characterization of two foot-slope soils in Nsukka area of Eastern Nigeria. Soil Science, USA. Vol. 150: 527-534

Asadu, C.L.A., Obasi, S.C., and Dixon, A.G.O., (2010). Variation in soil physical properties in a cleared forestland continuously cultivated for seven years in eastern Nsukka, Nigeria. Comm. in Soil Sci and Plant Anal, 41(2):133-134.

Asadu, C.L.A., Obasi, S.C., Dixon A.G.O., Ugele N., Chibuike G.U., (2013). Soil fertility recovery in cleared forestland cultivated and fallowed for seven years. *J. Agric. Biodiversity Res*. Vol. 2, July, 2013. Pp: 110-116.

Blake GR (1965). Bulk density In: Methods of soil analysis, Part I (Ed.): Black, C.A; American Society of Agronomy. Madison, Wisconsin, USA. pp. 375-390.

Brady NC, Weil RR (2002). The nature and properties of soils, 13th Ed. Prentice- Hall Inc., New Jersey, USA. 960p.

Bray KH, Kurtz LT (1945). Determination of total organic and available forms of phosphorus in soils. Soil Sci. 59: 39-45.

Bremner JM (1965). Total nitrogen. In C. A. Black (Ed.). Methods of soil analysis part II. Am Soc Agron. 9: 1149–1178.

Buol S, Hole F, McCracken J, Southard R (2003). Soil genesis and classification, 5th ed. Iowa State Press, USA. pp. 126-327.

Certini G (2005). Effect of fire on properties of soil - A review. Oecologia, 143: 1-10.

Chapman HD (1965). Cation exchange capacity. In: C.A. Black, L. E., Ensminger and F. E. Clark (Eds). Methods of soil analysis. Agronomy. 9: 891-901. American Society of Agronomy. Inc., Madison, Wisconsin.

Ezeaku PI (2011). Methodologies for Agricultural Land use Planning; Sustainable Soil Management and Productivity. Pp 107-111.

Ezeaku PI, Eze FU (2014). Effects of land use in relation to slope position on soil properties in a semi-humid Nsukka area, southeastern Nigeria. *J. Agric. Research*, 53: 369-373.

FAO (1995).Guidelines; Land Evaluation for Rainfall Agriculture.Soil Resources Management and Conservation Services, Land and Water Development Division Rome.FAO Soil Bulletin. 52, pp. 237.

FAO (1999). Small-Scale Palm Oil Processing in Africa. Food and Agricultural Organization service bulletin. Pp 148

FAO (2007). Land Evaluation: Towards a Revised Framework. Rome, Italy.

FAO (food and agricultural organization) (2002). Land and agriculture: A Compendium of recent sustainable development initiatives in the field of agriculture and land management. Pp 57.

FAO(1976). A Framework for Land Evaluation: FAO Soil Bulletin 32. Rome, Italy.

Gaiser T (1993). The significance of Soil Organic Matter for Soil productivity on Tropical Acrisols and Vertisols. Dissertation, University of Hohenhein, Stutgart.

Gupta V, Germida J (1988). Distribution of microbial biomass and its activity in different soil aggregate size classes as affected by cultivation. 20: 777-786

Jackson ML (1973). Soil chemical analysis, prentice, hall of India private ltd. New Delhi. 498p.

Jawad IT, Taha MR, Majeed ZH, Khan TA (2014). Soil stabilization using lime: Advantages, disadvantages and proposing a potential alternative. Res. J. Appl. Sci. Eng. Technol. 8(4): 510-520.

Landon JR (Ed.) (1991). Booker tropical soil manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York. 474p.

Marler JB, Wallin JR (2006) human health, the nutritional quality of harvested food and sustainable farming system. Nutritional security institute. Bellevue.

McLean EO (1965). Aluminum. pp. 978-998. In: C.A. Black (Ed.). Methods of Soil Analysis. Agron. No.9. Part II. Am. Soc. Agron, Madison, Wisconsin. USA.

Miller RW, Donahue RL (1995). Soils in our environment, 7th Ed. Prentice Hall Inc., Englewood Cliffs, New Jersey. 649p.

Nweke IA (2015). Physical and Chemical Properties of Four Contrasting Soils under Different Land Use System. *Advances in Research* Vol 3(2): 236 – 243.

Oguike PC, Mbagwu JS (2009). Variations in some physical properties and organic matter content of soils of coastal plain sand under different land use types. *World J. Agric. Sci*., 5: 63-69.

Oyedele D, Awotoye O, Popoola S (2009). Soil physical and chemical properties under continuous maize cultivation as influenced by hedgerow trees species on an alfisol in South Western Nigeria. Afr. J. Agric. Res. Vol 4.

Rhoades JD (1982). Cation Exchange Capacity. In: Page, A.L.,(Ed.), Methods of Soil Analysis Part 2. 2nd Edition Agron. Monogor. 9. ASA, Madison, WI. Pp. 149-157.

Rowell DL (1994). Soil science: Methods & Applications. Addison Wesley Longman Singapore Publishers (Pte) Ltd., England, UK. 350p.

Sanchez PA, Uehara G (1980). Management considerations for acid soils with high phosphorus fixation capacity. In Khasaenh FE, Sample EC, Kampeth EJ. (Eds,The Role of Phosphorus in Agriculture, Am. Soc. Agron. pp471- 515. USA

Sys C, Van Ranst E, Debaveye J (1991). Land evaluation part 1. Inter. Train. Centre for Post-Grad. Soil Scientist. State Univ. Ghent, Ghent, Belgium. 274 pp.

Tisdale SL, Nelson WL, Beaton JD, Havlin JL (1995). Soil fertility and fertilizer, 5th Ed. Prentice-Hall of India, New Delhi. 684p.

Van Reeuwijk LP (1992). Procedures for soil analysis, 3rd Ed. International Soil Reference and Information Center (ISRIC), Wageningen, the Netherlands. 34p.