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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.

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ABSTRACT

Forest land provides a wide range of ecosystem services such as reducing the impact of raindrops on the soil and maintenance of soil fertility, whereas fallowing is one method used in restoring the fertility status of degraded farmlands. This study evaluated the physicochemical properties of an Alfisol under fallow and adjacent forestland, and their suitability for cocoyam, pigeon pea, and sweet potato. The fallow plots were brought into cultivation in the year 1998 under the IITA-UNN long-term collaborative research. Soil samples were collected from 0-20 cm depth in triplicates using an auger and cylindrical core from the seven representative fallow plots previously grown to sole cassava from the year 1998–2003 and under fallow till the year 2016 as well as the adjacent forest land. The result obtained showed that the fallow land had higher fertility nutrients than the forest land in the year 2016. The fallow land gave the highest values of SOC, total nitrogen, percentage base saturation, total exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and exchangeable acidity when compared with the forest land. Using the FAO's principle of limiting conditions as guide, both fallow and forest soils are marginally suitable (S3) for cocoyam production but highly suitable (S1) for both pigeon pea and sweet potato production.

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1. Introduction

Determining the changes in soil properties of an actual swidden (an area of land cleared for cultivation by slashing and burning vegetation) and its subsequent fallow during a swidden cycle have some aspects of great significance for relevant fields of science and technology (Nakano and Miyauchi, 1996). The two main aspects are as follows; determining these changes is a basic step for understanding nutrient cycling in the whole ecosystem of a swidden and the subsequent fallow; understanding these changes can indicate the factors responsible for the changes in the fertility and other growing conditions for the crops during the respective stages of the cycle namely; clearing a forest, burning the debris of felled or slashed plants, growing crops, abandoning the swidden and fallowing till the next cycle (Nakano and Miyauchi, 1996). Fallowing is one method used in restoring the fertility status of degraded farmlands (Asadu*et al.,* 2013). Its effect cannot be overemphasized in the improvement of agriculture because fallowing a soil gives it the potential to capture nutrients and make them available for crops; it reduces weeds, pest and disease infestations, restores soil organic matter and rehabilitates the population of soil organisms that decreased during the cultivation period (Styger et al.,2006). Again, long fallow period was found to increase the yield and protein content of wheat and its benefits extended beyond the next crop planted in the area (Grain Research and Development Corporation, 2001). In the tropics, the decision on land utilization types lies solely on the hands of the landowners who are mostly peasant farmers and not on the outcome of professional land evaluation, thus resulting to suboptimal land productivity and poor yield as land potential qualities are not often related to the crop growth requirements (Ezeaku, 2011). Therefore, assessment of soil physicochemical properties for land utilization types is useful and paramount for sustainable agricultural productivity (Selassie *et al.,* 2015). Generally, a sound understanding of land use effects on soil properties provides an opportunity to evaluate the sustainability of land use systems (Woldeamlak, 2003) and their suitability for a defined use to optimize and sustain agricultural productivity.

Cocoyam (*Colocasia esculenta*), Pigeon Pea (*Cajanus cajan*) and Sweet Potato (*Ipomoea batatas*) belonging to the families of Araceae, Fabaceae, and Solanaceae respectively are the most important food crops grown in Nigeria. Cocoyam is the fifth most harvested corm crop in the world with the production estimate of 9 million tonnes in (FAO, 2012). Nigeria is the world's largest producer of cocoyam with an estimated 4.55 million metric tonnes in 2012 with about 43.1% of the total production in Africa (FAO, 2012). Global annual production of pigeon pea is about 3.6 million tonnes (Mt) valued at around US$ 1,600 million (FAO, 2007). The crop represents about 5% of world legume production (Hillocks et al., 2000) with more than 70% being produced in India. Globally, sweet potato ranked third after Irish potato and cassava in the world's root and tuber crops (Ikeorgu, 2003). Tewel *et al.* (2013) reported that sweet potato is only a minor root crop in tropical Africa despite its potential as indicated in its growth in terms of production.

Many studies have addressed the effects of fallowing and 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 cocoyam, pigeon pea and sweet potato production in Nsukka, Southeastern Nigeria have not been thoroughly examined. Therefore, this study (which is part of a long-term soil fertility management experiment established in 1998 at Amagu, Edem-Nru in Nsukka) compared 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,

2. Materials And Methods

2.1 Site Description: The study area was at Amagu Edem-Nru, in Nsukka, Enugu State. It lies within the latitude 6º 52′ N and longitude 7º 23′ E in the Savannah zone of Southeastern Nigeria with an elevation of 447.2 m above sea level (Oko-ibom and Asiegbu, 2006).The climate of the area is characterized by an average annual rainfall of about 1550 mm and average temperatures (minimum and maximum) of 22 ˚C and 30 ˚C respectively (Asadu *et al.,*2013) while the average relative humidity is 60% (Asadu *et al.,* 2010).Asadu (1990) reported that the soils in this area are generally derived from the residua of False-bedded Sand-stone or Upper-coal Measure Formation as a result of disintegration of the rocks. These geological formations give rise to the sandy and clayey soils respectively (Akamigbo and Asadu, 1990). The natural vegetation of Nsukka is characteristically derived Savannah agro-ecological zone with different land uses such as forestry, cultivated areas and grass-lands in a soil-landscape system. Cassava, maize, yam, pigeon pea, egg-plants, oil palm and pumpkins production is the dominant livelihood strategy of all members of the farming community. Asadu *et al.,* (2013) reported that some part of a forest in Amagu Edem-Nru, in Nsukka, was cleared in January 1998 and partitioned into seven plots of 8 m by 5 m and each plot was replicated three times. Randomized Complete Block Design (RCBD) was used in establishing the trials. Seven treatments were applied: sole cassava (*Manihot esculenta* Crantz) (SC), sole pigeon pea (*Cajanus cajan*) (SP), sole 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 1 m × 1 m on ridges made with hoes. The land was continuously cropped for five years (1998–2003) and afterward left to fallow till the year 2016. Presently, the fallow plots are covered pre-dominantly with Siam weed (*Chromolaena odorata*), guinea grass (*Panicum maximum*) and elephant grass (*Pennisetum purpureum*). There are also some shrubs and oil palm (*Elaeis guineen-sis*) trees that have re-established since the fallowing began.

2.2 Soil Sampling and Laboratory Analysis: Following the previous studies, the seven fallow plots were sampled each in triplicates from the fallow land; triplicate samples were also collected from the adjacent forest giving a total of twenty-four (24) samples all from 0-20 cm soil depth using an auger and core sampler. Soil samples were air-dried, crushed, passed through a 2 mm sieve and analyzed using standard procedure. Soil particle size distribution was determined by the Bouyoucos hydrometer method (Van Reeuwijk, 1992). Bulk density was determined by the core method (Blake and Hartge, 1986). Pore size distribution was determined using the water retention data as follows: macroporosity from the volume of water drained at 60 cm of tension/volume of bulk soil; microporosity from volume of water retained at 60 cm of tension/volume of bulk soil; and total porosity from the sum of macroporosity and microporosity (Brady and Weil, 2002). Hydraulic conductivity was measured using Klute and Dirksen method (1986).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, 1996). Available phosphorus (P) was extracted with Bray (II) solution. Organic carbon content was determined using Walkley-Black's titration method (Jackson, 1973).Total nitrogen (N) was determined using Kjeldahl digestion, distillation, and titration method, as described by

Bremmer (1965). Exchangeable Na and K were analyzed by Flame photometer (Rhoades, 1982) while exchangeable Ca and Mg were determined by titration method using 0.1N EDTA (Chapman, 1965). Cation Exchange Capacity (CEC) was after that estimated titrimetrically using 0.1N NaOH (Chapman, 1965). Exchangeable Acidity (EA) was determined as described by Mclean (1965). Percentage Base Saturation was determined by calculation as follows: PBS = TEB/ECEC × 100

Where; PBS: percentage base saturation; TEB: total exchangeable bases and ECEC: effective cation exchange capacity. The soil physicochemical properties 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 $p<0.05$. In table 8, computation of relative changes between the values obtained in 1998 and those obtained during the other years was calculated, that is, values in bracket, using the formula below:

$$\text{Relative change (\%)} = \frac{\text{Value at current year} - \text{Value at 1998}}{\text{Value at 1998}} \times 100$$

2.3 Land Suitability Evaluation: The suitability of the soils for the production of cocoyam, pigeon pea, and sweet potato 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 that indicated by its most limiting characteristics for the conventional approach (FAO, 1995). The detailed land and soil requirements for each of the crops are presented in Tables 1–3.

Table 1. Land and soil requirement for cocoyam production (Gooding, 1987)

Land qualities	**S1**	**S2**	**S3**	**NI**
Temperature (˚C)	21 – 27	25 – 30	30 – 35	>35
Total rainfall (mm)	≥2000	1300 – 1999	1000 – 1299	<1000
Base saturation (%)	>60	40 – 60	20 – 39	<20
Soil pH	>5 – 6.5	4.5 – 5	4 – 4.4	<4.0

Table 2. Land and soil requirement for pigeon pea production NBSS & LUP (1994)

Land qualities	**S1**	**S2**	**S3**	**NI**
Temperature (˚C)	25 – 28	22 – 24	20 – 21	<20
Total rainfall (mm)	800 – 1000	600 – 800	400 – 600	<400
Base saturation (%)	>60	40 – 60	20 – 40	<20
Soil pH	5.0 – 7.5	7.6 – 8.0	8.1 – 9.0	>9.0

Table 3. Land and soil requirement for sweet potato production Reddy and Shiva Prasad (1999)

Land qualities	**S1**	**S2**	**S3**	**NI**
Temperature (˚C)	16 – 25	26 – 30	31 – 32	>32
Total rainfall (mm)	≥1300	800 – 1300	500 – 800	<500
Base saturation (%)	50 – 80	45 – 50	45 – 40	<40
Soil Ph	4.5 – 6.5	6.6 – 8.2	>8.2	>8.2

Table 4: 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 the 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 N: Not Suitable	Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at a currently acceptable cost; the constraints are so severe as to preclude successful sustained use of the land in the given manner.

The textural classes in the table 4 are within the textures representatives of the soils derived from false-bedded sandstone parent materials which occupy the lower slopes of Nsukka area in Nigeria (Akamigbo and Asadu, 1983, Asadu, 1990, Asadu et al., 2004).

3. Results and Discussions

3.1 The Effect of Land Use on Soil Physical Properties: The mean effect of land use on soil physical properties is shown in table 5. Generally, the contents of sand and clay fractions were the most significantly influenced by land uses and as such dominated over the silt fraction so that the order in magnitude is sand > clay > silt. The low silt content may be due to its low values in the parent material of the soil (Akamigbo, 1984).

Table 5: Mean effect of the different fallowed plots and forest on selected Physical properties of soil.

Land use	Sand (g/kg)	Silt (g/kg)	Clay (gkg)	TC	BD (kg/m3)	Map(%)	Mip (%)	Tp (%)	Ks cm/hr
SC	728.50	72.80	198.70	SL	1350	9.15	48.74	57.89	64.60
C+M+P	735.20	59.50	205.30	SCL	1310	7.95	48.27	56.22	68.00
C+P	741.90	59.50	198.70	SL	1350	7.80	48.76	56.56	53.40
SM	741.90	59.50	198.70	SL	1420	5.70	46.39	52.09	29.40
M+P	755.20	39.50	205.30	SCL	1360	8.90	50.62	59.52	65.00
SP	768.50	26.10	205.30	SCL	1390	7.49	48.62	56.11	25.80
EP	748.50	72.80	178.70	SL	1270	6.72	47.61	54.33	70.40
Forest	721.90	46.10	232.00	SCL	1280	9.46	49.44	58.90	125.00

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.

Bulk density values where generally significantly affeceted by fallow in 2016 (Table 5) except the highest bulk density value (1420 kg/m^3) obtained from the plots previously grown to sole maize plot that was significantly higher than the lowest value (1270 kg/m^3) obtained from the control plot (Ep) and (1280 kg/m^3) obtained from the forest.. Total porosity values ranged from 59.5% to 52.1%, and the values are within those plots described as good agricultural soils. The saturated hydraulic conductivity (Ks) obtained from the forest land was the highest value (125.00cm/hr). Also, fallowing has been reported to be important in the improvement of both soil properties and saturated hydraulic conductivity of soils.

3.2 *The effect of land use on soil chemical properties*. Tables; 6 shows the mean effects of land use on soil chemical properties. The pH of the soil measured in water ranged from 4.27 to 4.33, indicating an extreme acid reaction (Landon, 1984). This may be due to the acidic nature of the parent material from which the soils were derived combined leaching of cations prevalent in the soils of the area which had earlier been reported (Asadu et al., 2015; Asadu,1990).

Table 6: Mean effect of the different fallowed plots and forest on Chemical properties of soil.

Land use	pH	OC (g/kg)	TN (g/kg)	EA	Ca^{2+}	Mg^{2+}	Na^{2+}	K^+	TEB	CEC	BS (%)	Av P (mg/kg)
					Cmol/kg							
SC	4.33	9.80	0.98	4.80	3.73	1.20	0.02	0.12	5.07	13.20	52.20	3.73
C+M+P	4.30	8.90	0.70	4.93	3.67	1.20	0.01	0.05	4.93	15.47	50.80	3.10
C+P	4.33	10.30	0.75	4.67	4.73	1.60	0.01	0.07	6.41	13.33	57.80	3.41
SM	4.33	9.10	0.70	4.40	5.07	0.57	0.01	0.06	5.71	15.33	57.00	3.72
M+P	4.27	8.00	0.89	4.53	4.00	0.73	0.01	0.06	4.81	14.80	50.90	2.79
SP	4.30	11.70	0.79	5.47	4.00	1.20	0.01	0.06	5.28	12.93	47.50	3.73
EP	4.33	13.80	0.84	5.07	3.93	0.93	0.01	0.06	4.94	13.07	52.20	3.73
Forest	4.30	12.60	0.84	5.07	3.27	0.67	0.01	0.12	4.07	12.47	45.30	4.04

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; OC: Organic Carbon; TN: Total Nitrogen; EA: Exchangeable Acidity;Ca^{2+}:exchangeable calcium;Mg^{2+}:exchangeable magnesium; Na^{+}: exchangeable sodium; K^{+}:exchangeable potassium; TEB: Total Exchangeable Bases, CEC: Cation Exchange Capacity; %BS: Percentage Base Saturation; Av P: Available Phosphorus.

The SOC values ranged from 8.00g/kg to 13.80g/kg. Soil organic carbon content was, however, highest (13.80g/kg) under the control plot (EP) and lowest (8.00g/kg) under plot sown with maize + pigeon pea. SOC value in forest (12.60g/kg) is statistically the same with the values of other plots. The low organic matter content in the soil could be due to rapid decomposition and mineralization of organic materials contributed by sparse vegetation and high temperatures (Landon, 1984).The total nitrogen values ranged from 0.70g/kg to 0.98g/kg whereby the plot SC gave the highest value (0.98g/kg) of TN and lowest value (0.70g/kg) under the C+M+P and SM plots. Following the ratings of total N of >1% as very high, 0.5-1% high, 0.2-0.5% medium, 0.1-0.2% low and <0.1% as very low N status as indicated by Landon (1991), the present fallowed plots as well as the undisturbed forest land qualities have high N status , and this could be due to higher soil organisms that help in organic matter decomposition and it is good because high Nitrogen increases the biomass of the soil and also this Nitrogen has been found to increase crop yield when combined with organic fertilizer (Asadu and Unagwu, 2012). The exchangeable acidity consists of H^{+} and Al^{3+}, and the values of exchangeable H ranged from 3.73Cmol/kg to 4.80Cmol/kg while that of exchangeable Al ranged from 0.53Cmol/kg to 1.20Cmol/kg (Table 6). Exchangeable Al is generally detrimental to plants, and as soil pH decreases, exchangeable acidity (EA) increases (Cronan and Grigal, 1995) so that soils with pH values below 5.2 are likely to exhibit the Al^{3+} problem. The low soil organic matter levels of the soils could also have contributed to the high EA values. The range of values of exchangeable Na (0.01 – 0.02 cmol/kg) in all the soils indicates very low concentrations which are below the critical limit for sodicity (Brady and Weil, 2010). Exchangeable Ca, Mg and K were generally rated moderate, low and very low for all plots except for some of the fallow plots (SC, C+M+P, C+P, M+P, SP, and EP) where Ca^{2+} was low. Low exchangeable bases have been attributed to leaching losses of these bases below the root zones for most crops (> 100 cm depth). The dominant exchangeable cations in the soils tend to be mainly calcium and magnesium while low content of potassium and sodium appeared to be due to absence of minerals high in them in the parent material. The TEB values ranged from 4.07Cmol/kg to 6.41Cmol/kg. However, TEB content has the highest value (6.41Cmol/kg) on cassava and pigeon pea and the lowest value (4.07Cmol/kg) on the undisturbed forest land. In other words, Plot C+P gave the highest value, and it is significantly different with the values obtained in other plots and forest, and this could be due to the macro and microclimate that hinders the impact of raindrops on soil (Brady and Weil, 2002). According to Landon (1991), the soils having CEC of > 25 cmol/kg, 15 -25 cmol/kg, 5-15 cmol/kg and <5 cmol/kg are classified as high, medium, low and very low respectively. Based on the above ratings, the CEC values of the soils are rated medium in other words, the soils in the area of study have medium CEC status. M. Yakubu et al. (2007) opined that organic matter content of soils which generally influences the CEC is generally low, and therefore the CEC values may not be attributed to the amount of organic matter, but for most tropical soils the contribution of organic matter to CEC is often significantly higher than 50 % (Asadu and Akamigbo, 1990).

According to FAO report 2014, soils with base saturation of > 50% are regarded as fertile soils while soils with less than 50% are not fertile soils. Therefore, the soils are generally fertile except for SP and forest plots. The low base saturation experienced in the forest (45.3%) could be attributed to leaching of soluble cations with water down the profile.

The available phosphorus was very low (2.79 – 4.04 mg/kg), and this may be due to phosphorus fixation, the intensity of soil weathering or soil disturbance and the acidic nature in the soil

3.3 The Overall Comparison of the Physicochemical Properties of Soil under Fallow and Adjacent Forest Lands

The comparison of the Physicochemical properties of fallow and forest soils showed that the fallow land had higher fertility than the forest land (fallow > forest land) in the year 2016 but from Table 7, the forest land had a higher concentration of all the nutrients in the year 1998 than in the year 2016. However, the fallow plots (SC, C+P, SP, and EP) in the year 2016 gave the highest values of SOC, total nitrogen, percentage base saturation, total exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), and EA. This could be due to soil nutrient regeneration or regrow associated with long-term fallowing of the land which is as a result of accumulation, decomposition and mineralization of the organic residues such as dead animal bodies and leaf droppings often lead to higher values of SOC, total nitrogen and exchangeable bases. Then, the forest land is of medium fertility in the year 2016 as it had medium values of exchangeable bases, total nitrogen, percentage base saturation, and SOC. This could be due to low amount of organic residue when compared with the fallow plots. Although the texture is an inherent soil property, management practices may contribute indirectly to the changes in the physicochemical properties of the soil. Forest soil for instance, in particle size distribution particularly, may be modified by sheet and rill erosion.

Furthermore, two other nutrients that showed higher values during the fallow years when compared with the undisturbed forest were exchangeable Ca and exchangeable H^{+}. All the other nutrients (except exchangeable Na and exchangeable K that were equal) wherein high concentration in the fallow land than they were in the forest land.

Table 7a: The Overall Comparison of the Soil Chemical Properties under Fallow and Adjacent Forest Lands.

Soil Properties	1998 Mean	1999-2004 Mean	First fallow Year mean (2005)	Ninth fallow Year mean (2013)	Undisturbed f Forest mean (2013)	Tenth fallow Year mean (2014)	Undisturbed forest mean (2014)
pH (H_2O)	4.30	4.27 (-0.7)	4.13 (-4.0)	4.57 (6.3)	4.60 (7.0)	4.33 (0.7)	4.37 (1.6)
SOM (g/kg)	2.28	3.00 (31.6)	2.53 (11.0)	2.58 (13.2)	2.47 (8.3)	2.48 (8.8)	2.72 (19.3)
Total N (g/kg)	0.13	0.15 (15.4)	0.09 (-30.8)	0.22 (69.2)	0.23 (76.9)	0.10 (-23.1)	0.10 (-23.1)
Na^+ (Cmo1/kg)	0.16	0.81 (406.3)	0.15 (-6.3)	0.19 (18.8)	0.18 (12.5)	0.27 (68.8)	0.27 (68.8)
K^+ (Cmo1/kg)	0.15	0.13 (-13.3)	0.21 (40.0)	0.15 (0.0)	0.16 (6.7)	0.15 (0.0)	0.10 (-33.3)
Mg^{2+} (Cmo1/kg)	0.47	1.53 (225.5)	1.47 (212.8)	0.66 (40.4)	0.80 (70.2)	1.20 (155.3)	1.47 (212.8)
Ca^{2+} (Cmol/kg)	0.87	2.03 (133.3)	0.60 (-31.0)	0.60 (-31.0)	0.60 (-31.0)	1.64 (88.5)	2.13 (144.8)
ExAcidity (Cmo1/kg)	0.87	2.83 (225.3)	0.77 (-11.5)	2.87 (229.9)	2.67 (206.9)	5.62 (546.0)	5.20 (497.7)
CEC (Cmo1/kg)	2.44	7.40 (203.3)	7.87 (222.5)	9.98 (309.0)	9.60 (293.4)	8.23 (237.3)	8.53 (249.6)
Av. P (mg/kg)	11.00	13.67 (24.3)	21.67 (97.0)	4.53 (-58.8)	4.35 (-60.5)	7.55 (-31.4)	7.77 (-29.4)

Source: Asadu *et al.,* 2014 but values for 2016 were from field data

Table 7b: The Overall Comparison of the Soil Chemical Properties under Fallow and Adjacent Forest Lands.

Soil Properties	Eleventh fallow year mean (2015)	Undisturbed forest mean (2015)	Twelfth fallow year mean (2016)	Undisturbed forest mean (2016)
pH(H_2O)	4.74 (10.2)	4.40 (2.3)	4.31 (-0.2)	4.30 (Nil)
SOM (g/kg)	16.61 (628.5)	17.23 (655.7)	10.21 (347.8)	12.60 (452.6)
Total N (g/kg)	1.04 (700.0)	1.17 (800)	0.81 (523.1)	0.84 (546.2)
Na^+ (Cmo1/kg)	0.16 (Nil)	0. 17 (6.3)	0.01 (-93.8)	0.01 (-93.8)
K^+ (Cmo1/kg)	0.16 (6.7)	0.17 (13.3)	0.07 (-53.3)	0.12 (-20.0)
Mg^{2+}(Cmo1/kg)	0.68 (44.7)	0.60 (27.7)	1.06 (125.5)	0.67 (42.6)
Ca^{2+} (Cmol/kg)	0.53 (-39.1)	0.67 (-22.9)	4.16 (378.2)	3.27 (275.9)
ExAcidity(Cmo1/kg)	5.45 (526.4)	4.40 (405.7)	4.84 (456.3)	5.07 (482.8)
CEC (Cmo1/kg)	9.92 (306.6)	9.20 (277.0)	14.02 (474.6)	12.47 (411.1)
Av. P (mg/kg)	4.13 (-62.5)	4.04 (-63.3)	3.46 (-68.5)	4.04 (-63.3)

Source: Asadu *et al.,* 2014 but values for 2016 were from field data

Land Suitability Evaluation*:* The matching of the land qualities/characteristics in tables 5–6 with land and soil requirements for suitability rating for cocoyam, pigeon pea and sweet potato production (Table 1–3) resulted in the suitability classes shown in Tables 8–10.

Table 8: Suitability Class Scores and Aggregate Suitability Classification of the Soils for cocoyam production

Land use	MAR (mm)	MAT (ºC)	BS (%)	Soil pH	ASC
SC	S2	S1	S2	S3	S3
C+M+P	S2	S1	S2	S3	S3
C+P	S2	S1	S2	S3	S3
SM	S2	S1	S2	S3	S3
M+P	S2	S1	S2	S3	S3
SP	S2	S1	S2	S3	S3
EP	S2	S1	S2	S3	S3
Forest	S2	S1	S2	S3	S3

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; MAR: Annual Rainfall; MAT: Mean Annual Temperature; BS: Base Saturation; Soil pH; ASC: Aggregate Suitability Class; S1: Highly suitable; S2:

Table 9: Suitability Class Scores and Aggregate Suitability Classification of the Soils for Pigeon Pea Production.

Land use	MAR (mm)	MAT (ºC)	BS (%)	Soil pH	ASC
SC	S2	S1	S2	S1	S2
C+M+P	S2	S1	S2	S1	S2
C+P	S2	S1	S2	S1	S2
SM	S2	S1	S2	S1	S2
M+P	S2	S1	S2	S1	S2
SP	S2	S1	S2	S1	S2
EP	S2	S1	S2	S1	S2
Forest	S2	S1	S2	S1	S2

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; MAR: Annual Rainfall; MAT: Mean Annual Temperature; BS: Base Saturation; Soil pH; ASC: Aggregate Suitability Class; S1: Highly suitable; S2: Moderately suitable; S3: Marginally suitable.

Table 10: Suitability Class Scores and Aggregate Suitability Classification of the Soils for Sweet Potato Production.

Land use	MAR (mm)	MAT (ºC)	BS (%)	Soil pH	ASC
SC	S1	S2	S1	S1	S2
C+M+P	S1	S2	S1	S1	S2
C+P	S1	S2	S1	S1	S2
SM	S1	S2	S1	S1	S2
M+P	S1	S2	S1	S1	S2
SP	S1	S2	S1	S1	S2
EP	S1	S2	S1	S1	S2
Forest	S1	S2	S1	S1	S2

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; MAR: Annual Rainfall; MAT: Mean Annual Temperature; BS: Base Saturation; Soil pH; ASC: Aggregate Suitability Class; S1: Highly suitable; S2: Moderately suitable; S3: Marginally suitable.

Table 8 shows the suitability classes of the soils for the production of cocoyam. All the fallow plots (SC, C+M+P, C+P, SM, M+P, SP, and EP) are Marginally Suitable (S3) while the forest plot is also marginally suitable (S3). All the fallow plots (SC, C+M+P, C+P, SM, M+P, SP, and EP) are moderately suitable (S2) in both pigeon pea and sweet potato production, while that of forest plot is also moderately suitable (S2) in Table 9 and Table 10. Generally, the low pH values of the soils also pose a limitation to the production of the three crops (cocoyam, pigeon pea, and sweet potato) and this can be mitigated by liming and by use of tolerant cultivars.

4. Conclusion and Recommendation

From this study or based on my findings, it can be concluded that the fallow land has retrieved back its fertility after several years of fallow (from seven years and above) because of its high content in the physicochemical properties of soil and thus can be used for arable crop production especially these three principal crops (cocoyam, pigeon pea and sweet potato) unlike in the forest soil which has lost most of its physicochemical properties either by leaching or surface erosion.

The land suitability classes of Alfisols of Southeastern Nigeria for cocoyam, pigeon pea, and sweet potato carried out in this study showed that both fallow and forest soils are Marginally suitable for the growth and production of cocoyam. Also, soils in the fallow and forest plots are moderately suitable, or the growth and production of pigeon pea and sweet potato and these are based on the FAO's principle of limiting conditions. To enhance the productivity levels of these lands for optimum cocoyam, pigeon pea and sweet potato production, agriculturists or farmers should embark on land fallowing after several years (from seven years and above) of cultivation of crops in a land because type and length of fallow are essential for soil fertility restoration and then for the forest land, it's recommended that sustainable agronomic and soil conservation practices like protecting the soil against erosion and leaching, organic and inorganic manuring, etc, should be used on the forest land whenever it is to be used for the production of any crops. These management practices will also help to upgrade the suitability classes of the soils for the production of the crops.

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