VOLUME 2, 2018
DOI: 10.31058/j.as.2018.22009

Changes in Soil Physico-Chemical Properties in Fallow Farmland in the Rainforest Zone of Southern Nigeria

Anthony Inah Iwara[1]*, Labaran Daniel Abalaka[2]

[1] Department of Geography & Environmental Management, University of Abuja, Nigeria
[2] Department of Architecture, Kaduna State University Kafanchan Campus, Nigeria

Email Address

iwaradream2008@gmail.com (Iwara, A. I.)
*Correspondence: iwaradream2008@gmail.com

Received: 1 January 2018**; Accepted:** 20 February 2018**; Published:** 13 April 2018

Abstract:

The study examined changes in soil physico-chemical properties in fallow communities in the Rainforest Zone of Southern Nigeria. Fallow vegetation of 1-year, 3-year, 5-year and 10-year, were studied. The quadrat approach of sampling was employed to collect surface soil samples (0 – 15cm) from six plots of 10m x 10m across the four fallow communities. Results showed that the mean contents of organic matter (OM), total nitrogen (TN), effective cation exchange capacity (ECEC) and available phosphorus (Av. P) substantially increased in the 3-10 years fallows presumably due to the increase in litter accumulation following the establishment of woody vegetation. PCA result identified soil nutrient, soil acidity and particle size composition as soil properties that progressively changed across the fallow soils. The study suggested that farmers should be encouraged to allow woody trees on their farmlands to speedy up soil fertility restoration.

Keywords:

Fallow Vegetation, Soil Physicochemical Properties

1. Introduction

One of the commonest and traditional ways of restoring the fertility of a disturbed soil after a period of food crop cultivation is through bush fallow. Fallow describes a resting period for disturbed agricultural land between two cropping cycles during which soil fertility is restored [1], [2], [3]. Fallows or forest regeneration is a common terminology in ecological studies as it pertains to the reestablishment of forest after a period of food crop cultivation or disturbance [2]. Fallows help in nutrient restoration and as well as serve as carbon sequester (carbon sink function) among others [3]. The clearing of forest vegetation for the cultivation of crops leads to nutrient element loss through soil erosion, alteration of the floristic and structural composition of vegetation and reduction in species diversity [4], [5]. The farming operations that follow land preparation of food crop cultivation may affect the rate of vegetation regeneration vis-à-vis nutrient returned to the soil. In Agoi-Ekpo just like in other communities in

Cross River State and Nigeria as a whole, land preparation for cropping is usually characterized by slash and burn. This practice has significant impact on nutrient returned to the soil. Christanty [6] observed that phosphate availability is increased after burning, and decline during cropping period as a result of its uptake by crops.

Agoi-Ekpo has a large expanse of forested area which is predicated upon by her low population. It is thus common to find fallow lands of more than 10 years which perhaps are hard to find in other communities in Yakurr Local Government Area. The length of fallow determines soil resilience, which is the soil's ability to restore itself after natural or anthropogenic disturbance [4], [7]. Thus, the deliberate practice of allowing a disturbed piece of land to fallow results in soil nutrient and vegetation change. The development of forest during fallow time also affords the soil adequate cover and protection from harsh climatic conditions mostly the erosive force of rainstorm and helps to improve the soil structure as well as ensure the soil eco-balance and nutrient fluxes. Nutrient change occurs because organic matter is added from vegetation.

Changes in nutrient in the soil during the process of fallow occur due to the increase in soil organic matter and soil humus, which helps to hold exchangeable cations [4], [8]. Aweto [4] stated that soil organic matter which declines during cultivation, normally builds up during the fallow period if the rejuvenating fallow vegetation produces adequate litter which more than off sets the rate of soil organic matter decomposition and mineralization. He further stated that organic matter build-up in the soil may not be immediate with the beginning of the fallow period. This means that the process of organic matter diminution during cropping due to leaching, erosion and low quantity of litter generated may continue into the first few years of the fallow period, but the pattern of buildup changes with the increase in fallow age and production of adequate litter [4]. Organic matter is added to the soil as litter and from dead roots and root products. It is essential in the soil during nutrient restoration for sustaining soil health and crop productivity [9].The proportion of nutrient build-up in the soil depends on the type and age of fallow. The soils in Agoi-Ekpo could be said to have a high level of resilience as a result of the long fallow system that is practiced among the people. The area is one of the villages in Yakurr Local Government Area of Cross River State that has over 70% of her natural forest intact. Despite, the unique ecological endowment of the area, not many studies have been carried out to assess the changes that take place in soil fertility during fallowing. The aim of the study was to understand the changes in soil physico-chemical properties in fallow vegetation of different years. Specifically, the study assesses the changes in soil nutrient across different fallow communities such 1-year old, 3-year old, 5-year old and 10-year old fallows.

2. Materials and Methods

2.1. Study Area

The study was carried out in Agoi-Ekpo, one of the villages in Yakurr Local Government Area of Cross River State. Its geographical coordinates are 5 ° 50' 0" North and 8 ° 16' 0" East. The area falls within the lowland of south-eastern Nigeria called the Cross River plain. The relief is gentle except in places where granite rises above the general level of the surface. Agoi-Ekpo lies within the hot-wet equatorial climate of the tropics. It exhibits the characteristics of the humid tropics which are high temperature, heavy rainfall and high relative humidity. Vertisol are the main soils type found in the area. The geology/parent material is of cretaceous sediments [10] while the topography of the study sites is near level. The area has luxuriant forest vegetation. As a result of the luxuriant vegetation characteristics, several wild birds and animals, insects, butterflies etc abound in the area.

2.2. Sampling Procedure and Data Collection

Before data collection, a reconnaissance survey was made to the area, during which fallows of 1-year old, 3-year old, 5-year old and 10-year old fallows were identified and delineated for soil sampling. Identification of fallows was done by the local farmers. In each fallow, 8 plots of $100m^2$ were established from which 6 plots were randomly selected. In each selected plot, surface soil samples of 0-15cm were collected with a soil auger and put in polythene bags with labels. A total of 28 soil samples were randomly collected for the study. The soil samples were then taken to the laboratory for analysis. Soil organic carbon was determined by the method of [11] after which values obtained were multiplied by 1.72 (Pluske et al., 2009 cited in 12) to converted to organic matter; total nitrogen by the Kjeldahl method (13) and available phosphorus was determined by the method of [14]. The soils were leached with 1M neutral ammonium acetate to obtain leachates used to determine exchangeable bases and soil cation exchange capacity, while pH value was determined using a glass electrode testronic digital pH meter with a soil: water ratio of 1:2. Soil particle size composition was analysed using the hydrometer method [15].

2.3. Data Analysis

Data obtained were analysed using tables, averages and One-Way analysis of variance (ANOVA). One-Way ANOVA was performed to determine if significant variation existed among soil properties of the sampled fallows. A multivariate technique through the use of principal components analysis (PCA) was performed to reduce the set of soil variables as well as pick out the most significant soil properties that substantially increased across the fallow vegetation.

3. Results and Discussion

3.1. Soil Physical Properties

Results of the physical properties of the studied fallow soils are shown in Table 1. It showed that the soils of the 1-year, 3-year and 10-year fallows were sandy loam with sand making up more than 50% of the inorganic mineral fragment, while the textural class for soil in the 5-year fallow was loam with sandy constituting less than 50% of the inorganic mineral fragment. Sand content was comparatively high in the 10-year fallow, followed by the 3-year fallow and then 1-year fallow, but low in the 5-year fallow with mean values of 64.5%, 58.6%, 56.8% and 48.6% respectively. Silt content was comparatively high in the 5-year fallow, followed by the 1-year and 3-year fallow, while the 10-year fallow had low silt content with mean values of 33.3%, 29.4%, 27.4% and 25.3% respectively. In addition, clay proportion happened to be relatively high in the 10-year fallow and low in the 3-year fallow with mean values of 10.2% and 14.0% respectively. Analysis of Variance result indicates that sand ($F = 9070.54$, $p<0.05$), silt ($F = 4002.15$, $p<0.05$) and clay ($F = 35.56$, $p<0.05$) contents varied significantly among the fallow soils. This implies that the fallow soils are dissimilar being sandy loam and loam in nature.

***Table 1.** Physical properties of the studied fallow soils*[a]

Soil properties	Fallows			
	1-year	**3-year**	**5-year**	**10-year**
Sand (%)	56.5±0.05	58.6±0.06	48.6±0.04	64.5±0.11
Silt (%)	29.4±0.04	27.4±0.05	33.3±0.06	25.3±1.06
Clay (%)	14.1±0.06	14.0±0.68	18.1±0.58	10.2±0.58

[a]*values are means ±standard errors*

3.2. Chemical Properties of Soils

The chemical properties of the fallow soils are shown in Table 2. Soil pH shows whether the soil is acidic, neutral or alkaline, as such, it provides useful information on the availabilities of cations. The information in Table 2 showed that the fallow soils were acidic with mean pH range of 5.00 to 5.57. The value of pH values varied significantly among the fallow soil ($F = 63.23$, $p<0.01$). It showed that pH value increased in the 3-year fallow after which it decreased and later showed some increment in the 10-year old fallow. The low pH value recorded in the 1-year fallow is expected due to the increase in soil erosion as a result of the sparse vegetal cover or vegetation. The leaching of some basic cations particularly calcium from the surface horizons of soils by high rainfall may be responsible for the acidic nature of soil [16]. The generally acidic nature of the fallow soils is attributed to heavy rainfall in the area. The pH values observed across the fallow soils have the potential to upset nutrient availability in the soil [17]. The pH value obtained in the study is consistent with the findings of Agbede [18] that the pH in Nigeria soils falls with the range 4.5 to 7.5.

The content of organic matter (OM) increased steadily with the fallow age. The trend of OC reported in the present study is consistent with the findings of Aweto (1981) cited in [4] who also observed a progressive increase in OC and other nutrients with the increase in fallow ages. OM content increased from the 3 - 10 years fallow with high content recorded in the 5-year fallow. The 1-year fallow had the lowest OM content of 0.21 mg/kg. The dominance of *Chromolaena odorata and* cassava in the 1-year may be responsible for the low level of OM. Similar reason is attributed to the OM content in the 3-year fallow. According to [4], litter produced by *C. odorata* is inadequate to offset the rate of organic matter decomposition, hence the low level of OM in the 1-3 years of fallow. However, with the replacement of *C. odorata* and other herbaceous species with trees, a considerable accretion of organic matter occurred in soils of the 5 – 10 years fallow. The established woody trees also help to minimize the low of litter and nutrient to soil erosion. This is not the case with the 1-3 years of fallow where the existence of herbaceous species cannot afford the soil adequate protection from the degrading force of heavy rainfall. In the 1-3 years fallow, nutrient diminution is high and continues if woody trees are not established [4].The content of OM varied significantly among the fallow soils ($F = 76917.49$, $p<0.01$). This implies that the soil in the 5 – 10 years fallow have abundance of OM than the soil of the 1 – 3 years fallow. High amounts of OM in the soil are known to improve soil quality [19], [20]. The result is also consistent with the findings of [21] when they reported that soil carbon increases with time after fallow due to biomass accumulation.

The proportion of total nitrogen (N) increased substantially in the 5 – 10 years fallow soils with mean values of 0.22% and 0.20% respectively. From the 1-year fallow to the 10-year fallow, TN increased in the soil by 122.2%. As expected, the lowest accretion of TN in the soil was found in the 1-year fallow. TN content varied significantly across the fallow soils (F = 166.11, $p<0.01$). Like OM, high amount of N in the soil helps to improve soil quality and encourages agricultural productivity and sustainability [20], [22]. This result indicates that older fallows help to improve the availability of essential nutrients (fertility) in the soil. The mean content of available phosphorus (Av. P) was considerably higher in the 5 – 10 years fallow, but low in the young fallow (1 – 3 years). As shown in Table 2, the content of Av. P started to increase in the fallow soils in the 3-year fallow. Av. P content varied significantly across the fallow soils (F = 2471.02, $p<0.01$). The increase in Av. P in soils of the 5 – 10 years fallow may be associated with the high OM content in the fallow soils. Studies have shown that the build-up of available phosphorus in the soil during the fallow periods is of considerable importance since its deficiency in the soil is a factor that frequently limits crop yield [23]. Generally, there is a consistent increase in the level of available phosphorus with increase in the length of fallow period. It is an indication that fallow age is more important for phosphorus determination. Another reason ascribed to the lower level of available phosphorus in the 1 to 3-year fallow could be the increased rate of phosphorus uptake by rapidly growing forbs and shrubs vegetation and slower rate of nutrient returns to the soil through leaf fall and mineralization [24].

The main exchangeable cations in soils are calcium, magnesium, potassium, sodium and to a lesser extent ammonium. Exchangeable means that they are held loose enough in the minerals which make up soils and the organic matter in soils so that they can be used by plants [25]. Exchangeable bases are important properties of soil and sediments as they relate information on the soil ability to sustain plant growth and retain nutrients. The proportion of exchangeable calcium (Ca) increased with the age of fallow and tended to show substantial increment in the 10-year fallow. As shown in Table 2, contents of Ca increased from the 3-10 years fallow and similar trend in the accretion of Mg (exchangeable magnesium), K (exchangeable potassium) and Na (exchangeable sodium) was observed. The result however showed that the contents of Ca and Mg were comparatively higher in the 3-year fallow than in the 5-year fallow. This trend in Ca and Mg accretion in the fallow soils (3 – 5 years) may presumably due to nutrient uptake and storage in the vigorously regenerating woody fallow vegetation [4]. The contents of Exchangeable bases varied significantly across the fallow soils ($p<0.01$). The contents of exchangeable bases were comparatively high in the 10-year fallow and low in the 1-year fallow. From the 1-year fallow to the 10-year fallow, the contents of Ca, Mg, K and Na increased by 155%, 67.8%, 70% and 57.1% respectively.

The content of soluble aluminium (AL^{+++}) varied significantly among the fallow soils (F =13829.37, $p<0.01$). High content of AL^{+++} was observed in the 5-year fallow followed closely by the 10-year fallow, while the 3-year fallow had the lowest level with mean values of 0.64cmol/kg, 0.36cmol/kg and 0.12cmol/kg respectively. AL^{+++} was not detected in the 1-year fallow. The changes in pH may be responsible for the variation in AL^{+++} contents in the fallow soils. For instance, AL^{+++} increased in the 5-year fallow due to the decrease in pH value. AL^{+++} however, decreased with the increase in pH value as noticed in the 3-year and 10-year fallows. Literature shows that pH is the principal factor governing concentrations of soluble and plant available metals [26]. Metal solubility tends to increase at lower pH and decrease at higher pH values [27]. On acidic soils, aluminium (Al) toxicity is one of the main constraints on crop productivity and it occurs up to 40% of the arable lands of the world [28]. Al is the third most abundant element in the earth’s crust and is toxic to plants when

DOI: 10.31058/j.as.2018.22009

solubilised into soil solution at acidic pH values (Kochian, 1995 cited 25). Apal [25] stated that plants will be affected extractable aluminium is >2. From this, it therefore implies that the fallow soils have low AL^{+++} which is not toxic to plants.

The content of hydrogen (H^+) ion concentrations in the fallow soils showed that H^+ was affected pH values. Soil acidity is as a result to hydrogen (H+) ion concentrations in the soil. This is because the higher the H^+ concentration in the soil, the lower the pH value. The highest H^+ concentration in the fallow soils was observed in the 1-year fallow with a mean value of 1.44cmol/kg, followed by the 5-year fallow with a mean value of 0.80cmol/kg. This is apparent as these two fallow soils have low pH values. The content of H^+ varied significantly among the fallow soils ($F = 8345.49$, $p<0.01$). Base saturation (BS) increased steadily across the fallow soils. The highest BS values were recorded in the 3-year fallow (92%) followed closely by the 10-year fallow soil (91%) and then the 5-year fallow soil (80%). The values obtained imply that BS tends to be higher under vegetal cover. In a related study, [29] showed that base saturation was higher in soil under the tree canopies than in the open grassland. In addition, the concentration of effective cation exchange capacity (ECEC) increased across the soils with the age of fallow. Across the fallow ages, the 10-year fallow had the highest ECEC with a mean value of 9.72cmol/kg, followed closely by the 3-year fallow (8.70cmol/kg), while the 1-year fallow had the lowest ECEC value of 5.41cmolkg. The susceptibility of the 1-year fallow to soil erosion caused by heavy rainfall usually experienced in the area is responsible for the low ECEC and this has considerable effects on Ca, which was low. Peverill et al., [30] stated that acidic soil with low effective cation exchange capacity in high rainfall environments are most expected to have low Ca concentration in the soil. The low litter input in this fallow age may also be responsible for the low ECEC. High ECEC value in the 10-year fallow is attributed to the increase in litter accumulation which increases the organic matter of the soil. This is consistent with the findings of [31] that OM is a reservoir of soil exchangeable cations and its favours the increases of ECEC in the soil. The content of ECEC varied significantly among the fallow soils ($F = 12743.98$, $p<0.01$).

Table 2. *Chemical properties of the study fallow soils*[a]

Soil properties	Fallows				F-value
	1-year	3-year	5-year	10-year	
pH	5.00±0.00	5.57±0.04	5.28±0.03	5.42±0.03	63.23*
OM (%)	0.21±0.01	3.46±0.01	4.76±0.01	4.24±0.01	76917.49*
TN (%)	0.09±0.00	0.17±0.00	0.22±0.00	0.20±0.01	166.11*
Av. P (Mg/kg)	5.75±0.01	5.87±0.00	6.25±0.00	6.25±0.01	2471.02*
Exch. Ca (cmol/kg)	2.58±0.05	5.77±0.04	4.58±0.05	6.58±0.05	1137.20*
Exch. Mg (cmol/kg)	1.18±0.04	1.95±0.03	0.98±0.05	1.98±0.05	114.41*
Exch. K (cmol/kg)	0.10±0.00	0.13±0.00	0.15±0.01	0.17±0.00	48.26*
Exch. Na (cmol/kg)	0.07±0.00	0.10±0.00	0.11±0.00	0.11±0.00	55.34*
AL^{+++}(cmol/kg)	0	0.12±0.00	0.64±0.00	0.36±0.00	13829.37*
H^+ (cmol/kg)	1.44±0.00	0.56±0.00	0.80±0.00	0.47±0.01	8345.49*
Base saturation (%)	73±0.52	92±0.52	80±0.58	91±0.44	312.50*
ECEC (cmolkg)	5.41±0.00	8.70±0.01	7.30±0.01	9.72±0.01	12743.98*

[a] *values are means ± standard errors; *Significant at 1% alpha level*

3.3. Result of PCA Showing Soil Properties that Showed Significant Change

PCA was performed for the 15 soil properties by grouping the fallow soil data. Principal loadings (correlation coefficients) and the variances (eigenvalues) for the soil variables were computed. Based on the procedure of using varimax rotation (variable maximization) as well as the Kaiser rule of selecting components with eigenvalues >1(Gaur and Gaur, 2006 cited in 2) only three components were extracted (Table 3). The extracted components accounted for 97.3% of total variance in the original data set. On PC_1 (principal component one), six soil properties with positive values loaded heavily on it. The soil properties included phosphorus (0.986), AL^{+++} (0.910), exchangeable potassium (0.889), total nitrogen (0.851), organic matter (0.837) and exchangeable sodium (0.805). The positive loadings implied that the contents of phosphorus, AL^{+++}, exchangeable potassium, total nitrogen, organic matter and exchangeable sodium in the soil progressively increased in the 1-10 years fallow. PC_1 was regarded as measuring soil nutrient. It accounted for 38.6% of the variance in the linear combination of soil properties. PC_2 had two soil properties with positive values that loaded heavily on it. The variables were pH (0.954) and base saturation (0.831). Similarly, the positive loadings indicated that the contents of pH and base saturation in the soil increased in the 1-10 years fallow. PC_2 symbolized soil acidity and it accounted for 30.7% of the variance in soil properties. PC_3 also had two soil properties that loaded both positively and negatively on it. The negatively loaded soil properties were clay (-0.980) and silt (-0.916), while the positively loaded soil property was sand (0.957). The negative loadings showed that the contents of clay and silt in the fallow soils decreased, while the content of sand increased across the fallow soils or studied fallow period. PC_3 represented particle size composition and it accounted for 27.8% of the variance in soil properties. The result above showed that soil nutrient, soil acidity and particle size composition represent significant soil properties that progressively changed across the fallow soils. It shows that soil nutrient, acidity and sand increased, while clay and silt decreased in the 1 – 10 years fallow. This is contrary to the study of [5] that showed that forest sand decreased with fallow age while there was substantial degradation of clay particles in the savanna. In a related study, [2] studied the effects of fallow genealogical cycles on the build-up of nutrients in soils of the Cross River rainforest, south-southern Nigeria. The study found that topsoil available phosphorus, topsoil exchangeable sodium and topsoil exchangeable potassium constituted continuously increased across the fallow generations. In another study, [5] revealed that a good number of the soil properties increased gradually with increase in fallow age.

Table 3. *Rotated PCA results.*

Soil properties	**Principal components**		
	PC_1	**PC_2**	**PC_3**
P	.986	.071	-.021
AL	.910	.016	-.404
K	.889	.287	.239
TN	.851	.476	-.172
OM	.837	.522	-.131
Na	.805	.509	.057
pH	.250	.954	.100
BS	.301	.831	.434
H	-.585	-.762	-.255
Ca	.562	.709	.420
ECEC	.537	.692	.480

Clay	-.022	.001	-.980
Sand	-.087	.233	.957
Silt	.153	-.351	-.916
Mg	-.017	.667	.716
Eigenvalues	**5.8**	**4.63**	**4.17**
% variance	**38.64**	**30.86**	**27.79**
Cumulative exp.	**38.64**	**69.5**	**97.29**

4. Conclusions

The study has apparently shown that the contents of essential nutrients especially organic matter, total nitrogen and available phosphorus increase with the age of fallow. The PCA result further shows that soil nutrient, soil acidity and particle size composition progressively changed (increased) across the fallow ages. The study therefore implies that increase in fallow time results in the steady accretion of essential nutrients in the soil for plant growth.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

References

[1] Styger, E.; Fernandes, E. C. M. Contributions of Managed Fallows to Soil Fertility Recovery. The World Bank, Washington, DC, USA. 2005, 426 -427.

[2] Offiong, R. A.; Iwara, A. I. Effects of fallow genealogical cycles on the build-up of nutrients in soils of the Cross River rainforest, south-southern Nigeria. *Ethiopian Journal of Environmental Studies and Management*, 2011, 4, 4, 84 – 95.

[3] De Almeida, C. L.; de Araǘjo, J. C.; Costa, M. C. A.; de Almeida, A. M. M.; de Andrade, E. M. Fallow reduces soil losses and increases carbon stock in Caatinga. 2017.
Available online: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S2179-80872017000100142 (Accessed: 20/12/ 2017)

[4] Aweto, A. O. Shifting cultivation and secondary succession in the tropics. UK: MPG Books Group. 2013

[5] Onijigin, E. O.; Fasina, A. S.; Oluwadare, D. A.; Ogbonnaya, U. O.; Ogunleye, K. S.; Omoju, O. J. Influence of fallow ages on soil properties at the forest-savanna boundary in south western Nigeria. *International Journal of Plant & Soil Science*, 2016, 10, 1, 1-12.

[6] Christanty, L. "Shifting cultivation and tropical soils: patterns, problems and possible improvements", In. Marten, G. G. (Ed) Traditional agriculture in southeast Asia. 1986, 226–240.

[7] Ogban, P.I.; Obi J.C. The relation between natural fallow and soil quality in Akwa Ibom State, Southeastern Nigeria. *Nigerian Journal of Agriculture, Food and Environment*, 2010, 6, 3&4, 34– 43.

[8] Nye, P. H.; Greenland, D. J. The soil under shifting cultivation. Commonwealth Agricultural Bureau, Farnham Royal, UK. 1960.

[9] Awale, R.; Emeson, M. A.; Machado, S. Soil organic carbon pools as early indicators for soil organic matter stock changes under different tillage practices in inland pacific Northwest. 2017. Available online: https://www.frontiersin.org/articles/10.3389/fevo.2017.00096/full (Accessed: 21/12/ 2017)

[10] Oden, M.I.; Okpamu, T.A.; Amah, E.A. Comparative analysis of fracture lineaments in Oban and Obudu Areas, SE Nigeria. *Journal of Geography and Geology*, 2012, 4, 2, 36 – 47.

[11] Walkley, A.; Black, I. A. An examination of the Detjareff Method for Determining Soil Organic Matter and a Proposed Modification to the Chromic Acid Titration Method. Soil Science, 1934, 37, 29-38.

[12] Iwara, A.I.; Ogundele, F. O.; Ibor, U. W.; Deekor, T. N. Multivariate analysis of soil-vegetation interrelationships in a south-southern secondary forest of Nigeria. *International Journal of Biology*, 2011, 3, 3, 73 – 82.

[13] Bremner, J. M.; Mulvaney, C. S. Nitrogen in: Page AI, Miller RH, Keeney DR (Eds.); The method of soil analysis: Agronomy. Monogram, Madison: ASA. 1982.

[14] Brady, N. C.; Weil, R. R. The nature and properties of soils. New Jersey, Prentice-Hall. 2002.

[15] Bouyoucos, G. J. Hydrometer method for making particle size analysis of soils. *Soil Science Society of America Proceedings*, 1926, 26, 464-465.

[16] Foth, H. D. Fundamentals of soil science. 8th Edition. New York: John Wiley & Sons. 2006.

[17] Osemwota, O.I. Effect of abattoir effluent on the physical and chemical properties of soils. *Environ Monit Assess*, 2010, 167, 399–404.

[18] Agbede, O. O. Soil husbandry: life for national food security and economic empowerment. An Inaugural Delivered on March 19th, 2008 at Nasarawa State University Keffi, Nigeria. 2008

[19] Bandel, A. V.; James, B. R.;,John, J.; Meisinger, J. J. Basic principles of soil fertility II. Soil Properties Available online:

[20] Aweto, A. O. Secondary succession and soil fertility restoration in south-western Nigeria: soil andvegetation interrelationships. *J. Ecol.*, 1981, 69, 3, 957-963.

[21] Dolle, M.; Schmidt, W. Impact of tree species on nutrient and light availability: evidence from a permanent plot study of old-field succession. *Plant Ecol.*, 2009, 203, 273 - 287.

[22] Aweto, A.O.; Dikinya, O. The beneficial effects of two tree species on soil properties in a semi-arid savanna rangeland in Botswana. *Land Contamination & Reclamation*, 2003, 11, 3, 339-344.

[23] Adepetu, J.A.; Adetunji, M.T.; Ige, O.U. Soil fertility and crop nutrition. Jumak Publishers. 2015.

[24] Onijigin, E.O.; Fasina, A.S.; Oluwadare, D.A.; Ogbonnaya, U.O.; Ogunleye, K.S; Omoju, O.J. Influence of fallow ages on soil properties at the forest-savanna

boundary in south western Nigeria. *International Journal of Plant & Soil Science*, 2016, 10, 1, 1-12.

[25] Apal. Soil test interpretation guide. Available online: http://www.apal.com.au/images/uploads/resources/Soil_Test_Interpretation_Guide_1.pdf (Accessed :17/09/14)

[26] Brallier, S.; Harrison, R.B.; Henry, C.L.; Dongsen, X. Liming effects on availability of Cd, Cu, Ni and Zn in a soil amended with sewage sludge 16 years previously. *Water, Air and Soil Pollution*, 1996, 86, 195–206.

[27] Rieuwerts, J.S.; Thornton, I.; Farago, M.E.; Ashmore, M.R. Factors influencing metal bioavailability in soils: preliminary investigations for the development of a critical loads approach for metals, Chemical Speciation & Bioavailability, 1998, 10, 2, 61-75.

[28] Krstic, D.; Djalovic, I.; Nikezic, D.; Bjelic, D. Aluminium in acid soils: chemistry, toxicity and impact on maize plants. 2012. Available online: http://cdn.intechopen.com/pdfs/26525/InTech-Aluminium_in_acid_soils_chemistry_toxicity_and_impact_on_maize_plants.pdf (Accessed: 19/11/17)

[29] Snelder, D. J. Soil properties of Imperata grasslands and prospects for tree-based farming systems in Northeast Luzon, The Philippines. Agroforestry Systems, 2001, 52, 27–40.

[30] Peverill, K. I.; Sparrow, L. A.; Reuter, D. J. Soil analysis: an interpretation manual. *Catena*, 2000, 39, 301–303.

[31] Hassan, A.M.; Murabbi, A.; Victor, A. O. Depth Distribution of Available Micronutrients under Different Land-use Systems. Direct Res. *J. Agric. Food Sci.*, 2016, 4, 5, 81.