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Nitrogen Status of Soils of Selected Land-uses of Two Cropping Systems in the Humid Tropical Rainforest, Southeastern Nigeria

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Abstract

Nitrogen status of soils provides information about the capacity of soils to sustain crop productivity and maintain environmental safety. Nitrogen status of soils of selected land-use types of perennial and annual cropping systems were evaluated in the humid tropical rainforest zone, southeastern, Nigeria. Experimental design was a 6 x 3 factorial replicated 3 times in a randomized complete block setup. Total N, NH_4-N, NO_3-N and organic N were determined. Also correlation between selected soil properties and various N forms were estimated. Nitrogen forms significantly (LSD 0.05) decreased in the order Oil palm > cocoyam > cashew > rubber > cassava > yam, oil palm > cocoyam > rubber > cashew > yam > cassava, oil palm > cashew > rubber = cocoyam > yam > cassava and oil palm > cashew > rubber > cocoyam > yam > cassava for NH_4-N, NO_3-N, organic N and total N respectively and with each higher in the surface 0-15 cm than the other soil depths. Mean soil concentrations of land uses under perennial and annual cropping systems were 3.69 and 2.23 mg kg^{-1} NH_4-N, 8.56 and 5.50 mg kg^{-1} NO_3-N, 0.20 and 0.17 g kg^{-1} organic N and 0.22 and 0.19 g kg^{-1}total N respectively, with the former better than the later. Nitrogen status of the various land use types correlated with soil clay, silt, OM, available P, ECEC and pH. In general, N status varied with land uses under perennial and annual cropping systems and low indicating the need for external N input for crop sustenance and inability for environmental pollution.

Keywords: Nitrogen, Land use, Cropping Systems, Humid Tropics and Southeastern Nigeria

1.0 Introduction

Nitrogen is the most important nutrient element that is essential for the physiological processes of chlorophyll and protein synthesis in plants. It is also associated with global warming, acid rain and eutrophication of surface and ground water systems (Aulakh and Malhi, 2005; Fan et al., 2010; Jha et al., 2010; Hirel et al., 2011) and as such of serious environmental concern.Total N content of soils consists of about 90-98% organic and less than 2% inorganic fractions (Meysner et al., 2006; Sabiene et al., 2010). Through certain biochemical processes especially those related to N mineralization and immobilization, soil organic and inorganic N fractions could be transformed from one form into another (Fan et al., 2010). Organic nitrogen is associated with nucleic acids, amino acids, proteins and amino sugars (Brady and Weil, 2004; Mubyana- John and Musamba, 2014) while the inorganic fractions include ammonium and nitrate nitrogen that are soluble, available and constitute the forms easily taken up by plants and microbes or lost through leaching (Sabiene et al., 2010). Nitrate nitrogen is very mobile, with concentrations often low in soils due to intense leaching especially in the humid tropics, particularly southeastern Nigeria with high intense rainfall, skeletal and fragile soils (Onweremadu et al., 2011; Hirel et al. 2011). Ammonium nitrogen is usually fixed by clay minerals, with availability often low in soils high in clay contents. Soil N status varies depending on certain natural and anthropogenic factors, with the later often very important (Hope et al., 2005). Critical anthropogenic factors include those related to land use types and crop management systems (Guggenberger et al., 1994, 1995; Onweremadu et al., 2011). It has been reported that changes in land use and cropping systems influences soil organic matter and its indices especially the organic carbon, humus, organic and mineral nitrogen (Johnson, 1992; Aberra and Belachew, 2011). Also studies indicate that changes in land use can cause changes in land coverage and associated carbon and nitrogen stock (Bolin and Sukumah, 2000; Sun et al., 2005; Zhijing et al., 2013) and that past land use practices are associated with modifications of decomposition dynamics through the alteration of soil aeration, water dynamics and aggregation and the biochemistry and quantity of crop residues (Drinkwater and Snapp, 2006). Furthermore, research has shown that the conversion of forest into agricultural land use depressed total soil N and organic matter due to reduction in plant litter, high rate of soil disturbance, breakdown in soil aggregation and reduction in soil cohesion (Khreast et al., 2008; Zhang et al., 2011; Gebrelibanos and Assen, 2013). For instance, it has been reported that in Deltaic soils of Seronga, Okavango, Mozambique, the concentration of total N depressed in the order grassland, cultivated, fallow and woodland due to low N mineralization rates, NH_4-N in the order grassland, woodland, fallow and cultivated land due to depressed rates of nitrification and NO_3-N in the order grassland, cultivated, woodland and fallow land uses due to increased leaching rates (Mubyna-John and Masamba, 2014). Also depressed N in a decreasing order of paddy field followed by forestland and slopping cropland land uses have been indicated (Yang et al., 2005). Others included decreased NO_3-N and NH_4-N in desert than other land uses (Hope et al., 2005), greater NO_3-N load in grassland than row crop land use (Jha et al., 2010), no significant difference in total nitrogen content of various land uses in Mexico (Geissen et al., 2009) and southern Ethiopia (Moges and Holdens 2008, Moges et al., 2013) and increased total N in grassland and cultivated land than woody land due to increased N mineralization (Mubyana-Musamba, 2014). Influence of cropping systems and soil management practices included reduction in N leaching for perennial than annual cropping systems due to the ability of perennial vegetation to maintain high soil organic nitrogen content, greater water concentration and provide greater evapotranspiration during vulnerable leaching periods (Brye et al., 2001; Schilling et al., 2008; Jha et al., 2010), increased N with tree coverage (Albretch and Kandji, 2003; Paras-Alcantara et al., 2013), perennial grass than winter wheat and fallow land use (Sabiene et al., 2010) and increased soil N with manure and legume cover cropping (Mubyana-John and Musamba, 2014). Variation in N distribution with soil profile depth has been widely reported (Malhi et al., 2009; Fan et al., 2010; Onweremadu et al., 2011; Paras-Alcantara et al., 2013; Zhijing et al., 2013). For instance, it has been observed that total N decreased with profile depth in most Southern Spain Mediterranean agricultural land uses (Paras-Alcantara et al., 2013) and southern Ethiopian soils of various land uses (Kiflu and Beyene, 2013) ascribable to the leaching of soluble organic nitrogen and high clay content (Diecow et al., 2005). Also high nitrate concentrations have been reported within the 0-400 cm soil depth of various land uses for dry land agriculture in Northern China (Fan et al., 2010) and in the 10-30 cm depth of most land uses in southern, Nigeria (Onweremadu et al., 2011). Equally no distinct pattern with depth has been reported for NO_3 and NH_4-N in land uses of a watershed on loess plateau in China (Zhijing et al., 2013).

Nitrogen status of soils could be influenced by soil physicochemical properties especially OM, texture, pH, moisture content and CEC. It has been indicated that soil N is directly related to the OM content (Moges et al.,2013) and with high total N content of surface soils due to high organic matter accumulation (Gebrelibanos and Assen,2013). Total N has also been reported to be highly negatively correlated with sandy but positively with silt and clay soil fractions (Onweremadu et al., 2011). It has been indicated that the influence of texture on soil N status included a low concentration in sandy soil due to high drainage and leaching loses and an increased concentration in silt and clay due to high NH_4-N fixation by clay minerals (Burke et al., 1989). Influence of soil pH have been reported as increased total N, NO_3-N and NH_4-N with high pH due to enhanced OM decomposition and N mineralization (Zhijing et al., 2013).

In the tropics and Nigeria in particular, N status of soils of most land uses has been reported (Onweremadu et al., 2011; Moges et al., 2013; Mubyana-John and Musamba, 2014). There appears however to be a dearth of information on N distribution of soils of land uses under different cropping systems. The objectives of the present study were therefore to determine the soil N status and to correlate the N forms with selected physico-chemical properties of soils of land uses under annual and perennial cropping systems in Umuaka, Southeastern, Nigeria.

2.0 Materials and Methods

2.1 Study Location and Soil Sampling

Study location was Umuaka, located between latitudes 5^0 27^1 and 5^0 39^1 N and longitudes 7^0 21^1 and 7^0 39^1E in the humid tropical rainforest zone, Southeastern, Nigeria. Its mean monthly temperature ranges between 19.97-32.73^{o}C, mean monthly relative humidity of 70.62-81.08% and mean annual rainfall of between 1657.4-2114.7 mm (IPEDC, 2006). The rainfall pattern is bimodal with peaks in the months of July and September and a short dry spell, the August break in the month of August. Soils are derived from Coastal Plain Sands (Orajiaka, 1975) and included an Arenic Kandiudult (oil palm, rubber, cassava and yam) and Typic Paleudult (cashew and cocoyam) (USDA, 2004). The main economic activities of the area consist of farming, hunting, trading and sand mining. Two cropping systems (annual and perennial) consisting of three land use types each were used for the study. Annual cropping systems included a seven months old cassava farm grown on plots previously cultivated to maize/yam/melon intercrop, a six months old yam farm that has received some organic and inorganic fertilizer amendments and a six and half months old cocoyam farm that was mulched with oil palm fronds. Perennial cropping system consisted of a more than thirty years old cashew, fifteen to twenty years old oil palm underlain by calapogonium cover crop and more than twenty five years old rubber plantations that have been previously fertilized with various inorganic fertilizers. Three replicate soil samples were collected from three depths (0-15, 15-30 and 30-45 cm) of each of the six land use types, making a total of 54 soil samples. The experimental design was a 6 x 3 factorial of six landuse types and three soil depths replicated three times in a randomized complete block setup. The soil samples were air dried, sieved with a 2 mm diameter mesh and subsamples subjected to routine analyses using standard methods. Particle size (Gee and Or, 2002), gravimetric moisture content obtained as the difference between the wet and oven dried soil samples, pH in 1:2.5 soil/water ratio using the glass electrode of the pH meter, available P (Olson and Sommers, 1982), organic carbon (Nelson and Sommers, 1996) and value converted to organic matter by multiplication using a factor of 1.724 (Van Bemmelen factor), exchangeable cations (Thomas, 1996) and ECEC as summation of exchangeable cations. Determination of total N and N fractions in the soils were conducted as follows:

Total N was determined colorimetrically using the following procedure; finely ground soil sample (0.2 g) was weighed into a digestion flask and 1 g of copper catalyst plus 4mls of Conc. H_2SO_4 were added and digested on a digestion block till frothing stopped. The tube was cooled and about 20 ml de-ionized water added before filteration into a 100 ml flask and subsequent dilution to mark using de-ionized water. A 10 ml aliquot of the clear supernatant was pipetted into a 20 ml volumetric flask and 6 ml of potassium sodium tartarate, 2ml alkaline sodium phenate and 2 ml sodium hypochlorite solutions added before mixing and making-up to mark with deionized water. The N in the solution was then determined at a wavelength of 630 nm using a Spectrophotometer.
Total N in the sample was calculated using the relation:

$$\text{Sample N (g kg}^{-1}\text{)} = \frac{\text{Solution N x dilution factor x volume of solution}}{\text{Wt of sample x total volume of extract}}$$

Colorimetric determination of nitrate nitrogen was conducted as follows: A 10g soil sample was weighed into polythene bottle and 0.5 g activated carbon plus 40 ml Morgan solution added and shaken for 45-60 mins before filteration. Furthermore, 10 ml of the filterate was pipetted into a 25 ml volumetric flask and 2 ml of brucine reagent and 10ml Conc. H_2SO_4 rapidly added and thoroughly mixed and allowed to cool for 20 mins before finally making up to mark with de-ionized water. The brucine treated sample was read on a Spectrophotometer at a wavelength of 470 nm.

$$\text{Concentration of NO}_3\text{-N (mg kg}^{-1}\text{)} = \frac{\text{AC conc. (mg l}^{-1}\text{) x D.F x EV (L) colour}}{\text{Vol. of extract in (L) x wt of soil}}$$

Ammonium-Nitrogen was determined using the following procedures; A 10g soil sample was weighed into a polythene bottle and 0.5g activated carbon plus 40 ml Morgan extracting reagent added and shaken for 45-60 mins before filteration using whatman no. 2 filter paper. Also 10ml of the filterate, 6ml of potassium sodium tartarate and 2ml of alkaline sodium phenate solution were added into a 25ml volumetric flask and shaked thoroughly before the flask was made up to mark using de-ionized water. The NH_4-N in the solution was determined in a spectrophotometer at a wavelength of 630 nm and the concentration in the sample calculated as:

$$\text{Concentration of NH}_4\text{-N in the sample (mg kg-1)} = \frac{\text{AC conc. (mg l}^{-1}\text{) x D.F x EV (L)}}{\text{vol. of extract (L) x Wt of soil}}$$

Where AC = Concentration (mg l^{-1}), D.F = Dilution factor, EV = Final volume and Wt = Weight of soil.

3.0 Statistical Analysis

Data generated on nitrogen status of soils of the various land uses were subjected to analysis of variance (ANOVA) and means separated using LSD at 5% probability. Also correlation between soil properties and N forms was determined using correlation analysis. All analyses were conducted using Genstat Statistical Package (Buysse, 2004).

4.0 Results and Discussion

4.1 Soil Characterization

Sand, silt, clay and silt/clay ratios ranged from 693.6-873.6, 12.8-58.2, 113.6-293.6 g kg^{-1} and 0.04-0.34 and 713.6-933.6, 12.8-32.8, 53.6-273.6 g kg^{-1} and 0.05-0.29 in soils of land uses under annual perennial cropping systems respectively (Table 1). Moisture content varied as 18.7-41.4 and 29.4-38.3% under annual and perennial cropping systems. Whereas sand content decreased with soil, the reverse was the case for clay and moisture content in soils of all land uses for both cropping systems. Similar trends has been reported for soils of selected land uses in southeastern, Nigeria (Uzoho et al., 2007). Increased moisture content with soil depth could be due to high water retention by clay and depressed evaporative losses. Low silt/clay ratios of values below unity indicated that the soils were high weathered (Essoka and Esu, 2005: Hassan et al., 2005). Sand dominated the textural class of soils of both cropping systems, ascribable to the parent material which is Coastal Plain Sands (Lekwa and Whiteside, 1986).

Chemical properties of the soils are presented in Table 2. Soils were acidic with pH values decreasing with profile depths as was the OM and exchangeable Ca and signifying their contributions to soil reactions in the land use types of both cropping systems. The C/N ratios of the soils were low and indicating the potentiality of N mineralization. Besides exchangeable Mg, values of other exchangeable bases, ECEC and OM were low. The low OM could be responsible for these poor fertility attributes since the fertility of tropical soils depend on their OM content. Phosphorus content of the soils ranged from low to moderate (Enwezor et al., 1990) and decreased with depth in all land uses (Uzoho et al., 2007) of both cropping systems. In general there was no much variability between the physico-chemical attributes of soils of land uses under annual and perennial cropping systems.

4.1 Ammonium Nitrogen

Mean NH_4-N content averaged over soil depths varied with land use types (Table 3) being distinctly (LSD 0.05) higher in Oil palm and lower in yam relative to other land use types. Concentrations decreased in the order Oil palm > cocoyam > cashew > rubber > cassava > yam. Variation in NH_4-N concentration with landuse has been reported (Mubyna-John and Masamba, 2014). Low values for yam land use in this study could be ascribed to increased fixation due to the high clay content. Mean NH_4-N concentrations were 3.69 and 2.23 mg $kg^{-1}$for land uses under perennial and annual cropping systems respectively indicating that the former was better than the later. High NH_4-N under perennial than annual cropping systems has been reported and ascribed to high mineralization of accumulated plant litter (Gebrelibanos and Assen, 2013). In all land uses of both cropping systems NH_4-N decreased seriously with soil depths, contrary to no distinct pattern and with the least concentration being in the 10-30 cm depth of soils of a watershed in loess plateau in China (Zhijing et al., 2013). Also, increased concentration down the soil depth has been reported and attributed to leaching losses (Yang et al., 2004). Besides cashew, oil palm had the best NH_4-N concentration in the 0-15 cm soil depth. Concentrations in cocoyam and rubber were better than other land uses in the 15-30 and 30-45 cm soil depths respectively. Ammonium nitrogen was positively and distinctly ($P \leq 0.05$) correlated with clay content ($r = 0.65$) and ECEC ($r = 0.57$) but not significantly ($P \leq 0.05$) with silt content ($r = -0.01$), pH ($r = 0.29$), OM ($r = -0.05$) and available P ($r = -0.33$) (Table 4). Significant correlation between NH_4-N and pH attributed to increased mineralization (Zhijing etal., 2013) and with silt and clay due to high NH_4-N fixation ((Burke et al., 1989).

4.2 Nitrate Nitrogen

Mean NO_3-N decreased in the order oil palm > cocoyam > rubber > cashew > yam > cassava with oil palm better than the others (Table 5) probably due to the influence of the leguminous cover crop (Calapogonium) in fixing N and depressing nitrate loses by leaching and erosion. Variation in soil NO_3-N with land use types have been indicated and ascribed to changes in rates of organic N mineralization and losses due to plant and microbial uptake, leaching, runoff and erosion (Yang et al., 2004; Fan et al., 2010). In this study, cocoyam (8.67 mg kg^{-1}) had the second best NO_3-N concentration apart from oil palm (9.47 mg kg^{-1}) ascribable to organic matter addition and reduction of erosion and leaching losses by the palm frond mulch. Poor values in cassava and yam could be due to poor litter accumulation, nitrification rate and losses from leaching and plant uptake (Mubyana-John and Masamba, 2014). Mean NO_3-N concentration was better under perennial (8.56 mg kg^{-1}) than annual (5.50 mg kg^{-1}) cropping systems probably due to the ability of the former to recycle leached nitrate. Averaged over land uses, concentrations of NO_3-N decreased with soil depth probably due to the high organic matter content of the surface soil depths. No distinct pattern of N distribution with depth but with the highest concentration being in the 10-30 cm soil depth of land uses of a watershed on loess plateau in China (Zhijing et al., 2013). In all land uses, NO_3 concentrations were higher than NH_4-N contrary to a reverse trend of higher NH_4-N than NO_3-N obtained for some land uses in southwestern, China (Yang et al., 2004). Several workers have reported high nitrate loss or accumulation in the soil profile (Li et al., 2005; Wu et al., 2005). Whereas cashew had the best concentration in the surface 0-15 cm depth, oil palm and rubber were in the 15-30 and 30-45cm soil depths respectively due to differences in nitrification rates (Yang et al., 2004) and indicating greater leaching and tendency for ground water contamination in the oil palm and rubber land uses.

Nitrate nitrogen was not distinctly ($P \leq 0.05$) related with silt content ($r = -0.01$), pH ($r = 0.24$), OM ($r = -0.01$) and available P ($r = -0.35$) but with clay content ($r = -0.60$) and ECEC ($r = 0.50$) (Table 4). Poor relationship between soil organic carbon with ammonium and nitrate nitrogen has been reported (Sabiene et al., 2010). Significant correlation between NO_3-N and soil pH has been reported due to increased nitrification rates (Zhijing et al., 2013).

4.3 Organic Nitrogen

Soil organic N consisted of 88-92% of total N. Others have reported means of 90-98% (Meysner et al., 2006; Sabiene et al., 2010). Concentrations averaged over soil depths decreased as oil palm > cashew > rubber = cocoyam > yam > cassava (Table 6). Land uses under perennial (0.20 g kg^{-1}) were better than those under annual (0.17 g kg^{-1}) cropping systems probably due to large litter accumulation. Higher concentration in cocoyam (0.19 kg^{-1}) than the other annual (0.14 and 0.17 kg^{-1} for cassava and yam respectively) cropping systems could probably be due to the influence of mulching. In all land uses, mean concentration decreased with soil depth due to high organic material accumulation on the soil surface. Concentrations in the 0-15 and 15-30 cm soil depths were distinctly better in oil palm relative to other land uses while that in the 30-45 cm depth was not serious (LSD 0.05) between oil palm and cashew but higher than others. There was no significant correlation between organic N and other soil properties.

4.4 Total Nitrogen

Total N averaged over soil depths decreased as oil palm > cashew > rubber > cocoyam > yam > cassava with oil palm better relative to others (Table 7) probably due to higher N mineralization of soil organic matter and fixation by the leguminous cover crop. Increased total N with soil organic matter content and fixation by crops have been reported by others (Gebrelibanos and Assen 2013; Moges et al., 2013; Mubyana-John and Masamba 2014). According to Moges et al. (2013), the direct relationship of total N with organic matter has been attributed to binding of most soil N with organic carbon. Land uses under perennial (0.22 g kg^{-1}) had better total N than those under annual (0.19 g kg^{-1}) cropping system as have been observed for other N forms due to high organic litter accumulation (Moges et al., 2013). Landon (1992) classified total N as high, medium or low when values are above 2.1, 1.4-2.1 and below1.4 g kg^{-1} respectively suggesting that values of between 0.19-0.22 g kg^{-1} reported for land uses under perennial and annual cropping systems studied are very low. As expected mean N concentration was higher in the surface (0-15 cm) than the lower soil depths due to higher organic litter content of surface soil (Yang et al., 2004). Decrease in total N content with increased soil depth has been reported (Zhijing et al., 2013). For the various land uses, best N concentration in the 0-15 and 15-30 cm soil depth was in oil palm while that in the 30-45 cm soil depth was in cashew land use type. Nitrogen concentration of the 30-45 cm soil depth was higher than the 15-30 cm depth in cashew signifying higher tendency of N leaching and pollution of ground water system in the land use.

Total nitrogen was positively and significantly ($P \leq 0.05$) correlated with OM ($r = 0.54$) but not with clay content ($r = 0.18$), silt ($r = 0.30$), pH ($r = 0.14$), ECEC ($r = -0.03$) and available P ($r = 0.001$) (Table 5). Other workers have reported significantly positive relationship between total N and SOM (Yang et al., 2004; Sabiene et al., 2010) but non with CEC (Duguma et al., 2010). There was no serious ($P \leq 0.05$) relationship between organic N and clay content ($r = 0.25$), silt ($r = 0.28$), pH ($r = -0.03$), ECEC ($r = -0.16$), OM ($r = 0.24$) and available P ($r = 0.07$). Significantly positive relationship has been reported between available P and total N in central highland soil, Ethiopian (Duguma et al., 2010)..

5.0 Conclusion

Soils of the various land use types were dominantly sandy, acidic with low organic matter and plant nutrient contents exception being P. Total N and its forms varied with land use types and decreased in the order; Oil palm > cocoyam > cashew > rubber > cassava > yam, oil palm > cocoyam > rubber > cashew > yam > cassava, oil palm > cashew > rubber = cocoyam > yam > cassava and oil palm > cashew > rubber > cocoyam > yam > cassava for ammonium N, nitrate N, organic N and for total N respectively. In all land use types, total and N forms decreased with soil depths with concentrations under perennial greater than annual cropping systems. Concentrations of total N and its fractions correlated with soil properties especially sand, silt, clay, OM, available P, ECEC and pH. Generally, total N status of soils of land uses under both cropping systems (perennial and annual) were low suggesting the need for external N input for crop productivity and negating the probability of N pollution of the soils.

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Table 1. Soil Physical Properties of Land uses under Annual and Perennial Cropping Systems

Land use	Depth (cm)	MC (%)	Sand (g kg^{-1})	Silt(g kg^{-1})	Clay(g kg^{-1})	Silt/Clay ratio	TC
			Annual Cropping System				
Cassava	0-15	18.7	773.6	52.8	173.6	0.30	LS
	15-30	20.1	733.6	12.8	253.6	0.05	SCL
	30-45	24.2	693.6	32.8	273.6	0.12	SCL
Cocoyam	0-15	40.0	873.6	12.8	113.6	0.11	LS
	15-30	40.9	793.6	52.8	153.6	0.34	SL
	30-45	41.4	773.6	32.8	197.2	0.17	SL
Yam	0-15	20.1	693.6	52.8	253.6	0.21	SCL
	15-30	20.8	713.6	12.8	273.6	0.05	SCL
	30-45	21.0	693.6	12.8	293.6	0.04	SCL
			Perennial Cropping System				
Cashew	0-15	36.2	913.6	12.8	73.6	0.17	S
	15-30	38.1	933.6	12.8	53.6	0.24	S
	30-45	38.3	873.6	12.8	113.6	0.11	LS
Oil Palm	0-15	35.0	773.6	32.8	193.6	0.17	SL
	15-30	36.9	773.6	32.8	193.6	0.17	SL
	30-45	37.2	713.6	12.8	273.6	0.05	SCL
Rubber	0-15	29.4	853.6	32.8	113.6	0.29	LS
	15-30	29.6	813.6	12.8	173.6	0.07	SL
	30-45	30.5	833.6	12.8	153.6	0.08	SL

MC = Moisture content, TC = Textural class, LS = Loamy sand, SL = Sandy loam, S = Sand, SLC = Sandy clay loam

Table 2. Chemical Properties of Soil of Land uses under Annual and Perennial Cropping Systems

Land uses	Depth	pH (H_20)	OM	C/N	P	Ca	Mg	K	Na	ECEC
			g kg^{-1}		mg kg^{-1}	$cmol_c$ kg^{-1}				
			Annual Cropping System							
Cassava	0-15	6.27	5.43	18.53	7.77	2.20	3.00	0.04	0.13	5.58
	15-30	5.86	4.31	16.67	6.79	0.80	2.70	0.12	0.13	3.96
	30-45	5.71	4.50	20.08	2.73	0.90	1.80	0.15	0.05	3.11
Cocoyam	0-15	6.32	5.20	12.57	10.01	4.40	9.20	2.44	0.11	16.25
	15-30	5.96	5.30	11.82	7.63	2.40	3.30	0.20	0.05	6.00
	30-45	5.92	4.56	13.23	2.73	2.30	2.80	0.05	0.12	4.47
Yam	0-15	5.80	5.43	13.69	8.54	1.90	5.00	2.34	0.05	9.39
	15-30	5.60	4.70	12.98	8.40	0.70	1.50	0.15	0.05	2.40
	30-45	5.80	4.50	13.74	5.11	0.60	1.20	0.11	0.11	2.19
			Perennial Cropping System							
Cashew	0-15	6.11	4.31	11.36	7.63	0.80	9.00	2.74	0.03	12.71
	15-30	6.22	3.80	11.02	2.73	0.60	6.50	0.54	0.10	7.29
	30-45	6.08	3.80	10.50	1.89	0.40	3.50	0.51	0.10	4.65
Oil Palm	0-15	5.81	5.43	17.50	7.77	1.60	4.60	4.57	0.01	11.00
	15-30	5.76	4.48	17.32	7.63	0.60	1.50	1.00	0.09	3.38
	30-45	5.75	4.48	11.30	5.11	0.40	1.00	0.15	0.03	1.82
Rubber	0-15	6.12	5.26	12.71	8.26	1.00	1.50	5.48	0.08	8.24
	15-30	5.87	4.70	13.63	2.73	0.30	1.30	4.47	0.04	6.30
	30-45	5.86	3.80	13.78	1.05	0.30	1.00	2.94	0.02	4.44

Table 3. Ammonium Nitrogen (mg kg^{-1}) contents with depths of Soils of varying Land uses

Land use Types	Soil Depths (cm)			
	0-15	15-30	30-45	**Mean**
Cassava	1.70	1.60	1.30	**1.53**
Cocoyam	5.00	4.20	2.00	**3.73**
Yam	1.80	1.30	1.20	**1.43**
Cashew	5.40	3.60	2.00	**3.67**
Oil Palm	5.70	4.00	2.30	**4.00**
Rubber	4.00	3.40	2.80	**3.40**
Mean	**3.93**	**3.02**	**1.93**	

LSD's $_{(0.05)}$ for:

Land use = 0.19

Soil Depth = 0.13

Land use x Soil depth = 0.33

Table 4. Simple Correlation (r) between total, organic and inorganic nitrogen forms with selected soil Properties

Soil Properties	Total N	Organic N	Ammonium N	Nitrate N
Clay	0.18	0.25	0.65	-0.60
Silt	0.30	0.28	-0.01	-0.01
pH($H_2$0)	0.14	-0.03	0.29	0.24
ECEC	-0.03	-0.16	0.57	0.50
OM	0.54	0.24	-0.05	-0.01
Available P	0.001	0.07	-0.33	-0.35

Table 5. Nitrate Nitrogen (mg kg^{-1}) contents with Depths of Soils of varying Land uses

Land uses	Soil Depths (cm)			
	0-15	15-30	30-45	**Mean**
Cassava	4.50	3.30	3.50	**3.77**
Cocoyam	11.00	9.70	3.30	**8.67**
Yam	4.70	3.90	3.60	**4.07**
Cashew	12.00	6.70	5.30	**8.00**
Oil Palm	11.20	10.00	7.20	**9.47**
Rubber	9.00	8.20	7.40	**8.20**
Mean	**8.73**	**6.97**	**5.05**	

LSD's $_{(0.05)}$:

Land use = 0.22

Soil Depth = 0.15

Land use x Soil depths = 0.38

Table 6. Organic Nitrogen (g kg^{-1}) contents with Depths of Soils of varying Land uses

Land uses	Soil Depths (cm)			
	0-15	15-30	30-45	**Mean**
Cassava	0.15	0.14	0.12	**0.14**
Cocoyam	0.23	0.19	0.15	**0.19**
Yam	0.22	0.16	0.14	**0.17**
Cashew	0.21	0.20	0.20	**0.20**
Oil Palm	0.25	0.22	0.20	**0.22**
Rubber	0.23	0.20	0.15	**0.19**
Mean	**0.22**	**0.19**	**0.16**	

LSD.s (0.05):

Land use = 0.09

Soil Depth = 0.06

Land use x Soil depths = 0.15

Table 7. Total Nitrogen (g kg^{-1}) contents with Depths of Soils of varying Land uses

Land uses	Soil Depths (cm)			
	0-15	15-30	30-45	**Mean**
Cassava	0.18	0.15	0.13	**0.16**
Cocoyam	0.23	0.19	0.15	**0.20**
Yam	0.23	0.21	0.19	**0.18**
Cashew	0.22	0.20	0.21	**0.21**
Oil Palm	0.27	0.24	0.20	**0.24**
Rubber	0.25	0.20	0.16	**0.22**
Mean	**0.22**	**0.20**	**0.17**	

LSD.s (0.05):

Land use = 0.03

Soil Depth = 0.02

Land use x Soil depths = 0.05

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