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Influence of Topography and Management Practices on Nitrogen Content of Soils Formed in Biotite-Granite Parent Material on the Jos Plateau, Nigeria.

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ABSTRACT

Nitrogen is a macro nutrient that is essential to crop growth and production. One of the major constraints to sustainable crop production on the Jos Plateau is soil fertility. The availability of nitrogen and other essential plant nutrients in the soil is a key indicator of soil fertility. The content of nitrogen in soils is affected by a number of factors such as drainage, texture and slope steepness. This study was conducted on one of the important parent materials on the Jos Plateau, biotite-granite, taking into account the influence of topography and management practices by farmers. The result showed that the nitrogen content of the soils were quite low. The surface soils had a range of 0.021-0.140% with mean of 0.065%. The slope facets had means of 0.058%, 0.042%, 0.069% and 0.103% respectively for the upper foot slope, middle foot slope, lower foot slope and depression. The higher content of nitrogen in the depression was strongly correlated (r =0.694) with organic matter. The result for the profile pits revealed that soils in the upper foot slope and depression had higher contents at the surface (0.105% and 0.140%) while the middle foot slope had the lowest. The profile pits with and without application of burnt municipal waste had 0.150% and 0.090% respectively at the surface. T-test gave a value of 0.001 for nitrogen 0.01 to 0.001 for other soil properties indicating strong differences in the means for the two treatments. Crop rotation, planting of cover crops and mixed farming were suggested as management practices that could be used to increase nitrogen content of the soils.

Key words: Nitrogen, biotite-granite, Jos Plateau, soil fertility

INTRODUCTION

It has been observed that one of the major constraints to sustainable crop production on the Jos Plateau in Nigeria is low soil fertility (Olowolafe et al, 2007). The availability of the essential macro and micro nutrients in the soils are key indicators of soil fertility. Nitrogen is regarded as an essential nutrient for crop production because of its influence on plant growth, reproduction and general health of plants. The USDA-NRCS have stated that nitrogen is the most abundant element in the atmosphere and usually the most limiting nutrient in crop production. The truth of this statement is most strongly expressed in the tropical environment. The addition of nitrogen to the soil comes via the atmosphere through rainfall, organic matter, left over from previous crops grown through N fixation and addition from inorganic fertilizer. Wetselaar et al (1981) have observed that the losses of nitrogen from the soil system are partly due to the direct or indirect result of microbial activities which in the tropical environment is, to a certain limit, accelerated by high temperatures.

The nitrogen content of soils is affected by a number of factors including soil drainage, soil texture and slope steepness which impact N transport and transformation and which can limit the availability of the nutrient to crops (USDA-NRCS). Soil texture on the Jos Plateau is predominantly sandy (Galadima, 2018) and this makes the soils susceptible to N losses through leaching as water can quickly pass through the soil system taking the nitrogen out of the root zone and beyond the reach of plants. The objective of this paper is to analyse the content of nitrogen in soils formed on biotite-granite parent materials and suggest possible management practices that will ensure the availability of the nutrient for sustainable crop production.

STUDY AREA.

The Jos Plateau lies between lat. $8^0$30′N to $10^0$30′N and long. $8^0$20′E to $9^0$30′E and has an average elevation of about 1,250m above mean sea level. It experiences the Aw climate (Koppen classification) with two distinct seasons. The raining season usually lasts between April and September while the dry season is from October to March. These two seasons are influenced by the Inter-Tropical Discontinuity (ITD) which brings the area under the influence of two very distinct air masses i.e. the tropical maritime and the tropical continental. They are characterised by warm moist and cold dry conditions respectively. Mean annual rainfall is 1,260mm with a single maxima occurring between July and August. The mean annual temperature is about 24^0C. The Jos Plateau is located in the northern Guinea savanna vegetation zone characterised by tall grasses and open woodland. Human interference has greatly affected the original vegetation (Keay, 1953). The geological makeup of the area is comprised of Precambrian basement complex rocks (including migmatites, gneiss and older granites), the Jurassic younger granites (biotite-granite) and the Tertiary and Quaternary volcanic rocks (including basalts, pumice, lava flows and ash deposits) Macleod et al (1971). Olowolafe and Dung (2000) have stated that the varied geological and topographic features of the Jos Plateau have given rise to four major soil types in the area including Inceptisols, Entisols, Alfisols and Ultisols.

MATERIALS AND METHODS

The study was conducted exclusively in areas underlain by biotite-granite (younger granites) parent material which make up about 38% of the surface of the Jos Plateau. Soils were sampled on two sites using two criteria. On the first site soils were collected based on toposequence with samples collected

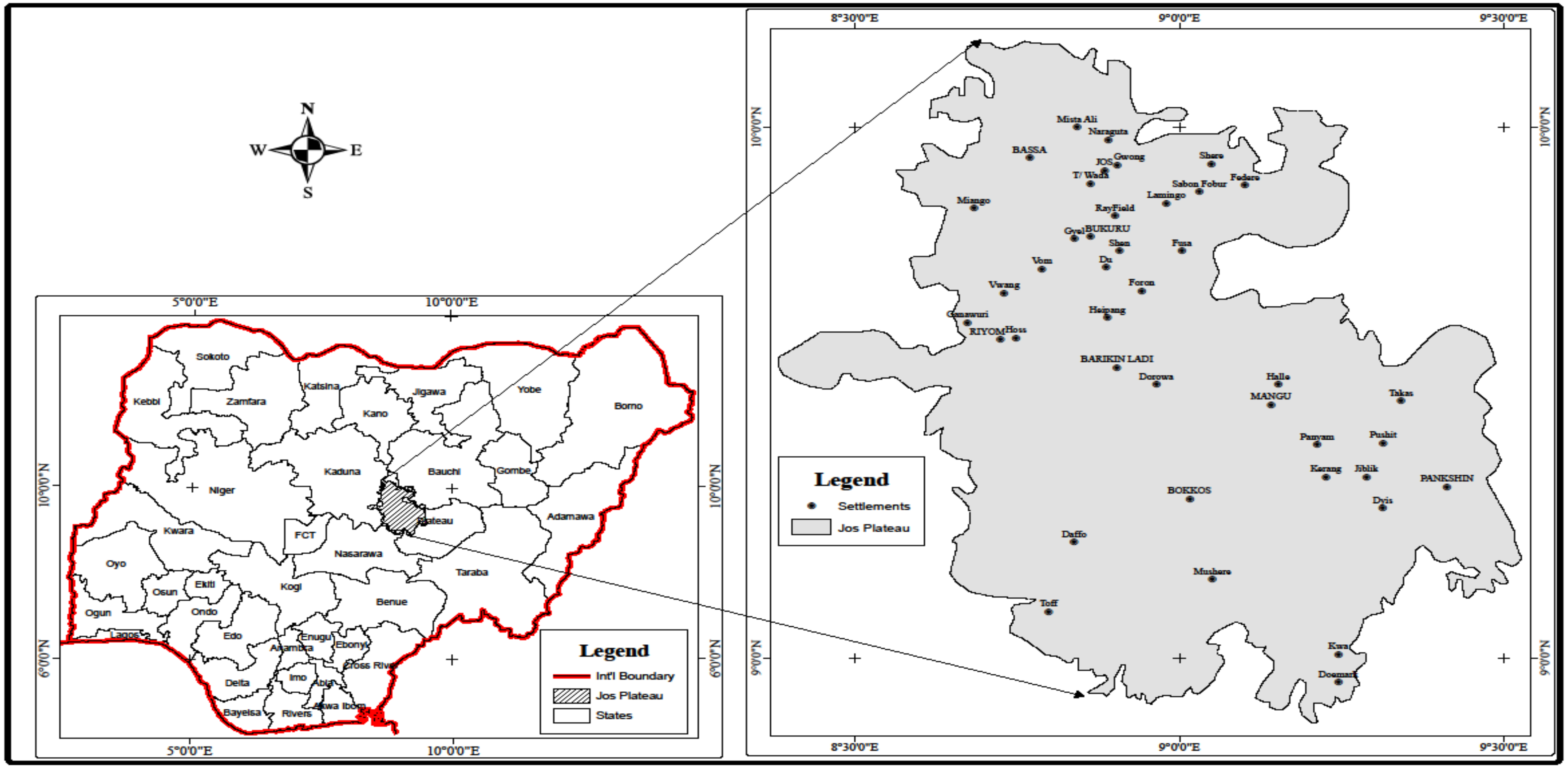

Figure 1: Jos Plateau, Nigeria

from the upper foot slope, lower foot slope and depression. On the second site a particular management practice that has been used for a long period of time was the criterion used. A total of 5 profile pits were dug to allow for an assessment of profile characteristics of the soils. Surface soil samples were also collected to show the trend in the distribution of nitrogen over the surface.

The hydrometer method was used in carrying out particle size analysis of the soil samples. This method was developed by Bouyoucos (1962). The method is based on the continuous reduction of the density of soil suspension. Measurement of pH was made on a 1:2.5 soil: water ratio using a glass electrode pH meter as described by Kalra (1995). Nitrogen was determined using the Kjeldahl method. The procedure involves digesting the sample in sulphuric acid and organic nitrogen is converted to ammonium sulphate. The solution is then made alkaline and NH_3 distilled. The evolved ammonia is trapped in boric acid and titrated with standard acid (0.01M HCl). The process recovers both organic and ammoniacal forms of nitrogen. The Walkley-Black method was used in organic carbon determination as described by Nelson and Sommers (1996). After the titration and organic matter determination, the percentage organic matter in soil was then calculated by multiplying the percentage organic carbon by 1.729. Cation exchange capacity was determined using the ammonium acetate (NH_4OAc) displacement method. Effective cation exchange capacity was obtained by summation of the exchangeable bases and exchangeable acidity while cation exchange capacity of the clay fraction was obtained by multiplying by 100 the ratio of ammonium acetate at pH 7 to percentage clay (Soil Survey Staff, 2010).

RESULTS AND DISCUSSION

The statistical data of analysis conducted on the surface soils are presented in table 1. The soils are dominated by sandy clay loam, sandy loam and loamy sand. Percentage sand for all the topographic positions ranged between 36 to 90% with mean of between 45-64.5% for the different topographic positions but the appreciable percentages of clay and silt had an ameliorating effect on the sand content. This is significant because sandy soils are known to be vulnerable to high loss of nitrogen through leaching because of their low water and nutrient holding capacities (USDA-NRCS(b)). Values of soil pH for the surface soils reveal that they ranged between 3.60-6.74 and a mean of 5.05. Mean values for the different slope positions showed that the lower foot slope with 4.73 was the most acidic while the depression with 5.71 was least acidic. Thus the soils at the surface are very strongly acidic (USDA, 1993). The generally low pH values of the soils may be attributed to the acidic nature of the parent materials from which the soils are derived as well as the leaching of basic cations out of the soil profile (Olowolafe, 2003).

The organic matter content of the soils is very important in analyzing the nitrogen content due to the fact that it is a major source of the nutrient in soils. Data in table 1 show that the organic matter content of the soils ranged between 0.45-2.93 with mean of 1.39. However, there were serious variations in the content according to slope with the middle foot slope with 0.64 having the least while the depression with 2.33 having the highest. This could be attributed to down slope movement of materials and their accumulation in the depression as well as the higher moisture content which is known to reduce the rate of decomposition of organic materials. CEC content of the soils ranged between 3.80- 14.50 cmol/kg with a mean of 7.71cmol/kg. The lower foot slope had the least content with a mean of 6.15cmol/kg while the depression had 10.90cmol/kg. The CEC content of the soils is quite low according to Holland et al (1989) who have rated soils with CEC of 5-15 cmol/kg as low.

The nitrogen content of the surface soils ranged between 0.021-0.140 with mean of 0.068%. However, the different slope facets had varied content with 0.058, 0,042, 0.069 and 0.103% for the upper, middle, lower foot slopes and the depression respectively. The higher

Table1. Effect of topographic position on the soil properties

	Topography	Min.	Max.	Mean	St.Dv.
Clay	1	8	28	15.3	6.77
	2	10	28	19	12.73
	3	10	34	24.5	8.50
	4	20	29	24.3	4.51
Silt	1	2	36	20.2	12.59
	2	10	34	22	16.97
	3	4	34	20.5	12.23
	4	24	36	30.7	6.11
Sand	1	36	90	64.5	18.67
	2	38	80	59	29.70
	3	40	86	55	18.26
	4	44	47	45	1.73
pH	1	3.60	6.74	4.88	1.12
	2	5.00	6.11	5.56	0.78
	3	4.00	5.60	4.73	0.61
	4	5.50	5.84	5.71	0.19
OM	1	0.58	2.10	1.15	0.57
	2	0.60	0.67	0.64	0.05
	3	0.45	2.92	1.40	0.86
	4	2.11	2.46	2.33	0.19
TN	1	0.030	0.105	0.058	0.033
	2	0.035	0.049	0.042	0.010
	3	0.035	0.130	0.069	0.036
	4	0.070	0.140	0.103	0.035
CEC	1	3.80	12.40	7.18	3.52
	2	6.70	11.70	9.20	3.54
	3	4.38	9.20	6.15	2.08
	4	4.40	14.50	10.90	5.64

Topography:1= Upper foot slope, 2= Middle foot slope, 3= Lower foot slope, 4= Depression

Table 2: Soil physical and chemical properties for profiles

		Particle Size distribution(%)					pH	%		cmol/kg
	Horizon	Depth	Clay	Silt	Sand	Text. Class	H_2O	OM	TN	CEC
Profile No.23 Upper Footslope Biotite-Granite										
102	Ap	0-10	14	28	58	SL	6.74	2.1	0.105	12.40
103	A2	10-30	20	34	46	L	6.11	0.6	0.049	11.70
104	Bw1	30-70	24	34	42	L	6.18	0.31	0.035	10.50
105	Bw2	70-89	24	40	36	L	5.73	0.38	0.014	9.80
106	BC	89-125	34	24	42	CL	5.33	0.84	0.042	14.40
Profile No.24 Middle Footslope Biotite-Granite										
107	Ap	0-15	10	10	80	LS	5.00	0.67	0.035	6.70
108	A2	15-27	14	12	74	SL	4.90	0.45	0.035	8.10
109	Bw1	27-61	18	16	66	SL	5.63	0.81	0.028	9.60
110	Bw2	61-90	24	14	62	SCL	5.70	0.71	0.007	8.40
111	Bw3	90+	16	18	66	SL	6.10	0.10	0.007	9.80
Profile 25:Depression Biotite-granite(Mangu Halle)										
112	Ap	0-17	14	14	72	S L	5.50	2.11	0.140	4.40
113	A2	17-33	16	28	56	S L	5.60	1.60	0.130	4.20
114	B1	33-61	20	30	50	L	5.50	1.50	0.140	5.30
115	B2	61-84	25	22	53	SCL	5.80	0.87	0.110	5.40
116	C	84+	16	18	66	S L	6.10	0.37	0.105	5.60
Profile No. 26 Gangare with application of urban waste										
117	Ap1	0-25	16	22	62	SL	5.80	4.82	0.15	28.61
118	A2	25-40	30	38	32	CL	6.60	2.48	0.12	10.82
119	Bg1	40-56	28	40	32	CL	6.10	0.33	0.04	9.30

120	B2	56+	16	18	66	SL	6.40	0.24	0.25	7.37
Profile No. 27 Gangare without application of urban waste										
121	A1	0-20	28	16	56	SCL	5.00	1.82	0.09	8.37
122	A2	20-50	26	18	56	SCL	4.60	1.39	0.05	8.72
123	Bw1	50-75	32	24	44	SCL	4.80	0.91	0.07	9.21
124	BC	75-100	30	24	46	SCL	5.00	1.05	0.07	11.52
125	C	100+	34	20	46	SCL	4.50	0.67	0.09	10.70

amount in the depression follows the same pattern with that of organic matter further stressing the importance of organic matter as a source of nitrogen in the soils. Indeed correlation analysis gave a strong and positive relationship of r = 0.694 between organic matter and nitrogen. This pattern of distribution with increase in content down slope was also reported by Weintraub et al (2015) who found that slope soils had lower total carbon and nitrogen stocks compared to relatively flat ridge soils. They attributed this to elevated N loss resulting from high rates of soil and particulate organic matter erosion. However, Raghubanshi (1992) has reported decrease in accumulation of organic carbon and nitrogen going down slope.

Profile characteristics show that soils in the depression and upper foot slope had appreciable amounts at the surface with values of 0.140 and 0.105% respectively. Nitrogen content was lowest at the middle foot slope as it was for virtually all the other soil properties. Profile distribution showed a general tendency for a decrease down the profile but the depression stands out because of the high content right down the profile. The nitrogen content of the soils can be regarded as low based on the standard given by Enwezor et al (1989) who have stated that soils with <0.15% are low. Even the soils in the depression that had the highest values were not up to this figure. The low nitrogen content of the soils can be attributed to a number of factors including the high preponderance of the sand fraction which affects both the water and nutrient holding capacities of soils, the faster rate of mineralization of organic matter in the tropical environment due to high temperatures and moisture as well as human factors including land use practices like bush burning and over gazing. The soil samples were collected on farmlands where the farmers were in the habit of annually tilling the soil as a means of weed control but this practice is known to increase the oxidation of organic matter and volatilization losses of nitrogen. Another important factor that could account for the low nitrogen content was the fact that the calculated C:N ratio for the soils

Table3. Results of t-test for soils with burnt urban waste

Soil variables	Soils with waste application		Soils without waste application		t-test
	Mean	Stdev	Mean	Stdev	
Clay(%)	13.67	1.51	20.67	3.01	0.001
pH (H_2O)	6.3	0.261	5.3	0.522	0.01
OM(%)	3.74	0.38	1.25	0.194	0.001
TN (%)	0.135	0.038	0.052	0.0098	0.001
CEC (cmol/kg)	22.14	2.7	9.03	1.09	0.001

were well below the 24:1 standard given by USDA/NRCS(2011) indicating that nitrogen is quickly mineralized in the soils.

The influence of management practices on nitrogen content was investigated by taking soil samples in an area where the farmers have been using burnt municipal wastes as fertilizer materials for a very long time. This was done at Gangare in Jos North LGA where dry season farmers have been using this method to fertilize their farms. A profile pit each was dug in an area with and without application of burnt municipal waste and the result showed that nitrogen content at the surface were 0.150 and 0.090% respectively (Table 2). Profile distribution showed a decrease down the profile for that without application while the cumulative effect of application had the highest content of 0.250% in the B2 horizon for the pit with application. Other soil properties also showed significant positive difference between the two treatments. T-test was conducted (Table 3) on the data generated and values obtained were 0.001 for nitrogen and between 0.01 and 0.001 for other soil properties indicating significant differences in the means of the two sets of data. This indicates that proper management can have positive effect on nitrogen content and soil fertility in general in the study area.

MANAGEMENT PRACTICES

Given the low levels of nitrogen in the soils studied, the need to increase the nitrogen stokes of the soils for sustainable crop production cannot be over emphasized. In view of the importance of organic matter as a source of nitrogen in the soils, any strategy to increase its content in the soil translates into higher nitrogen content. The farmers can use scientific methods of crop rotation by ensuring that leguminous crops are rotated with cereals and that in mixed cropping two cereals are not mixed on the same farm. This will allow an increase in the nitrogen content of soils over time.

Planting of cover crops has been recognized as a means for sustainable management of soil and water resources. They restore soil fertility, control weeds, avoid repeated seeding and cultivation traffic, conserve rain, reduce energy costs, improve soil physical properties and soil tilth and reduce soil erosion (Lal, 1995). It is suggested that farmers plant leguminous crops that add to the nitrogen content of the soil and may produce products that are useful to them. This can be achieved by planting any of the many varieties of local beans that are found in the different communities of the study area. Some species of forage grasses that could do well in the study area as suggested by Lal (1995) and Enwezor et al (1989) include *Andropogon gayanus* (Northern gamba), *Brachiaria decumbens* (Signal grass), *Cenchrus ciliaris*(Buffel grass), *Choris gayanus* (Rhodes grass), *Cynodon plectostachyus* (Giant star grass), *Digitaria smutsii* (Wolly finger grass), *Panicum maximum* (Guinea grass), *PennisetumPurpureum* (Elephant grass), *Setaria anceps* (Setaria) *and Sorghum almum* (Columbus grass). Some of the suitable legumes include *Cajanus cajan* (Pigeon pea), *Centrosema pubescens* (Common centro), *Gliricidia sepium* (Almond blossom), *Leuceana leucocephala* (Leucaena), *Macrotyloma uniflorum* (Horsegram bean).

Mixed farming to take advantage of animal droppings as fertilizer material and crop residues as feed for the animals is another source of organic matter and nitrogen to the soil. Mohammed-Saleem (1995) has stated that integrating animal and crop production systems is based on the premise that by-products from the two systems are used on the same farm. He further opined that the benefits of mixed farming included draught power, closed nutrient cycling, improved environmental quality, and that the use of roughages and low quality feeds contribute to overall higher output per animal per hectare. In addition, the volume of organic components that circulate through the soil and plants and animal manures will improve soil fertility and ensure long lasting carry over effects.

CONCLUSION

The nitrogen content of soils formed on biotite-granite parent materials on the Jos Plateau are low and this is capable of negatively affecting sustainable crop production in the area. However, the use of appropriate management practices can help to tackle this problem as demonstrated by the use of burnt municipal waste by the farmers. The uses of more scientific methods of crop production such as mixed farming, crop rotation and cover crops have been suggested as possible means of overcoming this challenge.

REFERENCES

Bouyocos, G.J. (1962). Hydrometer method improved for making particle size analysis Of soils. Agron. J. 54,464-465.

Enwezor, W. O., Udo, E. J., Ayotade, K. A., Adepetu, J. A. & Chude, V. O. (1989). A review of soil and fertilizer use research in Nigeria. Volume 4: Middle-Belt Zone. In: Literature review on soil fertility investigations in Nigeria (in five volumes). *Federal Ministry of Agriculture and Natural Resources, Lagos.*241-279.

Galadima, J.S. (2018). Analysis of organic matter content of soils on the Jos Plateau, Nigeria. Unpublished PhD. Thesis in the Department of Geography and Planning, University of Jos.

Holland, M. D., Allen, R. K. G., Barton, D. & Murphy, S. T. (1989). Land evaluation and Agricultural recommendations. Cross River National Park, Oban Division. Prepared by *ODNRI in collaboration with WWF.*

Kalra, Y.P. (1995). Determination of pH of soils by different methods: collaborative study. *Journal of the Association Off. Analytical Chemistry International* 78(2):310-321.

Keay, R. W .J. (1953). *An outline of Nigerian vegetation*. Government Printer, Nigeria.

Lal, R. (1995). *Sustainable Management of soil resources in the Humid Tropics*. United Nations University Press, Tokyo. 145.

MacLeod, W. N., Turner, D. C. & Wright, E. P. (1971). *The Geological Survey of the Jos Plateau*. Geological Survey Bulletin 32.

Mohammed-Saleem, M. K. (1995). Mixed farming systems in sub-Saharan Africa. In: Wilson, R. T, Ehui, S. & Mack S (eds). 1995. *Livestock Development Strategies for Low Income Countries.* Proceedings of the Joint FAO/ILRI Roundtable on Livestock Development Strategies for Low Income Countries, ILRI, Addis Ababa, Ethiopia, 27 February-02 March 1995. Food and Agriculture Organization /International Livestock Research Institute, Nairobi, Kenya.

Nelson, D, W & Sommers, L. E. (1996). Total Carbon, Organic Carbon, and Organic Matter. p. 961-1010. In: D. L. Sparks (ed.) *Method of Soil Analysis Part 3. Chemical Methods*. Soil Science Soceity of America Book Ser.5 SSSA and ASA Madison, Wis.

Olowolafe, E. A. (2003). Soil parent materials and soil properties in two separate catchment Areas on the Jos Plateau, Nigeria. Kluwer Academic Publishers. *GeoJournal* 56,201-212.

Olowolafe, E. A. and J. E. Dung, 2000. Soils derived from biotite-granites on the Jos Plateau, Nigeria: their nutrient status and management for sustainable agriculture. *Resources, conservation and recycling* 29,231-244.

Olowolafe, E. A., Osagbemi, M. O., Oche, C. Y., & Galadima, J. S. (2007). Soil Fertility Management Aspect of Urban Agriculture in Jos Area, Nigeria. Proceedings of the 49th Annual Conference of the Association Nigerian Geographers (ANG).285-293.

Raghubanshi, A.S. (1992). Effect of topography on selected soil properties and nitrogen mineralization in a dry tropical forest. *Soil Biology and Biochemistry*. 24:2, Feb. 1992. Pg. 145-150. Elsevier.

USDA/NRCS (2011). *Carbon to Nitrogen Ratios in cropping Systems*. Soils.usda.gov/sqi.

USDA/NRCS(a). Soil Organic Matter: Soil quality Kit-Guides for Educators. Soils.usda.gov/sqi.

USDA Soil Survey Staff (1999). Soil Taxonomy: *Basic system of soil classification for making and interpreting soil surveys*, 2nd ed. Agricultural handbook no. 436. Soil Management Support services. Technical monograph no. 19, 1999.

USDA-NRCS(b):Soil nitrogen- Soil quality Kit . Guides for Educators https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053274.pdf retrieved on 21/7/2018

Weintraub, S.R., Taylor, P.G., Porder, S. Cleveland, C. C., Asner, G.P. and Townsend, A. R. (2015).Topographic controls on soil nitrogen availability in a lowland tropical forest. Ecology 96: 6 June 2015 pgs 1561-1574. Ecological Society of America (ESA)

Wetse1aar,R., Denmead, O.T. and Galbally,I.E.1981Environmentalprob-lems associated with terrestra1nitrogen transformations in agrosystems In the wet monsoonal tropics. In: Nitrogen Cycling in South-East Asian Wet Monsoonal Ecosystems.Wetse1aar,R., Simpson, J. R. And Rosswali, T.(eds.),Australian Academy of Science, Canberra, pp.157-164.