UMYU Scientifica, Vol. 1 NO. 2, December 2022, Pp 53 – 61
https://doi.org/10.56919/usci.1222.007
ISSN: 2955 – 1145 (print); 2955 – 1153 (online)
A periodical of the Faculty of Natural and Applied Sciences, UMYU, Katsina

ORIGINAL RESEARCH ARTICLE

Assessment of Chemical Properties of Soils Derived from Basement Complex Rocks of the Jos Plateau

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ABSTRACT
Information on the chemical characteristics of soils is required in the sustainable the management of soil fertility and productivity. The objective of this study was to determine chemical characteristics of basement complex derived soils of the Jos Plateau. Soil study followed the approach in the Soil Survey manual and began by identification of three geologic units: granite gneiss, biotite granite and migmatite. Furthermore, eighteen soil profile pits were dug in each geologic units and eighty-four samples were taken from genetic horizons. Standard laboratory procedures were used to analyze soil samples for pH, organic matter, nitrogen and phosphorus. Results showed that organic matter contents in the soils were generally low and seemed to influence the distribution of nitrogen in the soils. Consequently, contents of total nitrogen were low. Mean contents of pH in the A horizon were 5.15, 4.64 and 5.58 respectively for soils derived from granite gneiss, biotite granite and migmatite. Low pH levels are linked to the basic cations draining out of the profile and the acidic character of the basement complex rocks from which the soils were formed. Soil reaction in most cases indicated that soils had a net negative charge. Available P contents in the magmatic soils was significantly higher than those of other geologic units. Effects of granite gneiss, biotite granite and migmatite parent materials on variation in soil chemical properties were more noticeable for soil reaction and available P contents.

ARTICLE HISTORY
Received :September 23, 2022
Accepted :December 9, 2022
Published:December 30, 2022

KEYWORDS
biotite granite, granite gneiss, migmatite.

INTRODUCTION
Data on soil chemical properties gives an insight into status of soil development and fertility. Results from various research indicates that soil reaction in soils derived from basement complex rocks range from acidic to neutral. This was observed in the rainforest area of southwest Nigeria as reported by Fagbami and Ajayi (1990), Fagbami and Shogunle (1995) and Ande (2010). A study of soils on slope positions in the tropical rain forest area of Nigeria by Atofarati *et al.* (2012) indicated that the soils were extremely to moderately acid in reaction. Further studies of the topsoils revealed a range of 1.78 to 2.86 cmol/kg in exchangeable acidity content. Exchangeable acidity was observed to decrease with depth in the profiles studied. In contrast Eshett *et al*, (1990) observed that the soils were strongly acidic with pH ranging from 4.3 – 5.3 for some soils on crest, middle and valley bottom slope positions in southeastern Nigeria. Furthermore, it was stated that this is typical of the southeast because of the parent rocks' acidity and the strong leaching effects brought on by the region's frequent heavy rains.

Some studies have also been carried out in the northern area of Nigeria. Upland top soils in Bauchi area of Nigeria were noted by Mutapha and Fagam (2007) to have a pH range of 5.22 – 6.44 (mean: 5.98). According to Oyinlola and Chude (2010), who studied basement complex rock derived Alfisols in the northern savanna region of Nigeria, the soils are moderately acidic, with a pH range of 4.6 to 6.8. (mean: 5.5). Owonubi and Olowolafe (2011) revealed

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How to cite: Owonubi Ayodele (2022). Assessment of Chemical Properties of Soils Derived from Basement Complex Rocks of the Jos Plateau UMYU Scientifica, 1(1), 53 – 61.
https://doi.org/10.56919/usci.1222.007

that the soils exhibited a modest total potential acidity for basement complex soils in the northern guinea savanna region. It was further observed that the contribution of exchangeable acidity to total potential acidity was very low (varying from 1.2 to 9.3%) while the contribution of pH dependent acidity was high (> 90%). Enwezor *et al.* (1990d) reported low leaching and a pH range of 5.5 to 7.0 for Alfisols derived from basement rocks in northwestern Nigeria

Organic matter levels have been a major factor affecting the fertility of Nigerian soils. For soils in southwestern Nigeria, these generally ranges from low to high across the soil profile (Atofarati *et al*., 2012; Fagbami and Shogunle, 1995a; Ande (2010). On the other hand, Enwezor *et al*. (1990d) noted that the organic matter content of basement derived soil of northwestern Nigeria is very low with the value being less than 2%. Mutapha and Fagam (2007) reported a range of 0.36 – 1.4% for upland topsoil of Bauchi state. According to Oyinlola and Chude's (2010) investigation of basement complex rock derived Alfisols in the northern savanna region of Nigeria, the soils were low to medium fertile and had organic carbon concentrations that ranged from 0.26 to 1.34%. Eshett *et al.* (1990) studied some soils on 3 slope positions (crest, middle and valley bottom) in southeastern Nigeria; and observed that the soils were low in organic matter.

Soil nitrogen also plays a major role in the fertility of some basement complex soils of Nigeria. Fagbami and Ajayi (1990) observed low levels of nitrogen in the soils for rain forest soils while Atofarati *et al*. (2012) documented a range of 0.06 to 0.23% in, nitrogen content of the topsoils on slope positions in the rain forest area. Nitrogen content was observed to decrease with depth in the profiles studied. Eshett *et al*. (1990) also noted low nitrogen levels for hillslope soils in southeastern Nigeria. In an investigation of basement complex rock derived Alfisols in the northern savanna area of Nigeria, Oyinlola and Chude (2010) reported that the total nitrogen contents of the soils are low with a range of 0.4 – 1.4g/kg. Enwezor *et al.* (1990d) also noted that nitrogen contents are generally low and never exceeding 0.1% for basement rock derived Alfisols in northwestern Nigeria. Further investigation by Enwezor *et al*. (1990c) in the Nigerian middle belt area indicated that basement complex derived soils of the Jos Plateau are moderately to strongly acidic while those of the Kaduna plains are slightly acid to neutral in reaction. Soils of the Jemaa Platform were noted to be generally moderately acidic.

Another major plant nutrient in the soil is Phosphorus and plays a major role in pedogenesis. Fagbami and Ajayi (1990) observed moderate to high values of phosphorus with a range of 7.1 to 76.4 μg/g in valley bottom soils of the rainforest zone. However, Atofarati *et al*. (2012) documented a range of 1.52 to 5.71g/kg in available phosphorus content of the topsoil for the same zone. Available phosphorus was observed to decrease with depth in the profiles studied. For northern savanna area, basement complex rock derived Alfisols Oyinlola and Chude, (2010) reported that available phosphorus contents fell within the low to medium fertility classes with a range of 3.9 – 19mg/kg. Eshett *et al*. (1990) studied some soils oof southeastern Nigeria; and observed that the soils were low in available phosphorus.

The objective was to determine chemical characteristics of basement complex derived soils of the Jos Plateau. The information obtained from this study would complement existing knowledge of the Nigerian basement complex derived soils.

MATERIALS AND METHODS

Field Survey

The land systems map of the Jos Plateau at a scale of 1: 250, 000 (Directorate of Overseas surveys, 1977) was used to identify three parent material: granite gneiss, biotite granite and migmatite within the basement complex area of the Jos Plateau. These three parent materials made up the only focus of the study (Figure 1). In each of these geologic units, sampling points were thus distributed at random. Consequently, 19, 35 and 30 soil samples were obtained from granite gneiss, biotite granite and migmatite geologic units respectively. Following the procedures in the Soil Survey Manual, the profiles were described and soil samples from genetic strata were taken (Soil Survey Division Staff, 1993).

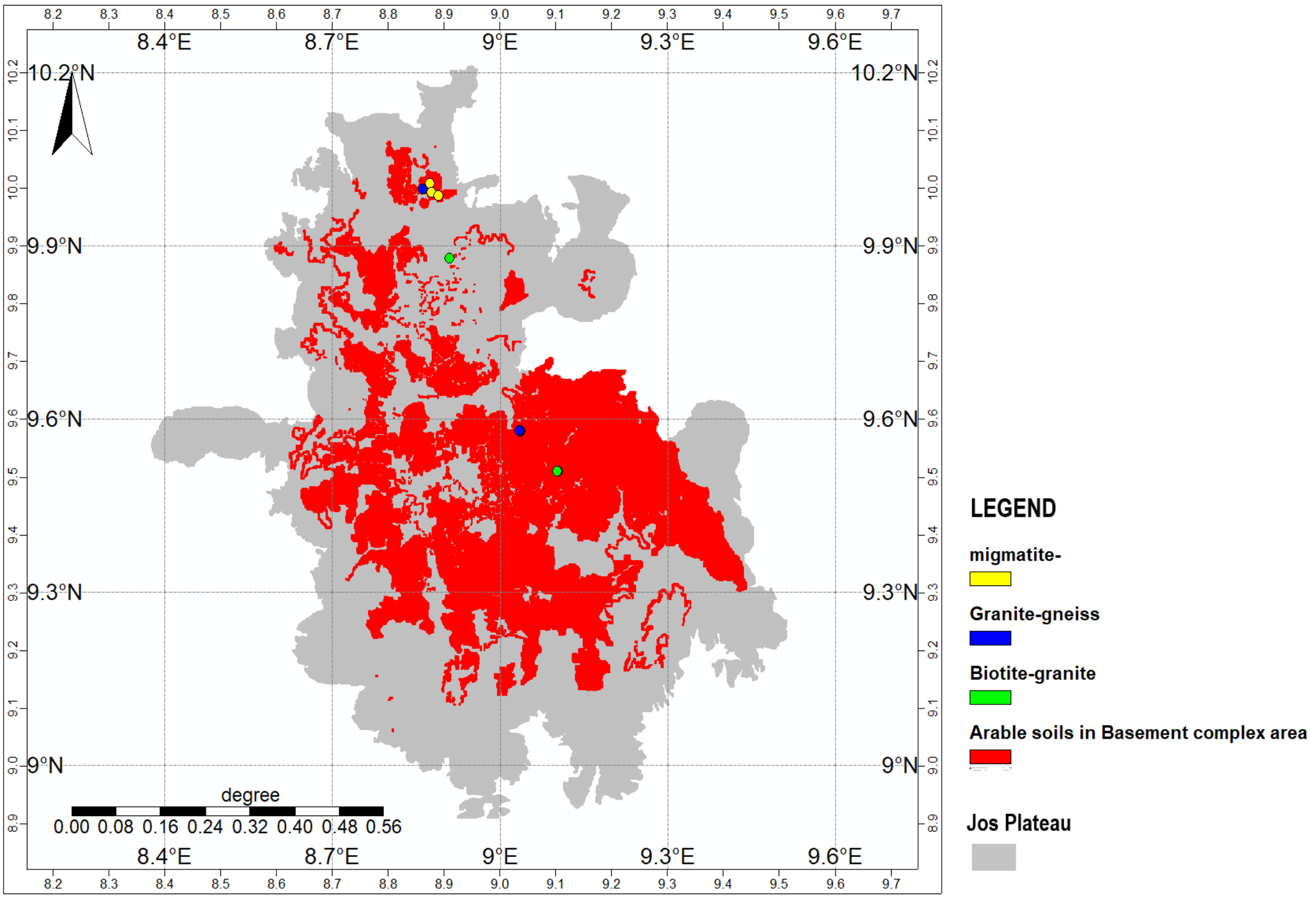

Figure 1: Sampling areas in arable soils of basement complex areas of the Jos Plateau

Laboratory Analysis and Statistical Analysis

Laboratory air drying, porcelain pestle and mortar crushing, and sieving to remove particles larger than 2 mm (gravel and other coarse pieces) were all done on soil samples. Then soil pH was determined in both distilled water and 0.01M $CaCl_2$ solution at a 1:2.5 soil/water or solution ratio as described by McLean (1982). Delta pH (dpH) values [pH ($CaCl_2$) – pH (H_2O)] were calculated following the procedure of Uehara and Gilman (1981). The Walkley-Black dichromate wet oxidation method, as described by Nelson and Sommers (1982), was used to measure organic matter. Sulphuric acid concentrate was utilized as a catalyst to start the reaction. The micro Kjeldahl technique of nitrogen determination entails wet digestion of a sample to transform organic nitrogen into NH_4^+-N before calculating the nitrogen level. Additionally, the amount of available phosphorus was estimated using the Bray-1 extraction method in accordance with the process outlined by International Institute of tropical Agriculture (IITA, 1979).

Statistical Analysis

Descriptive statistics was performed on soil data with respect to geologic units. The variation of soil data among geologic units in the basement complex area was compared using the one-way analysis of variance at a probability value of 0.05%.

RESULTS AND DISCUSSION

Soil Reaction and Acidity

Soil pH measured in water and 0.01M calcium chloride is presented in Table 1. The soil pH values did not show much variation with depth. Soil pH measured in water was in most cases higher than that measured in calcium chloride

Table 1: Selected chemical properties in soils derived from granite gneiss

SP	Profile	Horizon	Depth*	pH_a	pH_b	ΔpH	OM	TN	AP
Crest	1	A	0-9	5.03	4.36	-0.67	1.70	0.077	5.25
Upper foot slope	2	A	0-12	5.00	5.56	0.56	1.05	0.091	4.73
		B	12-30	5.50	4.22	-1.28	0.72	0.056	3.50
		BC	>30	5.73	4.11	-1.62	0.42	0.035	2.45
Middle foot slope	3	A1	0-7	5.24	4.56	-0.68	2.22	0.091	4.90
		A2	7-20	5.58	4.58	-1.00	1.53	0.035	3.50
		BW1	20-40	5.94	4.64	-1.30	0.83	0.035	3.33
		BW2	40-57	6.64	4.58	-2.06	0.62	0.021	2.98
		BW3	57-72	6.14	4.63	-1.51	0.50	0.028	2.28
		BW4	72-107	6.08	4.70	-1.38	0.21	0.007	2.45
		BC	>107	6.07	4.80	-1.27	0.17	0.007	2.05
Middle foot slope	4	Ap1	0-12	6.90	6.50	-0.40	0.95	0.053	1.75
		A2	12-23	6.90	6.30	-0.60	0.84	0.035	24.50
		Bg1	23-45	6.20	4.50	-1.70	0.84	0.245	4.75
		Bg2	45-135	5.30	4.30	-1.00	0.22	0.035	1.75
		Bgc3	135-200	5.30	4.70	-0.60	0.19	0.035	1.75
Toe slope	5	Ap	0-39	6.40	5.80	-0.60	0.65	0.18	4.20
		B1	39-64	5.80	5.00	-0.80	1.07	0.28	2.80
		B2	64-105	6.00	5.20	-0.80	0.67	0.07	2.28

Note: (1) SP = slope position and or landform, OM = organic matter (%), TN = total nitrogen (%), AP = available phosphorus (mg/kg)
(2) The major deleanated rock types on the basement complex areas at scale of at least
1: 250000 are granite gneiss, biotite granite and migmatite

According to McLean (1982), measuring pH in 0.01M CaCl2 provides a good approximation of what would occur in the field and is also independent of dilution over a broad range. Hence pH (CaCl2) was rated based on guidelines in the Soil Survey Division Staff (1993). Mean contents of pH (CaCl2) in the A horizon were 5.15 (± 0.82), 4.64 (± 0.51) and 5.58 (± 0.16) respectively for soils derived from granite gneiss, biotite granite and migmatite. Soil pH over migmatite and granite gneiss was significantly higher ($P<0.05$) than that over biotite granite. The 95% confidence interval for mean pH in the soils generally ranged from 4.32 to 5.73 indicating that the A horizons are extremely to moderately acid in reaction. The coarse texture of biotite granitic soils could be responsible for the significantly lower pH values observed.

Mean soil pH in the B horizons were 4.61 (± 0.31), 4.45 (± 0.57) and 5.51 (± 0.18) respectively for soils derived from granite gneiss, biotite granite and migmatite. Soil pH in the magmatic soils were significantly higher ($P<0.05$) than those of the other geologic units. The 95% confidence interval for mean pH in the soils generally ranged from 4.18 to 5.63 implying that the B horizons are extremely to moderately acid in reaction.

The acidic character of the basement complex rocks from which the soils were formed and the leaching of basic cations out of the profile are responsible for the low pH values (Olowolafe, 2003; Fasina and Adeyanju, 2006). Delta pH (ΔpH) values for B horizon in most cases indicated that soils have a net negative charge and consist of a mixture of variable and permanent charge minerals.

Organic Matter

Although A-horizon contents are larger than those of the B-horizons, organic matter is often low (2.0%) in the soils over granite gneiss, biotite granite, and migmatite (Table 9). The 95% confidence interval for mean organic matter generally ranged from 0.79 to 2.55% and 0.35 to 1.31 in the A and B horizons respectively.

Table 2: Selected chemical properties in soils derived from biotite granite

SP	Profile	Horizon	Depth*	pH_a	pH_b	ΔpH	OM	TN	AP
Upper foot slope	6	Ap	0-10	6.74	5.40	-1.34	2.10	0.105	2.45
		A2	10-30	6.11	5.20	-0.91	0.60	0.049	2.80
		Bw1	30-70	6.18	5.05	-1.13	0.31	0.035	1.98
		Bw2	70-89	5.73	5.00	-0.73	0.38	0.014	2.10
		BC	89-125	5.33	4.90	-0.43	0.84	0.042	1.61
Middle foot slope	7	Ap	0-15	5.00	4.53	-0.47	0.67	0.035	4.90
		A2	15-27	4.90	4.50	-0.40	0.45	0.035	3.15
		Bw1	27-61	5.63	4.61	-1.02	0.81	0.028	2.98
		Bw2	61-90	5.70	4.68	-1.02	0.71	0.007	2.98
		Bw3	>90	6.10	4.82	-1.28	0.10	0.007	2.80
Bottom slope	8	A1	0-30	5.70	4.80	-0.90	0.84	0.053	14.00
		Bw1	30-72	5.00	4.80	-0.20	1.87	0.123	15.80
		Bw2	72-93	5.30	4.10	-1.20	0.81	0.035	12.30
		Bw3	>93	5.00	4.00	-1.00	0.65	0.035	13.13
Summit	9	A1	0-20	5.00	3.80	-1.20	1.01	0.088	14.88
		A2	20-50	4.80	3.70	-1.10	1.39	0.053	10.50
		B	50-75	4.80	3.70	-1.10	0.91	0.070	3.88
		CB	75-100	5.00	3.80	-1.20	1.05	0.070	1.75
		C	>100	4.50	3.80	-0.70	0.67	0.088	3.50
Toe slope	10	Ap	0-33	5.5	4.4	-1.10	2.10	0.14	2.98
		B	33-84	5.5	4.3	-1.20	1.50	0.14	1.58
		C	84+	6.1	5.6	-1.50	0.37	0.11	2.28
Summit	11	A	0-20	4.00	3.90	-0.10	2.00	0.09	4.01
		AB	20-39	3.90	3.50	-0.40	1.57	0.06	2.52
		Bw1	39-74	4.60	3.60	-1.00	1.32	0.05	2.13
		Bw2	74-105	4.90	4.30	-0.60	0.65	0.04	1.51
		Bw3	105-125	5.60	4.10	-1.50	0.43	0.03	1.82
		BC	125-155	5.90	4.30	-1.60	0.05	0.02	1.54
		C	155-195	5.10	4.40	-0.70	0.05	0.02	2.10
Middle slope	12	A1	0-12	5.6	4.7	-0.9	1.37	0.11	7.58
		A2	12-23	5.5	4.2	-1.3	0.94	0.07	1.43
		Bt1	23-32	5.4	4.2	-1.2	0.79	0.07	1.88
		Bt2	32-68	5.4	4.4	-1.0	0.65	0.07	0.42
		Bt3	68-140	5.5	4.5	-1.0	0.15	0.02	0.97
		BC	140-200	5.3	4.1	-1.2	0.17	0.02	0.39

Note: (1) SP = slope position and or landform, OM = organic matter (%), TN = total nitrogen (%), AP = available phosphorus (mg/kg), (2) The major deleanated rock types on the basement complex areas at scale of at least
1: 250000 are granite gneiss, biotite granite and migmatite

Table 3: Selected chemical properties in soils derived from migmatite

SP	Profile	Horizon	Depth*	pH_a	pH_b	ΔpH	OM	TN	AP
Upper foot slope	13	Ap	0-7	6.60	5.80	-0.80	2.22	0.105	23.1
		Aw	7-38	6.50	5.70	-0.80	1.94	0.119	8.40
		B1	38-65	6.80	5.50	-1.30	0.10	0.077	3.68
		Bt2	65-81	6.70	5.90	-0.80	0.95	0.042	2.80
Lower foot slope	14	Aw1	0-21	6.80	5.60	-1.20	2.17	0.035	3.50
		Bt1	21-57	6.60	5.40	-1.20	2.39	0.098	4.38
		Bt2	57-73	6.40	5.30	-1.10	1.39	0.098	3.50
Alluvial terrace	15	Ap1	0-17	6.20	5.70	-0.50	2.49	0.158	28.00
		A2	17-34	6.60	5.70	-0.90	1.50	0.070	3.50
		Bwt1	34-55	6.50	5.40	-1.10	1.65	0.105	14.00
		Bwt2	55-82	6.30	5.40	-0.90	1.07	0.070	3.50
		BC	82-105	6.40	5.40	-1.00	0.65	0.053	3.50
		C1	105-130	6.40	5.60	-0.80	0.43	0.053	7.00
		C2	130-200	6.30	5.70	-0.60	0.07	0.035	5.30
Terrace	16	A1	0-20	5.60	5.30	-0.30	2.10	0.088	12.30
		A2	20-45	6.20	5.40	-0.80	2.91	0.105	10.50
		Bgw1	45-90	5.60	5.30	-0.30	0.88	0.070	3.50
		Bg2	90-125	5.80	5.50	-0.30	0.74	0.035	1.80
		BC	125-160	6.20	5.70	-0.50	0.07	0.035	7.00
Bottom slope	17	Ac1	0-10	4.20	3.80	-0.40	2.73	0.132	0.90
		Ac2	10-28	4.40	4.00	-0.40	2.55	0.124	0.90
		Bcv1	28-39	4.50	4.10	-0.40	2.51	0.122	1.34
		Btcv2	39-70	4.50	4.10	-0.40	2.47	0.120	0.90
		Btcv3	70-138	4.40	4.00	-0.40	2.15	0.104	0.90
		Bcv4	138-180	5.20	4.70	-0.50	2.27	0.110	0.00
Bottom slope	18	Ac1	0-14	5.30	4.80	-0.50	2.19	0.106	0.90
		Ac2	14-25	5.20	4.90	-0.30	2.27	0.110	2.69
		Bcv1	25-75	5.10	4.80	-0.30	1.51	0.073	1.80
		Btcv2	75-102	4.80	4.30	-0.50	0.67	0.032	0.90
		Btcv3	102-165	4.80	4.40	-0.40	1.89	0.092	0.90

Note: (1) SP = slope position and or landform, OM = organic matter (%), TN = total nitrogen (%), AP = available phosphorus (mg/kg)
(2) The major deleanated rock types on the basement complex areas at scale of at least 1: 250000 are granite gneiss, biotite granite and migmatite

These low contents are similar to that documented by Okusami *et al*. (1997), Owonubi (2008) and Aki *et al*. (2014) for some basement complex soils in Nigeria; and could be attributed to land use practices that encourages destruction of natural vegetation, unsustainable farming practices and warm tropical climate that encourages oxidation of organic matter (Brady and Weil, 1999). Okusami *et al*. (1997) noted for some basement complex soils that organic carbon followed a systematic decrease with depth. Similarly, a decreasing trend in organic matter distribution with depth was observed in the soils over the study area. This trend of organic matter distribution is most likely as a result of higher content of decomposed organic substances in the topmost mineral horizons. Brady and Weil (1999) also noted similar distribution of organic matter with soil depth in some Alfisols.

Total Nitrogen

The distributions of Total N in the soils seem to follow similar trends with that of organic matter. Generally speaking, total N in the soils over granite gneiss, biotite granite, and migmatite is low following the ratings of Enwezor et al, (1989), albeit A-horizon concentrations are higher than those of the B-horizons. The 95% confidence interval for Total N generally ranged from 0.04 to 0.13% and nil to 0.13% in the A and B horizons respectively. These implies that the fertility status of the soils are very low and appropriate management strategies are imperative for sustainable crop production on theses soils.

Available Phosphorus (P)

Available P contents in the magmatic soils was significantly higher ($P < 0.05$) than those of other geologic units. Both biotite granite and granite gneiss have statistically identical distributions of available P ($P > 0.05$). The available P in the A-horizon was distributed in the following order: granite gneiss (mean: 6.77 mg/kg; ± 6.41) > granite migmatite (mean: 9.58 mg/kg; ± 10.90) > biotite granite (mean: 24.59 mg/kg; ± 23.42). The mean content of available P over migmatite and biotite granite is not only unusually high for basement complex soils in the Northern guinea savanna of Nigeria, but their corresponding high standard deviations indicate that:

(1) Distribution of available P primarily in the Ap-horizon is erratic;
(2) Anthropogenic processes probably involving additions of external P sources to the soils for farming processes may be responsible for the observed trend in P distribution.

A-horizons over granite typically have low available P levels, which are similar to those seen in some basement complex soils in Nigeria's northern guinea savanna (Ezenwa and Esu, 1999; Owonubi, 2008). Distribution of available phosphorus showed a decreasing trend with depth. This trend in Available P is common with tropical basement complex soils. Available P has been noted to be higher in the surface soils due to higher content of organic matter content; and lower in subsurface soils due to low organic matter content and associated P fixation tendencies of clay (kaolinite, Fe and Al oxides) which is higher in the sub soil (Brady and Weil, 1999).

CONCLUSION

Soils over basement complex rocks of the Jos Plateau low pH values, organic matter, nitrogen, and available phosphorus contents. Furthermore, not much significant variation exist among sub units within the basement complex area with respect to granite gneiss, biotite granite and migmatite.

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