EVALUATION OF PHYSICOCHEMICAL PROPERTIES IN FOREST SURFACE SOILS OF KOGI STATE, NIGERIA

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Abstract: Evaluating the quality of soils is paramount for the maintenance of optimum growth conditions needed by plants. A field study was conducted to evaluate the physicochemical properties of the forest surface soils of Kogi State with the aim of establishing the fertility status of the forest. Forty surface soil samples were collected with soil auger at the depth of 0–20 cm from the study area. Standard analytical methods were employed to determine the physicochemical properties. The results showed that sand, silt and clay contents ranged from 51.80 to 94.00%, 3.50 to 31.00% and 2.00 to 22.60%, respectively. Texturally, the soils are mainly sandy loam and loamy sand textured with sand dominating the particle fractions of the soil. Soils were moderately acidic with mean pH value 5.52 ranged from 4.46 - 6.84. Electrical conductivity mean value was 0.237 dSm^{-1} which ranged from 0.036 to 0.574 dSm^{-1} indicating non-saline nature of the soils, suitable for plants growth and soil microbial processes. The soils were non- calcareous in nature and having mean $CaCO_3$ content of 1.03% (ranged from 0.08 to 2.00%). The mean of soil organic matter was 8.85 % (ranged from 3.19 to 13.35%) indicating high. Similarly, the mean cation exchange capacity was 15.02 $cmolckg^{-1}$ (ranged 12.20 to 18.60 $cmolckg^{-1}$) indicating moderate ability to retain nutrients. Finally, pH showed strong positive correlation with SOM, CEC and $CaCO_3$ content while soil EC showed strong negative correlation with pH, SOM and calcium $CaCO_3$ content. From this study, it was ascertained that these forest surface soils are considered to be quality due to non-saline, non-calcareous in nature and proven to contain significant quantities of SOM and CEC. Also, the soils were predominantly sandy loam and loamy sand and possess suitable pH for normal forest ecosystems.

Keywords: Ecosystems, forest, soil quality, surface soil, physicochemical properties

Introduction

Soils are the naturally occurring physical materials covering of the earth's surface and a mixture of organic matter, minerals, gases, liquids and organisms that together support life. It serves as a natural medium for plants growth (Osuocha *et al*., 2016). Soil, as an integral element of the natural environment, is a non-renewable resource (Massas *et al*., 2013). According to Decock *et al*. (2015), soil is a key component of the earth system as it controls the geochemical, biological, erosional and hydrological cycles and offers services, goods and resources for human kind. To Keesstra *et al*. (2016), soils play an important role in global food security, water security, biofuel security and human health. Soil is a significant determinant of the economic status of nations. Soil ecosystem services fulfils human needs (Robinson *et al*., 2012), assigning economic value to things that contribute to human well-being.

Based on this fact, soil quality has received great attention in recent years (Sinha *et al*., 2014). Specifically, Khormali *et al.* (2009) refers to soil quality as a concept that includes soil physical, chemical and biological factors and it is used as a framework for the evaluation of soil quality. The quality of soils does not depend on its ability to supply adequate nutrients alone but the nutrients must be in the right proportion as needed by plants (Ayeni and Adeleye, 2011). In addition, high quality soils not only produce better food and fibre, but also help to establish natural ecosystems and enhance air and water quality (Griffiths *et al*., 2010). The quality of growth and reproduction of soils cannot be understood without the knowledge of its soil nutrient. The soil and vegetation have a complex interrelation, because they develop together over a long period of time, the selective absorption of nutrient elements by different tree species and their capacity to return them to the soil brings about changes in soil properties (Sharma *et al*., 2010).

The nutrients strength of a soil to maintain and support the plant growth generally depends on its parent materials. Researchers have reported that the nature of parent material has been found to influence development and characteristics of soils (Umeri *et al*., 2017). The estimation of soil available nutrient contents in a complex heterogeneous system is of a great pedological as well as ecological importance (Olojugba and Fatubarin, 2015). Soil nutrients play a central role in transport and reaction of water, solutes and gases in soils. Their knowledge is very important in understanding soil behaviour to applied stresses, transport phenomena in soils; hence for soil conservation and planning of appropriate agricultural practices (Olorunfemi *et al*., 2018). A good knowledge of the variations of soil physical and chemical properties and their interactions as it relates to micronutrient status is essential for good land evaluation which is a pre-requisite for sound land use planning (Lawal *et al*., 2013). However, the physical and chemical properties of the soils play an essential role in controlling their fertility status (Ibrahim *et al*., 2010).

Physicochemical properties of soil are complex, often non-linearly related and spatially and temporally dynamic (Rakesh *et al*., 2012). Although there have been many studies on soil physicochemical properties of soil (Tukura *et al*., 2013), there has not been any information on the physical and chemical properties of forest soils in Kogi State, Nigeria. For this reason, this research was aimed to evaluate the physiochemical properties of forest surface soils in Kogi state of Nigeria. This requires management intervention to maintain the overall biodiversity, and to improve productivity and sustainability of the existing forests. This however pointed out the need to evaluate and document the physiochemical properties of forest for proper management planning.

Materials and Methods

Description of the study area

This study was conducted in forest vegetative zone of Kogi State, Nigeria. The capital of Kogi State is Lokoja which is located on the confluence of Rivers Niger and Benue lies on Latitude 6° 44' North and Longitude 7° 44' East. Going by the present composition of the state, Kogi State is quintessentially Nigeria, with three dominant ethnic groups namely; Igala, Ebira and Okun (Yoruba) and several minorities (Omotola, 2008). Kogi state has a total land area of 28,313.53 square kilometres and on the basis of the 1991 Nigerian national population census, the total population of Kogi state was 2,141,756 (Ali *et al*., 2012).

Kogi state just as many other states in Nigeria is blessed with natural resources. It has expensive fertile land for agriculture all over the state, coal at Okobo, Ankpa, huge deposits of iron ore at Ajaokuta and limestone at Obajana. The climate of the Kogi state is a tropical climate with two distinct seasons [rainy season (March – October) and dry season (November – March)]. The rainfall regime shows double maxima which is separated by a comparatively low rainfall period (dry period) in August called August Break. The mean annual rainfall ranges from 1,560 mm at Kabba in West to 1,808mm at Anyigba in the East. Average monthly temperature varies from 17 to 36.2^{o}C. The temperature shows some variation throughout the years. The state is known for cultivation of arable crops such as yam, cassava, maize, groundnut, cowpea etc (Omotola, 2008).

Sample collection and preparation

A total of 40 composite soil samples were collected from forest vegetative zone within villages of East, Central and West of Kogi State and used for this study. These forests are uncultivated and comprise of shrubs, woodlands and deciduous trees without the protection of the state forest reserve agency. In each forest site, five soil samples were randomly collected in different points at the depth of 0–20 cm soil auger. Also, each composite was meticulously put in plastic container separately, labelled and taken to the laboratory. Prior to analysis, the composite soil samples were air- dried at room temperature in the laboratory, ground in a porcelain mortar using a pestle, sieved through a 2-mm mesh sieve and stored for laboratory analysis. Each composite soil was then analysed for the various physicochemical properties using international standard methods.

Laboratory analysis

Particle size distribution was determined by using the bouyocous hydrometer method as described by Gee and Or (2002) and classification was carried out using the USDA classification system (Soil Survey Staff, 2009). Soil pH and electrical conductivity of the soil samples were determined using a pH meter and conductivity meter in a 1:1 soil – water ratio as demonstrated by Osayandes *et al*. (2015). Calcium carbonate content was estimated following the procedure described by Rowell (1994). The Soil Organic Carbon (SOC) was estimated using the Walkley - Black wet oxidation method and the soil organic matter was determined by multiplied organic carbon with 1.724 (Nelson and Sommers, 1982). The cation exchange capacity (CEC) at pH 7.0 was determined following the procedure described by Chapman (1965).

Quality control and quality assurance

All reagents and chemicals were of high analytical grade and high purity distilled water was used for all dilutions. All glassware and plastic containers used were soaked in 10% v/v HNO_3 solution overnight (Onianwa, 2001) and rinsed thoroughly with distilled water before used to avoid contaminants. Blank samples were used to verify the precision of the methods employed and to control possible contamination. In addition, the degree of reproducibility of results was ensured by using duplicate analysis for each soil sample to check for precision of the instrument and method used for analyses. Finally, the accuracy was checked by use of buffer solutions (pH 4 and pH 7) for pH determination and reference solution (0.01moldm^{-3} KCI) for EC determination.

Statistical analysis

Results obtained were subjected to statistical analysis to determine the mean and range. The existence of inter-relationships between physiochemical properties of soils was tested by using Pearson's Product-Moment Correlation Coefficient (r). This statistical analysis was performed using SPSS, Excel.

Results and Discussion

Physical property of a soil plays an important role in soil fertility because the amount and sizes of soil particles determine the porosity and bulk density which account for nutrients retention or leaching of nutrients (Unanaonwi *et al*., 2013). Result of the study (Table 1) indicated that sand has the highest particle size distribution (71.70%) which ranged from 51.80 % to 94.00 % while silt particle occupied 16.75 % (ranged from 3.50 % to 31.00 %) of soil and the least being clay whose content is 11.54 % (ranged 2.00%-22.60 %) of soil. Soils of the studied forest soils can be described as light with its higher % of sand. The size distribution directly influences the porosity which is highest for sand as is expected because sand has no ability to retain water. This finding is supported with the findings of Adugna and Abegaz (2016) that found sand content of soils of forestland to be the highest.

The results revealed that the textures of soil samples are mainly sandy loam and loamy sand textured. This is in conformity with what Uquetan *et al*. (2017) and Umeri *et al*. (2017) reported. In addition, the silt/clay ratio ranged from 1.06 to 2.73 with mean 1.50 was above 0.15 indicating that the soils are relatively young with high degree of weathering potential. This is in harmony with what was reported by Sharu *et al*. (2013) and Jimoh *et al*. (2016) on the soils. The finding further showed that about 48% of the soil samples contained more than 30% (clay + silt) contents. This has shown that silt plus clay content is a relatively important determinant of soil organic matter level in soils. The capacity of soils to maintain organic carbon is influenced by its (clay+ silt) content of soil (Bationo *et al*., 2007).

Soil pH

In soil, pH is known as a master variable because it influences almost every process in the soil system. The health of crops and other soil life, the availability of nutrients, and the activity of pesticides are all affected by pH (Omar, 2012). The result in Table 2 shows that the mean pH of 5.52 obtained is within the ideal pH range of 5.5-7.0 for optimum growth and nutrient availability to plants (Brady and Weil, 2010) and suitable for crop production in Nigeria (Lawal *et al*., 2013). Also, pH range of soil samples ranged from 4.46 to 6.84 with a mean value of 5.52 indicating that the soils were moderately acidic to almost neutral. This pH range is considered moderate based on the enumerated critical limits for interpreting soil pH levels by Abe *et al*. (2010). In addition, this pH range is almost the same with pH range reported in forest by Umeri *et al*. (2017); Osakwe and Akpoveta (2012) and Uquetan *et al*. (2017)

Electrical conductivity (EC) of the soil

Electrical conductivity is used to estimate the soluble salt concentration in soil and is commonly used as a measure of salinity (Wagh *et al*., 2013). The electrical conductivity measurement detects the amount of cations or anions (salts) in solution; the greater the amount of anions or cations, the greater the electrical conductivity reading (Atulkumar, 2015). The results in Table 2 revealed that the mean EC of soil samples was 0.237 dSm^{-1} (ranged from 0.036 to 0.574 dSm^{-1}). Here, all the soil sampled (100%) were salt free (that is, no saline). However, the EC values obtained were within the normal range of less than 1 dS/m which is considered non-saline and suitable for plants growth and soil microbial processes according to Deshmukh (2012) and Nachtergaele *et al*. (2009). Similar result of EC of soil was also reported by Jimoh *et al*. (2016) in Northern Guinea Savanna zone of Nigeria.

Soil organic matter (SOM) content

The benefits of a soil that is rich in organic matter and hence rich in living organisms (Bot and Benites, 2005). Soil organic matter serves multiple functions in the soil, including nutrient retention, water holding capacity, and soil aggregation and is a key indicator of soil quality (LaI, 2010). Results in Table 2 revealed that, the mean percentage of SOM of soil samples was 8.85% (ranged from 3.19 to 13.35%). The higher SOM content exhibited by the soil samples is consistent with that reported Ahukaemere *et al.* (2012); Straaten *et al*. (2015) and Adugna and Abegaz (2016) in forestlands. The higher organic matter under these forest lands might be attributed to continuous accumulation of un-decayed and partially decomposed plant and animal residues mainly in the surface soils of forestland.

Cation exchange capacity (CEC) of the soil

The results indicate that the mean value of CEC in the soil samples was 15.02 cmolc.kg^{-1} (ranged from 12.20 cmolc.kg^{-1} to 18.60 cmolc.kg^{-1}). The mean of CEC is considered moderate based on classified CEC by Abe *et al.* (2010). On the basis of this classification, 50% of the soil samples have CEC values >15 cmol kg^{-1}and 50% have moderate CEC. CEC is an important property of soil because it is a useful indicator of soil fertility and nutrient availability for flora growth (Hazelton and Murphy 2007). Thus high SOM increases cation exchange capacity (CEC).

Table 1: Laboratory result of physical properties of forest surface soils

Sampling Site	Sand (%)	Silt (%)	Clay (%)	Texture class	Silt/Clay	(Silt + Clay) (%)
1	60.50	25.00	14.50	Sandy loam	1.72	39.50
2	62.50	20.50	17.00	Sandy loam	1.21	37.00
3	86.00	8.50	5.50	Sandy	1.55	14.00
4	55.50	25.90	18.60	Sandy loam	1.39	44.50
5	62.10	21.00	16.90	Sandy loam	1.24	37.90
6	90.00	6.00	4.00	Sandy	1.50	10.00
7	82.00	10.00	8.00	Loamy sand	1.25	18.00
8	54.90	28.50	16.60	Sandy loam	1.72	45.10
9	63.20	18.90	17.90	Sandy loam	1.06	36.80
10	67.50	17.30	15.20	Sandy loam	1.14	32.50
11	56.90	26.40	16.70	Sandy loam	1.58	43.10
12	77.00	12.90	10.10	Loamy sand	1.28	23.00
13	80.10	10.90	9.00	Loamy sand	1.21	19.90
14	85.40	8.90	5.70	Sandy	1.56	14.60
15	71.50	15.80	12.70	Loamy sand	1.24	28.50
16	92.00	4.70	3.30	Sandy	1.42	8.00
17	58.90	30.00	11.10	Sandy loam	2.73	41.10
18	52.10	31.00	16.90	Sandy loam	1.83	7.90
19	75.00	14.50	10.50	Loamy sand	1.38	25.00
20	59.30	26.40	14.30	Sandy loam	1.85	40.70
21	56.90	26.00	17.10	Sandy loam	1.52	43.10
22	94.00	3.50	2.50	Sandy	1.40	6.00
23	59.60	22.00	18.40	Sandy loam	1.20	40.40
24	73.90	18.00	8.10	Loamy sand	2.20	26.10
25	66.80	18.30	14.90	Sandy loam	1.23	33.20
26	76.00	13.00	11.00	Loamy sand	1.18	24.00
27	93.00	5.00	2.00	Sandy	2.50	7.00
28	66.50	21.30	12.20	Sandy loam	1.75	33.50
29	69.50	18.80	11.60	Sandy loam	1.62	30.40
30	71.20	14.90	13.90	Loamy sand	1.07	28.80
31	90.10	6.00	3.90	Sandy	1.54	9.90
32	76.20	13,80	10.00	Loamy sand	1.38	23.80
33	51.80	25.60	22.60	Sandy loam	1.13	48.20
34	81.00	11.00	8.00	Loamy sand	1.38	19.00
35	72.10	18.50	9.40	Loamy sand	1.97	27.90
36	89.40	6.40	4.20	Sandy	1.52	10.60
37	79.10	12.50	8.40	Loamy sand	1.49	20.90
38	68.10	18.90	13.00	Sandy loam	1.45	31.90
39	82.90	10.00	7.10	Loamy sand	1.41	17.10
40	57.40	24.00	18.60	Sandy loam	1.29	42.60
Mean	71.70	16.75	11.54	Loamy sand	1.50	27.29
Range	51.80- 94.00	3.50-31.00	2.00-22.60		1.06-2.73	6.00-48.20

Table 2: **Laboratory result of chemical properties of forest surface soils**

Sampling Site	pH	EC (dSm^{-1})	$CaCO_3$(%)	SOM (%)	CEC (cmolckg-1)
1	4.74	0.456	0.20	5.01	12.50
2	5.95	0.141	1.30	9.93	15.80
3	4.81	0.343	0.43	6.62	13.30
4	5.78	0.124	1.43	9.98	16.20
5	5.85	0.114	1.50	10.09	16.60
6	5.53	0.255	0.83	8.38	14.30
7	6.39	0.070	1.80	11.67	17.40
8	4.49	0.574	0.18	3.19	12.00
9	4.46	0.538	0.08	3.31	12.20
10	5.91	0.105	1.63	11.49	17.00
11	6.33	0.076	1.75	11.63	17.30
12	4.79	0.372	0.40	6.59	13.10
13	6.46	0.062	1.85	11.68	17.50
14	5.71	0.177	1.13	9.86	15.20
15	4.73	0.414	0.33	6.51	12.80
16	6.07	0.080	1.68	11.62	17.20
17	5.43	0.202	0.95	9.83	14.80
18	4.49	0.478	0.10	3.35	12.30
19	5.29	0.301	0.73	8.32	14.00
20	4.85	0.450	0.28	6.49	12.80
21	5.68	0.187	0.98	9.83	14.90
22	5.44	0.309	0.63	8.19	13.90
23	6.84	0.036	2.00	13.35	18.60
24	5.58	0.150	1.23	9.91	15.60
25	6.22	0.087	1.65	11.60	17.40
26	5.78	0.132	1.35	9.97	16.00
27	5.83	0.128	1.43	10.00	16.40
28	4.74	0.401	0.38	6.57	12.90
29	4.59	0.476	1.25	4.97	12.40
30	5.71	0.167	1.08	9.85	15.00
31	5.26	0.308	0.63	8.24	13.80
32	6.63	0.046	1.80	11.73	17.80
33	5.90	0.237	0.88	8.41	14.60
34	5.45	0.212	0.90	8.61	14.70
35	4.81	0.361	0.48	6.71	13.90
36	5.52	0.158	1.18	9.90	15.50
37	6.70	0.043	1.90	13.26	18.30
38	4.95	0.328	0.55	8.17	13.50
39	5.88	0.108	1.57	10.91	16.80
40	5.35	0.282	0.78	8.38	14.70
Mean	5.52	0.237	1.03	8.85	15.02
Range	4.46-6.84	0.036-0.574	0.08-2.00	3.19-13.35	12.00-18.60

Electrical Conductivity (EC), Soil Organic Matter (SOM) and Cation Exchange Capacity (CEC)

Calcium carbonate content of the soil

The mean $CaCO_3$ content of soil samples showed 1.03% (ranged from 0.08% to 2.00%). On the basis of $CaCO_3$ rating suggested by Nachtergaele *et al*. (2009), the soils of the studied soils were non- calcareous in nature.

The results presented in Table 3 revealed the relationship between physicochemical properties of soil which might be positively or negatively, interfered with nutrient availability (Onwudike, 2015). There was a strong positive correlation ($p < 0.05$) between soil pH and SOM with correlation coefficient ($\gamma = 0.95$) which indicated the higher the pH (that is, the lower the acidity level of the soil), the higher the SOM. Also, significant negative correlations ($p < 0.05$) between soil EC with soil pH with correlation coefficient ($\gamma = -0.95$) which means that at low soil pH value, there is high soluble salt content and therefore high electrical conductivity. This research finding consistent with the study of Nur Aini *et al*. (2014) who reported that soil EC had significant negative relationship with the soil pH.

Table 3: Correlation coefficients between physicochemical properties of soils

Physico-chemical properties	Correlation coefficient (r)
Soil pH and SOM	0.95
Soil EC and pH	-0.95
Soil CEC and SOM	0.96
Soil pH and CEC	0.97
Soil pH and $CaCO_3$	0.92
Soil EC and SOM	-0.98

In addition, soil CEC showed strong positive correlation with SOM ($p < 0.05$) with correlation coefficient ($\gamma = 0.96$) which means that the higher the SOM, the more cation exchange capacity a soil has, the more likely the soil will have a higher fertility level. The research findings conform to the works of Olorunfemi *et al*. (2018) and Fasinmirin and Olorunfemi (2012) who all reported that soil samples with higher values of CEC were found to have high levels of organic matter and pH levels.

More so, there is a significant positive correlation between soil CEC and pH ($p < 0.05$) with correlation coefficient of ($\gamma = 0.97$). This finding agrees with findings of Olorunfemi *et al*. (2018) who all reported that soil samples with higher values of CEC were found to have high pH levels. Furthermore, a strong positive correlation existed between soil pH and $CaCO_3$ ($p < 0.05$) with correlation coefficient ($\gamma = 0.92$) which means that pH increased with increased in the amount of $CaCO_3$ present.

Finally, SOM showed negative correlation with EC ($p < 0.05$) with correlation coefficient ($\gamma = -0.98$) suggesting that high SOM tends to favour the immobilization of soluble ions in soils. This finding is supported by the works of Nelson *et al*. (2017) who all reported that SOM had significant strong negative relationship with the soil EC.

Conclusion and Recommendation

In conclusion, the forest soil samples in this study area contain significant quantities of all the nutrients analysed. These forest soils proven to contain high SOM, non-saline (that is, free from salt) and non- calcareous in nature. Also, the soils were predominantly sandy loam and loamy sand and possess suitable pH for normal forest ecosystems. These soils have moderate CEC values which might be due to the high SOM, presence of low amount of $CaCO_3$ and very low soluble salt in the soil.

In addition, pH showed strong positive correlation with SOM, CEC and $CaCO_3$. Also, soil EC showed negative correlation with pH and SOM. This correlation results showed that the interactions between these physicochemical properties seem to play an important role in supplying the soil with available nutrients. It is therefore recommended that, the conservation of these forests in Kogi state is an urgent need for the proper management practices of the forests which will in turn increase the quality of soils and the forest. This will reduce indiscriminate destruction of forest cover and protection of the surface soils.

Conflict of Interest

Authors declare that there is no conflict of interest related to this study.

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