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Effect of rainfall season on the chemical properties of the soil of a Southern Guinea Savanna ecosystem in Nigeria

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Investigations were carried out on the effect of rainfall pattern on some soil chemical properties during 2011 in the Southern Guinea savanna ecosystem in Nigeria. The study was carried out in Oro Forest Reserve in Kwara State of Nigeria. Twenty plots were randomly selected for soil sampling at for different seasons namely: January (dry season), May (beginning of rains), September (peak of rains) and November (end of rains). Different soil depths were sampled: 0 to 5, 6 to 10, 11 to 15 and 16 to 20 cm at five randomly selected locations. The chemical properties that were mostly influenced by rainfall pattern are soil organic matter, total nitrogen, soil pH, available phosphorus, exchangeable cations (Ca, Mg and K), and cation exchange capacity (CEC). The two major seasons that show profound influence on soil properties are dry season (January) and peak of rainy season (September). Soil pH and available phosphorus were higher in dry season (January) and at the beginning of rainy season (May) and remain low at the peak of the rainy season (September). In contrast, soil organic matter and total nitrogen were low in dry season (January) due to burning of the vegetation. However, nitrogen content increased at the peak of the rainy season (September), due to nitrogen fixation. The increase in the total exchangeable bases (TEB) could be attributed to their importance in the tissue synthesis. There was decline in most soil nutrients during active growth of the woodland savanna trees. Therefore, the limitation of N, P, Ca, Mg, Na and K is most likely to occur in September (peak of rainy season).

Key words: Soil properties, seasonal changes, Southern Guinea savanna, sampling depths.

INTRODUCTION

At different spatial and time scales, vegetation cover helps in protecting the soil from harsh climatic conditions, mostly soil erosion. The presence of dense vegetation affords the soil adequate cover, thereby reducing the loss in macro and micro nutrients that are essential for plants growth and energy fluxes (Iwara et al., 2011). The influence of soil factors on the composition and distribution of savanna vegetation in Nigeria has been reported (Child, 1974; Muogholu and Isichei, 1991). Others have discussed relationship between soil characteristics and distribution of plant communities in the Guinea Savanna (Menaut et al., 1985; Cole, 1986; Abdul Ameed et al., 2004). The evidence of possible literature shows that vegetation associations within the Guinea Savanna and tree species reflect differences in soil texture, structure and mineral content (Abdul Ameed, 2005). Change in soil chemical properties in the form of P mineralization–immobilization of organic P, are strongly

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influenced by seasonal variations in temperature, moisture, plant growth and root activity, and by organic matter accumulation from litter fall (Perrot et al., 1990; Mc Gvath et al., 2000). Land cover changes affect also soil properties and biogeochemical processes (Ross et al., 1999; Zeng et al., 2009). Each of the rainy and dry seasons of the seasonal climate of the tropical ecosystem, is characterized by a number of ecological phenomena which set up series of processes which influence the biotic and edaphic components of the ecosystem. Soil moisture is highly affected by soil texture and its stability. Various soil texture types may cause preferential flow or water immobilization (KodeSova et al., 2006, 2007). Bodner et al. (2008) discussed the impact of the rainfall intensity, soil drying and frost on the seasonal changes of soil hydraulic properties in the texture related range. Suwardji and Eberbach (1998) studied both aggregate stability and hydraulic conductivities. They documented the lowest aggregate stability during the winter and increased in spring.

The estimation of soil available nutrient contents - in a complex heterogeneous system, is of a great pedological as well as ecological importance. Understanding spatial changes in soil nutrients is important, as they may differ markedly among identical locations subjected to natural and man-made disturbances. Vertical, horizontal and temporal distribution of nutrients in soils are controlled by a combination of factors viz, parent material, topography, soil management practices and rainfall and area seasons. Similar to this, land use patterns and vegetation play important role in soil nutrient transformations and fertility. Anthropogenic changes such as fire (Sharma, 1988) alter several processes in soil; physical (porosity, soil structure and aggregate stability and water repel-lency), chemical (soil organic matter, nutrient availa-bility and cycling, pH and C: N) and biological (microbial composition, soil faunal diversity and density, biomass productivity and carbon sequestration). The use of C: N as an indicator of ecosystem stability has necessitated precise estimations on the soil C at N pools worldwide.

During literature review, we did not come across any study on seasonal variability on soil chemical properties in the Southern Guinea savanna in Nigeria, except for the limited information on the effects of savanna burning of the dry season on soil litter and the chemical composition of soil (Egunjobi, 1970). Thus, the present investigation is an attempt to document the seasonal dynamics of the chemical properties of the tropical savanna wood land ecosystem in Nigeria.

MATERIALS AND METHODS

Site description

The present study was undertaken in 2011 at Oro Forest reserve, a woodland savanna of the Southern Guinea vegetation of Nigeria. It covers about 5414 ha which are located in the North-Eastern portion (Lafiagi Section) of the reserve, at a place approximately 08°53^{1}E and 05°22^{1}N.

Topography and drainage

Most of the land of Oro Forest Reserve fall within an altitude of 120 + 155 m and the few isolated high lands in the north-eastern part, range in height from 1100 to 1150 m. The main drainage system within the reserve is the Oro River – a tributary of River Niger, which is about 20 km to the north of the reserve.

Geology

The main geological formation of the reserve is the pre-Cambrian Basement complex, composed of metamorphic and igneous rocks. This basement complex includes the oldest rocks known in Nigeria, the dominant clay mineral of the area was kaolinithe (a low activity clay) (Kowal and Knabe, 1972).

Climate

Oro Forest Reserve has a typical seasonal climate characterized by a two peaked pattern of rainfall- a feature common to all savanna types occurring south of latitude 9°N (Kowal and Knabe, 1972). However, the duration of the well defined dry and wet seasons varies from year to year.

Rainfall and temperature

The annual rainfall of 913.5 mm occurred between March and October. The rainfall within a year shows two maxima, the first one being 202.3 mm occurring in June, while the second one with 254.7 mm is in September 2010 (Figure 1). In 2011, the first maximum was 201.2 mm while the second maximum was 295.2 mm (Figure 2). The temperature was fairly constant for the year 2010 and ranged between 20.7 and 27.3°C for the minimums, while the mean monthly maximum temperature ranged between 22.5 and 27.6°C(Figure 1). In 2011, however, the temperature values ranged between 21.2and 25.3°C minimums, while the mean monthly maximum ranged between 23.5 and 28°C (Figure 2).

Plot description and samples collection

The study site was located in the North-Eastern of the reserve. In the location of the forest, one hectare (100 x 100 m) was separated and divided into 100 plots of 10 × 10 m.

Twenty plots indicated plots were randomly selected for soil sampling at four different sampling periods viz: January (dry season), May (beginning of rains), September (peak of rains) and November (end of rains). Soil samples were collected at four different top soil depths; 0 - 5, 6 - 10, 11 - 15 and 16 - 20 cm at five randomly selected locations of each plot for one mean sample. A Dutch auger was used to collect soil sample which were carefully kept in well labeled plastic bags and sent immediately to laboratory for analysis.

Statistical analysis

A Dutch auger was used to collect soil sample which were carefully kept in well labeled plastic bags and sent immediately to laboratory for analysis.

a. Particle size analysis: This was done by hydrometer method

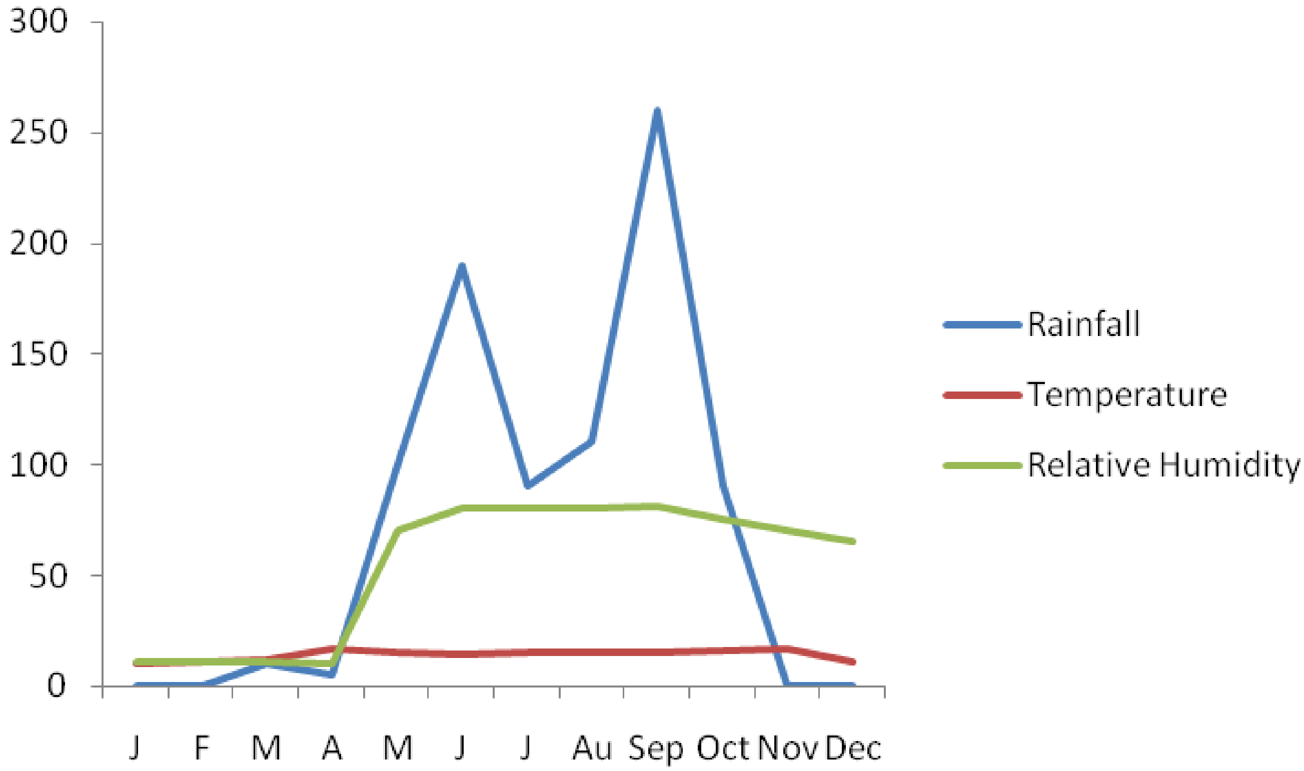

Figure 1. Rainfall (cm), temperature (°C) and relative humidity (%) distributions for 2010.

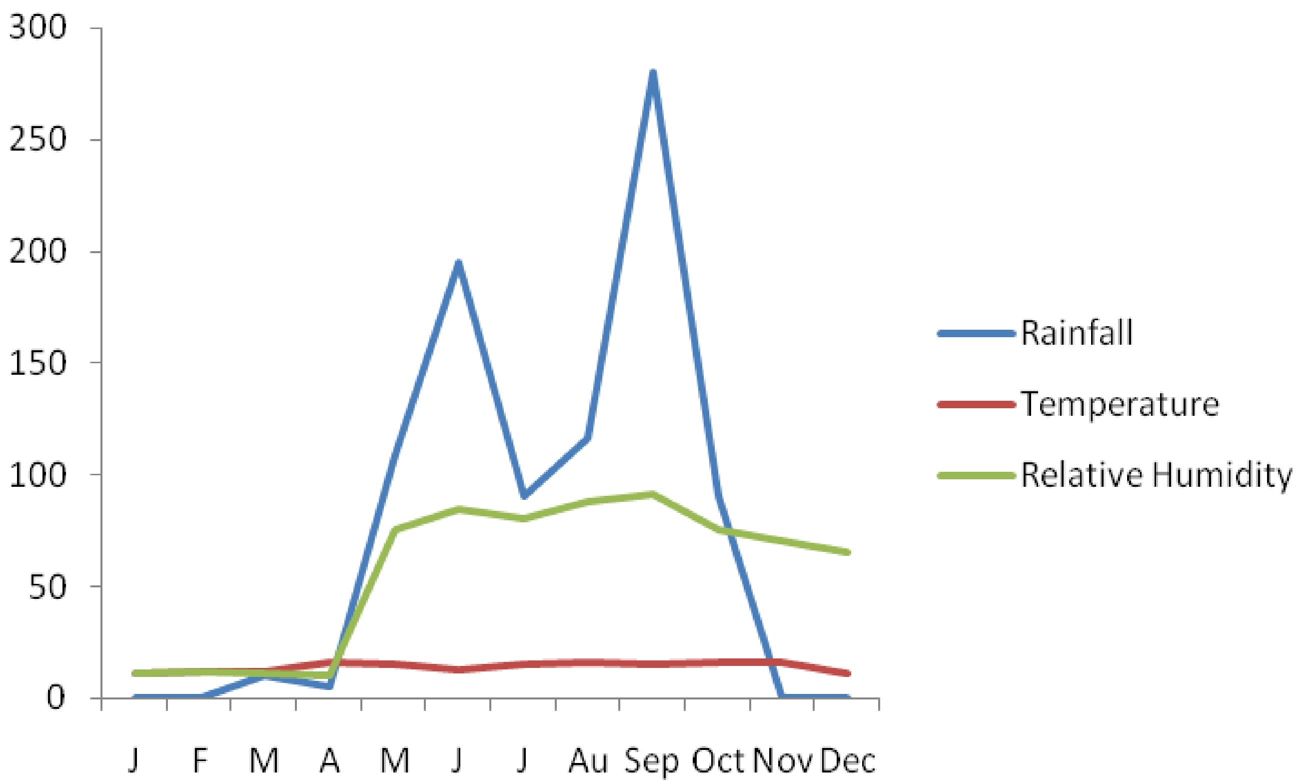

Figure 2. Rainfall (cm), temperature (°C) and relative humidity (%) distributions for 2011.

Table 1. The mean values (n=10) of some soil chemical properties across sampling time (0 - 20 cm).

Time of sampling	Properties												
	pH (H_20)	OC (%)	OM (%)	N (%)	C/N	Ca	Mg	K	Na	TEB	Av. P	E.A	CEC
						Cmol/kg of Soil							
A	6.3[a]	0.46[d]	0.8[d]	0.05[c]	6.43[b]	3.0[d]	0.88[b]	0.31[b]	0.05[a]	5.33[a]	2.08[a]	0.15[b]	4.81[b]
B	6.3[a]	0.58[c]	1.00[c]	0.06[b]	6.65[a]	3.36[c]	0.84[c]	0.35[a]	0.04[b]	5.11[b]	2.08[a]	0.15[b]	4.81[b]
C	6.1[b]	0.66[b]	1.12[b]	0.06[b]	6.25[c]	3.48[b]	0.96[a]	0.29[c]	0.04[b]	4.51[d]	1.73[b]	0.16[a]	4.93[a]
D	6.1[b]	0.85[a]	1.47[a]	0.08[a]	6.42[b]	4.24[a]	0.96[a]	0.29[c]	0.04[b]	4.87[c]	1.73[b]	0.16[a]	4.93[a]

Means on the same column followed by the same letter are not significantly different at P ≤ 0.05; A = dry season (January); B = beginning of rains (May). C = peak of rains (September); D = end of rains (November); OC = organic carbon, OM = organic matter, N = total nitrogen, C/N = carbon : nitrogen ration, Ca = calcium, K = potassium, Na = sodium; TEB = total exchange bases, Av. P = average phosphorus, EA = exchange acidity and CEC = cations exchange capacity.

(Gee and Bauder, 1986) using sodium haxametaphosphate (calgon) as dispensing agent.

b. Chemical analysis: The soil samples were dried for few days sieved to pass through 2 mm mesh and chemically analysed. The pH (in water) was determined in a 1:2.5 solution (soil: distilled water) and was measured with a standard glass electrode. The organic carbon content of the soil was determined according to Walkey and Black (1965) dichromate oxidation method. The percentage organic matter content in the samples was calculated by multiplying the values of organic carbon by the conventional Van Bammeller factor of 1.724. Total soil nitrogen was determined by Macro kjeldahl methods (Bremner, 1965). Available phosphorus was extracted using Bray II method (Bray and Kutz, 1965) and determined by spectrophotometer.

Exchangeable Na, K, Ca and Mg were extracted with $BaCl_2$ 0.1 m (Hendershort, 1993) and analysed by atomic absorption. Exchangeable acidity was determined from 0.1 NaCl extracts and titrated with 1.0 N HCl.

Cation exchangeable capacity (CEC) was determined by summing up total exchangeable bases (TEBS) and total exchangeable acidity (TEA), which the:

Base saturation = TEB/CEC x 100

Where TEB = Total exchangeable bases; CEC = cations exchangeable capacity

Statistical analysis

The data were analyzed using two way analysis of variance (ANOVA) and means were separated by Duncan new multiple range test and student t- test was used to test the level of significance of some properties in the pre and post burn era at 5% level.

RESULTS AND DISCUSSION

Effect of sampling month/periods on some chemical properties

Across the months of sampling, significant differences were observed for both exchangeable acidity (EA) and CEC. It is however noted there was no significant differences between the dry season (A) and the beginning of raining seasons (B) as well as peak and end of raining seasons (Table 1). Significant differences were recorded in the soil pH, soil organic carbon, total nitrogen and available phosphorus across the sampling time. There were significant differences in the values of calcium, magnesium, potassium and total exchange bases across the seasons (Table 1). However, calcium values were higher in the peak and end of rainfall. Potassium values were more at the beginning of rains, while sodium values had the highest values during the dry season. Total exchange bases values were more during the dry season and at the beginning of rains.

Effect of dry season on soil chemical properties

There were significant differences in soil pH, soil carbon, total nitrogen and available phosphorus among the sampling depths during dry season, (January A) p ≤ 0.05 (Table 2). The values of pH ranged from 6.2 to 6.3 and showed no appreciable trend down the depths, the organic carbon ranged from 0.31 to 0.63% at the 16-20 and 0-5 cm, respectively. It decreased down the depth. While the values of the available phosphorous ranged from 1.4 cmol/kg of soil to 2.8 cmol/kg of soil at 16-20 and 0-5 cm respectively, it decreased down the slope. In the same vein, there were significant differences among some of the parameters in the sampling depths at P ≤ 0.05 in this season, calcium (ca), magnesium (Mg), potassium (K) and EA decreased down the depths, the cation exchange capacity showed no appreciable trend down the depth. The sodium (Na) and total exchange bases (TEB) showed no significant difference during this season.

Effect of beginning of rains on soil chemical properties

At the beginning of the rains (May B) (Table 3), soil pH, soil organic matter, total nitrogen, calcium, magnesium, potassium and total exchange bases, exchange acidity

Table 2. Soil chemical properties in dry season (January).

Depth (cm)	Properties												
	pH (H_20)	OC (%)	OM (%)	N (%)	C/N	Ca	Mg	K	Na	TEB	Av. P	E.A	CEC
									Cmol/kg of Soil				
0-5	6.4^{a}	0.63^{a}	1.09^{a}	0.06^{a}	6.43^{a}	6.15^{a}	1.01^{a}	0.54^{a}	0.05^{ab}	7.75^{ab}	2.8^{a}	0.19^{a}	4.99^{b}
6-10	$6. 3^{b}$	0.56^{b}	0.97^{b}	0.05^{b}	6.92^{b}	4.13^{b}	0.87^{b}	0.32^{b}	0.05^{ab}	5.37^{a}	2.3^{b}	0.17^{b}	5.52^{a}
11-15	6.1^{d}	0.34^{c}	0.59^{c}	0.04^{c}	6.18^{c}	2.90^{c}	0.85^{b}	0.28^{b}	0.06^{a}	4.09^{b}	1.8^{c}	0.15^{c}	4.22^{d}
16-20	6.2^{c}	0.31^{d}	0.53^{d}	0.04^{c}	6.18^{c}	3.00^{c}	0.75^{c}	0.30^{b}	0.04^{b}	4.12^{b}	1.4^{a}	0.14^{c}	4.50^{c}

Means on the same column followed by the same letter are not significantly different at $P < 0.05$; OC = organic carbon, OM = organic matter, N = total nitrogen, C/N = carbon: nitrogen ration, Ca = calcium, K = potassium, Na = sodium; TEB = total exchange bases, Av. P = average phosphorus, EA = exchange acidity and CEC = cations exchange capacity. The description should be included into Methods chapter. It wouldn't be necessary use the same under each table.

Table 3. Soil chemical properties at the beginning of rain (May).

Depth cm	Properties												
	PH (H_20)	OC (%)	OM (%)	N (%)	C/N	Ca	Mg	K	Na	TEB	Av. P	E.A	CEC
						Cmol/kg of Soil							
0-5	6.4^{a}	0.73^{a}	1.26^{a}	0.07^{a}	6.14^{a}	2.41^{a}	0.86^{a}	0.53^{a}	0.04^{a}	6.84^{a}	2.8^{a}	0.19^{a}	4.99^{b}
6-10	$6. 4^{a}$	0.58^{b}	1.02^{b}	0.06^{b}	5.78^{b}	3.17^{b}	0.84^{b}	0.34^{b}	0.04^{a}	5.37^{ab}	2.3^{b}	0.17^{b}	5.52^{a}
11-15	6.1^{b}	0.57^{b}	0.98^{b}	0.05^{c}	6.43^{c}	2.66^{c}	0.84^{b}	0.27^{c}	0.04^{a}	4.09^{b}	1.8^{c}	0.15^{c}	4.22^{d}
16-20	6.1^{b}	0.42^{c}	0.72^{c}	0.04^{d}	8.24^{d}	2.20^{c}	0.84^{b}	0.25^{d}	0.04^{a}	4.12^{b}	1.4^{d}	0.14^{c}	4.50^{c}

Means on the same column followed by the same letter are not significantly different at $P \leq 0.05$; OC = organic carbon, OM = organic matter, N = total nitrogen, C/N = carbon : nitrogen ration, Ca = calcium, K = potassium, Na = sodium; TEB = total exchange bases, Av. P = average phosphorus, E.A = exchange acidity and CEC = cations exchange capacity.

Table 4. Soil chemical properties at the peak of rain (September).

Depth cm	Properties												
	pH (H_20)	OC (%)	OM (%)	N (%)	C/N	Ca	Mg	K	Na	TEB	Av. P	E.A	CEC
									Cmol/kg of Soil				
0-5	6.1^{b}	1.0^{a}	1.72^{a}	0.09^{a}	6.92^{a}	4.2^{a}	1.14^{a}	0.38^{a}	0.05^{a}	5.77^{a}	2.4^{a}	0.11^{ab}	7.04^{a}
6-10	$6. 3^{a}$	0.69^{b}	1.12^{b}	0.09^{a}	5.87^{c}	3.78^{b}	0.96^{b}	0.27^{b}	0.04^{ab}	5.05^{b}	1.8^{b}	0.07^{b}	5.12^{b}
11-15	6.1^{b}	0.53^{c}	0.91^{c}	0.06^{b}	5.57^{d}	2.76^{c}	0.92^{c}	0.27^{b}	0.04^{ab}	3.99^{c}	1.5^{c}	0.14^{a}	4.13^{c}
16-20	6.1^{b}	0.41^{d}	0.71^{d}	0.04^{c}	6.52^{b}	2.18^{d}	0.81^{d}	0.22^{c}	0.03^{b}	3.24^{d}	1.2^{d}	0.13^{ab}	3.42^{d}

Means on the same column followed by the same letter are not significantly different at $P \leq 0.05$; OC = organic carbon, OM = organic matter, N = total nitrogen, C/N = carbon : nitrogen ration, Ca = calcium, K = potassium, Na = sodium; TEB = total exchange bases, Av. P = average phosphorus, E.A = exchange acidity and CEC = cations exchange capacity.

and cation exchange capacity showed significant differences at $p \leq 0.05$ among the sampling depths. While sodium, total exchange bases showed no significant differences among the sampling depths. Organic matter, magnesium potassium available phosphorous and exchange acidity decreased down the depths. However, soil pH, calcium and cation exchange capacity (CEC) did show any appreciable variation down the depths.

Effect of peak of rains on soil chemical properties

At the peak of rainfall (September C) (Table 4), organic matter, nitrogen, calcium, magnesium, potassium, available phosphorous, total exchange bases, exchange acidity and cation exchange capacity showed significant differrences among the sampling depths at $p \leq 0.05$. They also decreased down the depths. Soil pH and sodium did not show any appreciable variations down the depths.

Effect of end of rains on soil chemical properties

At the end of rains, (November D) (Table 5), soil pH and exchange acidity showed significant differences and increased down the sampling depths at $p \leq 0.05$. While the soil organic matter, nitrogen, calcium, magnesium

Table 5. Soil chemical properties at the end rain (November).

Depth cm	Properties												
	pH (H_20)	OC (%)	OM (%)	N (%)	C/N	Ca	Mg	K	Na	TEB	Av. P	E.A	CEC
						Cmol/kg of Soil							
0-5	6.1[a]	1.23[a]	2.12[a]	0.09[a]	7.24[a]	6.2[a]	1.14[b]	0.38[a]	0.05[a]	6.77[a]	2.4[a]	0.12[ab]	7.04[a]
6-10	6.1[a]	0.73[c]	1.25[c]	0.07[c]	6.22[b]	3.92[b]	0.96[a]	0.27[b]	0.04[b]	5.05[b]	1.8[c]	0.07[b]	5.12[b]
11-15	6.1[a]	0.61[d]	0.55[d]	0.06[d]	6.19[c]	3.26[d]	0.92[c]	0.27[b]	0.04[b]	3.99[c]	1.5[c]	0.14[a]	4.13[c]
16-20	6.1[a]	0.81[b]	0.40[b]	0.05[b]	6.03[d]	3.57[c]	0.81[d]	0.22[c]	0.03[c]	3.24[d]	1.2[d]	0.14[a]	3.42[d]

Means on the same column followed by the same letter are not significantly different at $P \leq 0.05$; OC = organic carbon, OM = organic matter, N = total nitrogen, C/N = carbon : nitrogen ration, Ca = calcium, K = potassium, Na = sodium; TEB = total exchange bases, Av. P = average phosphorus, E.A = exchange acidity and CEC = cations exchange capacity.

sodium total exchange bases, available phosphorous and cation exchange capacity showed significant differences and decreased down the soil depths at $p \leq 0.05$.

DISCUSSION

Effect of sampling periods/months on some soil chemical properties

The changes in soil pH over the seasons which was higher in the first two seasons (dry and beginning of rains), might be attributed to the little rainfall and probably due to dry season burning in January which is annual occurrence in the savanna woodland, while the ash released from the accumulated litter following burning in January, caused a slight rise in the soil pH. In the same vein, the dissolution of the ash after early rains in May could be the major reason for slight increase in soil pH at this time (Ekinci, 2006). The distribution of organic matter which was higher during the peak might be due to higher rainfall at this period which favors litter decomposition and accumulation of soil organic matter. While the distribution of soil nitrogen which appeared to increase down the depths during the end of rains might be due to leaching of nitrates down the depths (Giacomo, 2005). The increase of total exchange bases during dry and beginning of rains might be attributed in part to little or no rainfall which reduced leaching of soluble cations and burning which in annual occurrence in the savanna woodland, as burning have been found to have increased soluble cations (Giacomo, 2005). The concentration of available soil phosphorous and exchange acidity at the upper depths during dry and beginning of rains could be due to absence of rainfall which led to little or no leaching of available phosphorous and exchange acidity.

The effect of sampling depths and rainfall patterns on some soil chemical properties

Soil pH

The results of the study revealed the effect of sampling depths and rainfall patterns on soil pH, soil organic carbon, total nitrogen and available phosphorus in a tropical Guinea woodland savanna. The distribution of soil pH which decreased down the depths in dry season and the beginning of rains might be due to little or no rains which resulted in little or no movement of cations down the profile in part and might be due to the distribution of soil organic matter which serves as store house for the exchange bases. Also, it might be due to the distribution of exchange acidity, which decreased down the depths. However, at the peak of rainfall (September) and end of rains (November) soil pH tends to increase down the sampling depths, due to vertical movement or translocation of dissolved cations as well as low organic matter down the depths as a result, soil pH increased down the depth.

Organic matter

The low of soil organic matter in the dry season of the year (January) might be due to low rains and burning that usually occurs in the area. Also, soil organic matter tends to decrease down the depths, as a result of low decomposition down the profile, due to little or absence of soil microorganisms that are responsible for the decomposition.

Complete consumption of the organic material on the forest floor in the studied area indicates that a very high intensity fire occurred at the study area in January 2011, which accounted for the low organic matter in January. However, the establishment of post fire vegetation, through both re-sprouting and seedling establishment was rapid on the burnt area during the peak of rainfall (September) (Table 3). This enhanced litter fall, hence more organic matter (Litton Santakes, 2002).

Total nitrogen

Other studies have reported variable results in relation to rainfall and fire effects on the nitrogen content of soils (Wan et al., 2001). Nitrogen is easily lost from system during an intense fire, as it volatilizes at temperatures as low as 200°C (White et al., 1973). This might be the reason why there was low nitrogen content in January (dry season) (Table 2). Actual losses of nitrogen due to volatilization have been estimated to vary from 75 kg/ha (Klemmendson, 1976) to 907 kg/ha (Grier, 1975). A likely explanation for decreased soil nitrogen in May (beginning of rains) (Table 2) might be due to leaching of nitrates during the beginning of rains as a result of absence of vegetation and consumption of litter layer led to increased infiltration rates in the burned soils.

The increased nitrogen contents at the peak of rains (September) (Table 4) and at the end of rains in November (Table 5), could be best explained by a possible increase in activity of nitrogen fixing microbes. Evidence exists to show that increased biological nitrogen fixation along with increased mineralization rates occur during rainy season, which resulted in increased nitrogen content at this time (Bergeron et al., 2002)

Exchangeable cations

The distribution of exchangeable bases (calcium, magnesium, potassium, sodium) showed decreased down the depths might be due in part to the higher organic matter at the upper depths during the dry and beginning of rains. The little or no rainfall at these periods might be due to the accumulation of the respective cation at the upper depth. At these periods, there was little or no leaching of these cations (Tables 2 and 3). At the peak rains, total exchange bases were low and decreased down the depths; this could be attributed to these elements being utilized by the regenerating plants, since these are reputed for their vigorous regeneration and growth following annual fires (Hopkins, 1974).

Considering the importance of these elements in tissues synthesis, there are enough indications to show that the disappearance of these elements could be due to the synthesis of plant tissues in newly flushing suckerings and sprouts from the plants of the herbaceous layer and possibly the flowers of ligneous savanna plants (Hopkins, 1974). At the end of rains, however, the vigorous tree growth might have been decreased which accounted for high exchange bases.

Available phosphorus

A large portion of the nutrient reserve in most forest ecosystems is contained in the organic material on the forest floor (Wagner and Wolf, 1998). The slight increase in phosphorus in dry season (January) (Table 2) and in May (beginning of rains) (Table 3), may be due to fire. De Ronde (1990) found that a high intensity wild fire resulted in an immediate increase in phosphorus level in the southern Cape Forestry Region of South Africa.

The distribution of available phosphorus between soil layers showed that it was fairly constant in dry season (January) and at the beginning of raining season (May) (Table 3) and decreased sharply during the peak of rainfall (September) (Table 4). This might be attributed to the growth of plants and accumulation of biomass during growing season (Styles and Coxon, 2007).

Exchange acidity and cation exchange capacity

Exchange acidity values were slightly low which might be the reason for slight acidity of the area and decreased down the depths due to the distribution of soil organic matter and little or no rainfall during dry and beginning of rains which might lead to little or no leaching. The increase in exchange acidity down the depths might be due to leaching of the elements down the depths due to high rainfall.

The low values of cation exchange capacity (CEC) in the dry and beginning of rains in the study area might be due to the distribution of soil organic matter, as soil organic matter was found to have influenced the distribution of cations exchange capacity. Also, organic matter had been identified as a store house for cations (Schlecht et al., 2006). In the same vein, cation exchange capacity decreased down the depths probably as a result of the decreased of soil organic matter down the depths.
The increased cations exchange capacity during the peak and end of rains might also be due to higher rainfall which favours rapid decomposition of dead plant materials that lead to accumulation of soil organic matter (Fatubarin, 1980).

Conclusion

This study shows that in Southern Guinea savanna in Nigeria, rainfall seasons have great effect on soil chemical properties. Van Reordivijii and Ong (1999), hypothesized that land use systems would most likely achieve long term sustainability, by mimicking patterns of resource use in the natural systems. The chemical properties that were mostly influenced by rainfall patterns were soil organic matter, total nitrogen, soil pH, available phosphorus, exchange cations (Ca, Mg and K), CEC. The two major rainfall seasons that showed profound influence on soil properties in the study area are dry season (January) and peak of rainy season (September). Some pH and available phosphorus values were higher in dry season (January) and at the beginning of rainy season (May). They were low during the peak of rains. In contrast, soil organic matter and total nitrogen were low in dry season (January) due to burning in the location. However, nitrogen content was later increased at the peak of rain due to nitrogen fixation activities. The decrease in the total exchangeable bases (TEB) during the peak of rainy season could be attributed to the importance in the tissue synthesis during this period. It was observed that there were decline in the soil nutrients except soil nitrogen during the peak of rainy season, which also coincided with the active growth period of forest trees (no data). Therefore, the limitation of N, P, Ca, Mg, K, to tree growth is most likely to occur in September (peak of rainy season) (Chen et al., 2006). Protection of the litter layer is strongly recommended to ameliorate soil degradation and nutrient limitation in the study area, since litter layer was not only the main source of soil organic matter and available nutrients, but also the regulator of soil microbial activity (Chen et al., 2003).

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