

*Full Length Research Paper*

# Effect of seasonal dynamics on the chemical properties of the soil of a Northern Guinea savanna ecosystem in Nigeria

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Investigations were carried out into the effects of seasonal changes on some soil chemical properties in the Northern Guinea savanna ecosystem in Nigeria. The study was carried out in Kamuku National Park is located in Birnin Gwari of Nigeria in 2011 and 2012. Twenty plots were randomly selected for soil sampling from 100 plots of 10 m × 10 m at four different seasons viz: January (dry season), May (beginning of rains), September (peak of rains) and November (end of rains). Different soil depths were sampled: 0 to 4.9 cm, 5 to 9.9 cm, 10 to 14.9 and 15 to 20 cm at five randomly selected locations. The chemical properties that were mostly influenced by seasonal changes 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 of 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 rainy season (September), due to nitrogen fixation. The increase in the total exchangeable bases (TEB) could be distributed 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, northern guinea savanna, sampling depths.

## INTRODUCTION

Nigeria is located in the tropical zone (between latitude 4° and 14° N and longitude 2°E) with a vast area of savanna vegetation. Savanna vegetation of Nigeria is diverse and can be classified into derived, southern Guinea and northern Guinea savannas. These classifications reflect

environmental characteristics such as lengths of growing periods, for instance, northern Guinea savanna has a growing periods of about 151 to 180, southern Guinea savanna has a growing periods of 181 to 210 days while derived/coastal savanna has a growing periods of 211 to

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270 days (Kowal and Knabe, 1972).

At different spatial and time scale, vegetation cover helps in protecting the soil from harsh climatic conditions, reducing soil erosion and loss in macro and micro nutrients that are essential for plants growth and energy fluxes (Iwara et al., 2011). The influence of soil factors in the composition and distribution of savanna vegetation in Nigeria has been reported (Child, 1974; Moughalu 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; Sharma, 1988; Abdulhameed et al., 2004). Evidence shows that vegetation associations within the Guinea Savanna and tree species reflect differences in soil texture, structure and mineral content (Abdulhameed, 2005). Change in soil chemical properties in the form of P mineralization – immobilization of organic P, are strongly influenced by seasonal variations in temperature, moisture, plant growth and root activity, and by organic matter accumulation from litter fall (Perrott et al., 1990; Mc Gvath et al., 2000). Land cover changes also affect 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 that influence the biotic and edaphic components of the ecosystem (Zeng et al., 2009). Soil water regime is highly affected by soil structure and its stability. Various soil structure types may cause preferential flow or water immobilization (Kodešová et al., 2006, 2007, 2008, 2009a,b). 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 structure related range. Swardji 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 available nutrients in soil has pedological as well as ecological importance (Iwara et al., 2011). 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, is controlled by a combination of factors viz, parent material, topography, soil management practices and rainfall and time in the area. Akin to this, land use patterns and vegetation play important rule in soil nutrient transformation and fertility. Anthropogenic changes alter several processes in soil, physical (porosity, soil structure and aggregate stability and water repellency), chemical (soil organic matter, nutrient availability and cycling, pH and C: N) and biological (microbial composition, soil faunal diversity and density, biomass productivity and carbon sequestration (Zeng et al., 2009).

During literature review, study on the seasonal dynamic on soil chemical properties in the Northern Guinea

savanna in Nigeria was sketchy, 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, 1975). Thus, the present investigation is an attempt to document the seasonal dynamics on the chemical properties of the tropical savanna wood land ecosystem in Nigeria.

## MATERIALS AND METHODS

### Site description

The present study was undertaken at Kamuku National Park is located in Birnin Gwari, Kaduna State of Nigeria. It is situated between latitudes 10°40'N; longitudes 6°11'E and 6°36'E in the north-central part of Nigeria.

### 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 (Kowal and Knabe, 1972).

### Climate

Northern Guinea savanna seasonal climate is characterized by a two peaks pattern of rainfall feature common in the northern Guinea savanna (Kowal and Knabe, 1972). The duration of the well defined dry and wet seasons, however varies from year to year.

### Rainfall and temperature

The annual rainfall of 913.5 mm occurred between March to October. The rainfall within a year shows two maxima, the first one of 244.3 mm occurring in June, while the second one with 239.7 mm is in September (Figure 1). The temperature was fairly constant for the year and ranged between 22.7 and 27.3°C for the minimums, while the mean monthly maximum temperature ranged between 30.5 and 37.6°C (Figure 2).

### Plot lay-out and soil sampling

The study site was located in the north-eastern and south-western portion of the reserve. In each location in the forest, one 100 m × 100 m was divided into 100 plots of 10 m × 10 m.

Twenty plots were randomly selected at each location 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 to 4.9, 5 to 9.9, 10 to 14.5 and 15 to 20 cm.

### Methods of samples collection and 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.

### Particle size analysis

This was done by hydrometer method (Gee and Bauder, 1986).

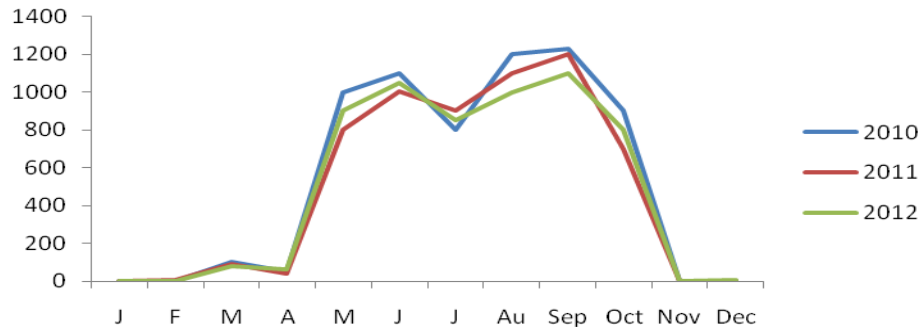


Figure 1. Rainfall (mm) distributions for 2010, 2011 and 2012.

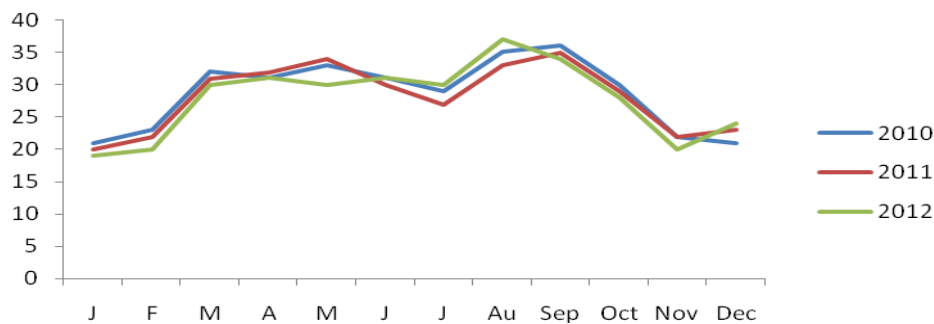


Figure 2. Temperature (°C) Distributions for 2010, 2011 and 2012.

using sodium hexametaphosphate (calgon) as dispensing agent.

### 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 Walkley 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. Available phosphorus was extracted using Bray II method (Bray and Kurtz, 1965) and determined by spectrophotometer.

Exchangeable Na, K, Ca and Mg were extracted with  $BaCl_2$  0.1 M (Hendershot et al., 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 =  $TEB/CEC \times 100$ , where TEB = Total exchangeable bases, and 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

### Soil pH, organic carbon, total soil nitrogen and available phosphorus (OC, N)

There were significant differences in soil pH, soil carbon, total nitrogen and available phosphorus among the sampling depths during dry season (January A)  $p \leq 0.05$  (Table 1). Also significant differences were observed among the sampling depths for the properties considered during the beginning of rains (May B) (Table 2), peak of rainfall (September C) (Table 3), while at the end of rain in November, pH showed no significant differences among 4.9 to 9.9, 10 to 14.9 and 15 to 20 cm, but there were significant differences in the soil carbon, total nitrogen and available phosphorus.

In the same vein, significant differences were recorded in the soil pH, soil organic carbon, total nitrogen and available phosphorus across the seasons. The soil pH, organic carbon, total nitrogen and available soil phosphorus decreased down the profile. Across the seasons, pH values were higher at the beginning and peak of rains, organic carbon values were higher at the

**Table 1.** Effect of seasonal changes on the soil chemical properties in dry season (January).

Depth (cm)	Properties												
	pH (H <sub>2</sub> O)	OC %	OM %	N %	C/N	Ca	Mg	K	Na	TEB	Av. P	E.A	CEC
						Cmol/kg of soil							
0-4.9	6.5 <sup>b</sup>	0.64 <sup>a</sup>	1.1 <sup>a</sup>	0.07 <sup>a</sup>	9.1 <sup>a</sup>	6.16 <sup>a</sup>	1.02 <sup>a</sup>	0.55 <sup>a</sup>	0.06 <sup>a</sup>	7.79 <sup>a</sup>	2.9 <sup>a</sup>	0.19 <sup>a</sup>	7.99 <sup>a</sup>
5-9.9	5.7 <sup>a</sup>	0.57 <sup>b</sup>	0.98 <sup>b</sup>	0.06 <sup>b</sup>	9.5 <sup>a</sup>	4.14 <sup>b</sup>	0.89 <sup>b</sup>	0.33 <sup>b</sup>	0.06 <sup>a</sup>	5.42 <sup>b</sup>	2.4 <sup>b</sup>	0.17 <sup>b</sup>	5.59 <sup>b</sup>
10-14.9	5.8 <sup>a</sup>	0.35 <sup>c</sup>	0.6 <sup>c</sup>	0.05 <sup>c</sup>	7.0 <sup>b</sup>	2.91 <sup>c</sup>	0.88 <sup>b</sup>	0.29 <sup>c</sup>	0.06 <sup>a</sup>	4.14 <sup>c</sup>	1.9 <sup>c</sup>	0.15 <sup>c</sup>	4.29 <sup>c</sup>
15-20	5.5 <sup>b</sup>	0.32 <sup>d</sup>	0.55 <sup>d</sup>	0.05 <sup>c</sup>	6.4 <sup>c</sup>	3.01 <sup>c</sup>	0.76 <sup>c</sup>	0.32 <sup>b</sup>	0.04 <sup>b</sup>	4.13 <sup>c</sup>	1.5 <sup>d</sup>	0.14 <sup>c</sup>	4.27 <sup>c</sup>

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 2.** Effect of seasonal changes on the soil chemical properties at the beginning of rain (May).

Depth (cm)	Properties												
	pH (H <sub>2</sub> O)	OC %	OM%	N %	C/N	Ca	Mg	K	Na	TEB	Av. P	E.A	CEC
						Cmol/kg of soil							
0-4.9	5.4 <sup>c</sup>	0.69 <sup>a</sup>	1.19 <sup>a</sup>	0.08 <sup>a</sup>	8.6 <sup>a</sup>	3.51 <sup>a</sup>	0.86 <sup>a</sup>	0.54 <sup>a</sup>	0.05 <sup>ns</sup>	4.96 <sup>a</sup>	2.8 <sup>a</sup>	0.19 <sup>a</sup>	5.15 <sup>a</sup>
5-9.9	5.8 <sup>a</sup>	0.57 <sup>b</sup>	0.98 <sup>b</sup>	0.07 <sup>a</sup>	8.1 <sup>b</sup>	3.27 <sup>b</sup>	0.82 <sup>b</sup>	0.35 <sup>b</sup>	0.05 <sup>ns</sup>	4.49 <sup>b</sup>	2.3 <sup>b</sup>	0.18 <sup>b</sup>	4.67 <sup>b</sup>
10-14.9	5.8 <sup>a</sup>	0.46 <sup>c</sup>	1.01 <sup>b</sup>	0.06 <sup>b</sup>	7.7 <sup>c</sup>	2.76 <sup>c</sup>	0.84 <sup>b</sup>	0.28 <sup>c</sup>	0.05 <sup>ns</sup>	3.93 <sup>c</sup>	1.8 <sup>c</sup>	0.16 <sup>c</sup>	4.09 <sup>c</sup>
15-20	5.5 <sup>b</sup>	0.43 <sup>c</sup>	0.74 <sup>c</sup>	0.06 <sup>b</sup>	7.1 <sup>d</sup>	2.30 <sup>c</sup>	0.84 <sup>b</sup>	0.26 <sup>c</sup>	0.05 <sup>ns</sup>	3.45 <sup>d</sup>	1.4 <sup>d</sup>	0.14 <sup>d</sup>	3.59 <sup>d</sup>

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 3.** Effect of seasonal changes on the soil chemical properties at the peak of rain (September).

Depth (cm)	Properties												
	pH (H <sub>2</sub> O)	OC %	OM %	N %	C/N	Ca	Mg	K	Na	TEB	Av. P	E.A	CEC
						Cmol/kg of soil							
0-4.9	5.6 <sup>b</sup>	1.0 <sup>a</sup>	1.72 <sup>a</sup>	0.08 <sup>a</sup>	12.5 <sup>a</sup>	4.22 <sup>a</sup>	1.14 <sup>a</sup>	0.48 <sup>a</sup>	0.05 <sup>a</sup>	5.89 <sup>a</sup>	2.5 <sup>a</sup>	0.29 <sup>a</sup>	6.18 <sup>a</sup>
5-9.9	5.9 <sup>ab</sup>	0.79 <sup>b</sup>	1.36 <sup>b</sup>	0.08 <sup>a</sup>	9.87 <sup>b</sup>	3.88 <sup>b</sup>	0.96 <sup>b</sup>	0.37 <sup>b</sup>	0.04 <sup>ab</sup>	5.25 <sup>b</sup>	1.7 <sup>b</sup>	0.08 <sup>b</sup>	5.33 <sup>b</sup>
10-14.9	6.0 <sup>a</sup>	0.54 <sup>c</sup>	0.93 <sup>c</sup>	0.07 <sup>b</sup>	7.71 <sup>c</sup>	2.86 <sup>c</sup>	0.92 <sup>c</sup>	0.28 <sup>b</sup>	0.04 <sup>ab</sup>	4.1 <sup>c</sup>	1.4 <sup>c</sup>	0.15 <sup>c</sup>	4.25 <sup>c</sup>
15-20	6.0 <sup>a</sup>	0.51 <sup>d</sup>	0.88 <sup>d</sup>	0.07 <sup>b</sup>	7.28 <sup>d</sup>	2.19 <sup>d</sup>	0.81 <sup>d</sup>	0.24 <sup>c</sup>	0.03 <sup>b</sup>	3.27 <sup>d</sup>	1.5 <sup>c</sup>	0.14 <sup>c</sup>	3.41 <sup>d</sup>

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, E.A = exchange acidity and CEC = cations exchange capacity.

peak and end of rains while the total soil nitrogen had the highest value at the end of rains. The available phosphorous values were higher during the dry season and at the beginning of rains.

#### Calcium, magnesium, potassium, sodium and total exchange bases (Ca, Mg, K, Na and TEB)

There were significant differences in calcium (Ca), magnesium (Mg), and potassium (K) among the sampling depths  $p \leq 0.05$  in dry season, while sodium (Na) and total exchange bases (TEB) showed no significant

difference during this season (Table 1).

At the beginning of rains (May) (Table 2), sodium showed no significant differences among the sampling depths, while calcium, magnesium, potassium and total exchange bases, showed significant differences among the sampling depths (November D) (Table 4). At the peak of rainfall (September C) (Table 3), there were significant differences among the sampling depths for calcium, magnesium, potassium, sodium and total exchange bases. They also decreased down the depth. Available phosphorous, exchangeable acidity and cations exchange capacity also decreased down the depth.

There were significant differences in the values of

**Table 4.** Effect of seasonal changes on the soil chemical properties at the peak of End (November).

Depth (cm)	Properties												
	pH (H <sub>2</sub> O)	OC %	OM %	N %	C/N	Ca	Mg	K	Na	TEB	Av. P	E.A	CEC
						Cmol/kg of soil							
0-4.9	5.8 <sup>ab</sup>	1.3 <sup>a</sup>	2.24 <sup>a</sup>	0.09 <sup>a</sup>	14.44 <sup>a</sup>	6.24 <sup>a</sup>	1.13 <sup>a</sup>	0.38 <sup>a</sup>	0.06 <sup>a</sup>	7.81 <sup>a</sup>	2.5 <sup>a</sup>	0.29 <sup>a</sup>	8.10 <sup>a</sup>
5-9.9	6.1 <sup>a</sup>	0.76 <sup>b</sup>	1.31 <sup>b</sup>	0.09 <sup>a</sup>	8.44 <sup>b</sup>	3.82 <sup>b</sup>	0.86 <sup>b</sup>	0.27 <sup>b</sup>	0.05 <sup>b</sup>	5.00 <sup>b</sup>	1.7 <sup>c</sup>	0.17 <sup>b</sup>	5.17 <sup>b</sup>
10-14.9	6.0 <sup>a</sup>	0.59 <sup>c</sup>	1.01 <sup>bc</sup>	0.08 <sup>ab</sup>	7.38 <sup>c</sup>	3.36 <sup>bc</sup>	0.82 <sup>c</sup>	0.27 <sup>b</sup>	0.05 <sup>b</sup>	4.50 <sup>c</sup>	1.6 <sup>c</sup>	0.14 <sup>c</sup>	4.64 <sup>c</sup>
15-20	5.9 <sup>a</sup>	0.51 <sup>c</sup>	0.88 <sup>c</sup>	0.07 <sup>ab</sup>	7.29 <sup>c</sup>	3.87 <sup>b</sup>	0.81 <sup>c</sup>	0.22 <sup>c</sup>	0.03 <sup>c</sup>	4.93 <sup>c</sup>	1.3 <sup>d</sup>	0.13 <sup>c</sup>	5.06 <sup>b</sup>

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, E.A = exchange acidity and CEC = cation exchange capacity.

calcium, magnesium, potassium and total exchange bases across the seasons. However, calcium values were higher in the peak and end of rainfall. Potassium values were higher at the beginning of rains, while sodium values had it highest values during the dry season. Total exchange bases values were more during the dry season and at the beginning of rains. Across the seasons, calcium and total exchangeable bases had the highest at the end of rains, while, magnesium and potassium had their highest values at the peak and end of rains. However, the values of sodium remain fairly constant at the beginning, peak and end of rains.

#### Exchangeable acidity (EA) and cations exchangeable capacity (CEC)

The exchangeable acidity (EA) and cation exchange capacity (CEC) showed significant differences in the sampling depths  $p \leq (0.05)$  (Table 1) during dry season, with the highest values of 0.19 cmol/kg soil recorded in 0 to 4.9 cm depth, for CEC, while the highest value of 7.99 cmol/kg of soil was recorded from 0 to 4.99 cm depth (Table 1). At the beginning of rains, the values of EA and CEC remained constant as that of the dry season (Table 2) and showed significant differences in the sampling depths and decreased down the depths.

At the peak of rainfall (September C), the values showed significant differences in the sampling depths with the highest values of 0.29 cmol/kg of soil recorded at 0 to 4.9 cm depth. Also CEC values were high during this period, with the highest value recorded at 0 to 4.9 cm depth (Table 3), they decreased down the depths.

At the end of rains (November D) (Table 4), the values of EA and CEC remained showed significant differences in the sampling depths and decreased down the depths. Across the seasons, significant differences were observed for both exchangeable acidity (EA) and CEC. The highest value of EA recorded at the peak and end of rains. In the same vein, the highest values of 5.59 cmol/kg of soil was recorded at the end of rains for CEC (Table 5).

## DISCUSSION

### Sampling depths and seasonal patterns of soils pH, soil organic carbon, total nitrogen and available phosphorus

The results of this study revealed sampling depths and seasonal patterns of soil pH, soil organic carbon, total nitrogen and available phosphorus in a tropical Northern Guinea woodland savanna.

#### Soil reactions (pH)

The distribution of soil pH down the depths in dry season and at the beginning of rains may be due to little or absence of rains which resulted in little or no movement of cations down the profile. 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 of dissolved cations as a result, soil pH increased down the depth.

The changes in soil pH over the seasons of the year, may be attributed to the dry season burning in January, 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 slightly increased in soil pH at this time (Fatubarin and Olojugba, 2014).

#### Organic matter

The distribution of soil organic carbon in the dry season of the year (January) may be due to low rains and burning that usually occurs in the area (Fatubarin and Olojugba, 2014) (Table 1). Also, soil organic carbon tends to decrease down the profile, as a result of low decomposition down the profile, due to little or absence of soil microorganisms that are responsible for the decomposition. This view was supported by Olojugba (2010) who was of the opinion that decrease of both

**Table 5.** The mean values (n=10) of some soil chemical properties across seasons (0 to 20 cm).

Season	Properties												
	pH (H <sub>2</sub> O)	OC %	OM %	N %	C/N	Ca	Mg	K	Na	TEB	Av. P	E.A	CEC
						Cmol/kg of soil							
A	6.3 <sup>b</sup>	0.46 <sup>d</sup>	0.8 <sup>d</sup>	0.05 <sup>c</sup>	9.20 <sup>b</sup>	3.0 <sup>d</sup>	0.88 <sup>b</sup>	0.31 <sup>b</sup>	0.05 <sup>a</sup>	4.24 <sup>a</sup>	2.08 <sup>a</sup>	0.15 <sup>b</sup>	4.39 <sup>c</sup>
B	6.3 <sup>a</sup>	0.58 <sup>c</sup>	1.00 <sup>c</sup>	0.06 <sup>b</sup>	9.67 <sup>a</sup>	3.36 <sup>c</sup>	0.84 <sup>c</sup>	0.35 <sup>a</sup>	0.04 <sup>b</sup>	4.59 <sup>b</sup>	2.08 <sup>a</sup>	0.15 <sup>b</sup>	4.70 <sup>b</sup>
C	6.28 <sup>b</sup>	0.66 <sup>b</sup>	1.12 <sup>b</sup>	0.06 <sup>b</sup>	11.00 <sup>c</sup>	3.48 <sup>b</sup>	0.96 <sup>a</sup>	0.29 <sup>c</sup>	0.04 <sup>b</sup>	4.77 <sup>d</sup>	1.73 <sup>b</sup>	0.16 <sup>a</sup>	4.93 <sup>b</sup>
D	5.98 <sup>c</sup>	0.85 <sup>a</sup>	1.47 <sup>a</sup>	0.08 <sup>a</sup>	10.63 <sup>b</sup>	4.24 <sup>a</sup>	0.96 <sup>a</sup>	0.29 <sup>c</sup>	0.04 <sup>b</sup>	5.53 <sup>c</sup>	1.73 <sup>b</sup>	0.16 <sup>a</sup>	5.69 <sup>a</sup>

Means on the same column followed by the same letter are not significantly different at  $P \leq 0.05$ ; 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, E.A = exchange acidity and CEC = cations exchange capacity.

microbial activities down the slope as well as decrease of soil air/porosity might responsible for the decrease of the soil organic matter (Tables 1 to 4). The distribution of organic carbon across the seasons might be due to high rainfall recorded at the peak of rains (September), which enhanced more decomposition and accumulation of soil organic carbon in the area (Fatubarin and Olojugba, 2014). The low organic matter found in January can be attributed to a very high intensity fire occurred in the study area in January. However, the establishment of post fire vegetation, through both re-sprouting and seedling establishment, was rapid on the burned plot during the peak of rainfall (September) (Table 3). This enhanced litter fall, hence more organic matter (Litton and Santelices, 2002).

### Total nitrogen

Other studies have reported variable results in relation to seasonal 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 1). Actual losses of nitrogen due to volatilization have been estimated to vary from 75 kg/ha (Klemmedson, 1976) to 907 kg/ha (Grier, 1975). A likely explanation for decreased soil nitrogen in May (beginning of rains) (Table 2) in burned plots, is through increased 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 3) and at the end of rains in November (Table 4), could be best explained by a possible increase in activity of nitrogen fixing microbes (Zeng et al., 2009). 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 (Zeng et al., 2009).

The low total nitrogen and C/N distribution during the dry season and at the beginning of rainy seasons might be due to low rainfall which reduced mineralization as well as the distribution of soil organic matter in the area. However, the moderate total nitrogen recorded during the peak of rainfall (September) (Table 3) might not be unconnected with the high rate of mineralization due to high rainfall (Mc Gvath et al., 2000).

### Exchangeable cations (Na, Ca, Mg, K)

The distribution of exchangeable cation except sodium, showed significant differences from their values in the proceeding November. 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 (Hopekins, 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 suckering and sprouts from the plants of the herbaceous layer and possibly the flowers of ligneous savanna plants. 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. Therefore, the limitation of N, P, Ca, Mg, K, to tree growth is most likely to occur in September (Peak of rainy season).

### 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 1) and in May (beginning of rains) (Table 2), 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 showed that it was fairly constant in dry season (January) and at the beginning of raining season (May) (Table 2) and decreased sharply during the peak of rainfall (September) (Table 3). This might be attributed to the growth of plants and accumulation of biomass during growing season (Styles and Coxon, 2007).

The low cation exchange capacity (CEC) in the area may be due to the distribution of soil organic carbon as well as low activity clays (Fatubarin, 1980). This situation could have arisen due to the excessive amount rainfall between May and September.

In the savanna woodland of this study, increased organic inputs from litter at the peak of raining seasons were recognized as a major contribution to the increased available P, which were consistent with the previous findings.

The low CEC might be due to change in the clay type and the nature of parent material (Olojugba, 2010a).

## CONCLUSION AND RECOMMENDATIONS

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 seasonal changes were soil organic matter, total nitrogen, soil pH, available phosphorus, exchange cation (Ca, Mg and K), cation exchangeable capacity (CEC). The two major 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 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. 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.

## Conflict of Interest

The authors have not declared any conflict of interest.

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