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Changes in Nutrient Contents of Soil Across Different Land Uses in a Forest Reserve

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Abstract

In order to assess the changes in soil chemical properties' resulting from conversion of forest to other agricultural land uses a study was conducted in Okomu Forest Reserve (Nigeria). Five soil samples collected from top and sub soils of marked points within the undisturbed forest, farmland, cocoa plantation, oil palm plantation and rubber plantation were analyzed for pH, organic carbon, total nitrogen, available phosphorus, exchangeable acidity, sodium, potassium, calcium and magnesium. The results showed variations in all chemical parameters across the land use types with soil depths (top and sub soils). Soil pH ranged from 4.88 (in the cocoa plantation subsoil) to 6.75 (in the forest top soil). Soils (top and sub soils) of the rubber plantation, forest and cocoa plantation had the highest stock of soil organic carbon (SOC), N and exchangeable Na respectively. Available P was highest in the top soil of the rubber plantation and sub soil of the farmland. Exchangeable Ca and Mg were highest in the top soil of the forest and sub soil of the rubber plantation. Exchangeable K and C:N was highest in the farmland top soil and cocoa plantation sub soil. Relationship among the chemical parameters varied with soil depth. Conversion of forest and cocoa plantation resulted in the highest decline (55.78% and 44.40%) in soil N. There is the need to regulate the conversion of natural forests to agricultural lands and plantations as conserve the nutrient cycling processes.

Keywords: conservation, farmland, land use, plantations, productivity, soil nutrients

Introduction

Land use changes have remarkable effects on the dynamics of soil properties (Ozgoz *et al*., 2013). A change from forest cover to cultivated land may hinder addition of litter that enhances nutrient content of soils (Ozgoz *et al*., 2013), increase rates of erosion (Biro *et al*., 2013), loss of soil organic matter and nutrient (Saha and Kukal, 2015), and accelerate rate of soil degradation (Barua and Haque, 2013). This process, in turn, leads to a decline in soil fertility and loss of biological activity and diversity (Yao *et al*., 2010). Vegetation cover is, therefore, a key indicator of soil degradation as plants play a role in the control of soil erosion (Cedar, 1998; Keesstra *et al*., 2009; Kropfl *et al*., 2013; Tejada and Benitez, 2014; Bochet, 2015).

Indeed, changes in land cover have significant effect on the amount and diversity of biomass returned to the soil, which also disrupt the richness of nutrient restored to the soil. It is perhaps a known fact that soil erosion intensity and amount of nutrient element loss varies depending on the vegetation type at a particular place and time. This is so because, the rate of nutrient element loss in both dissolved and sediment bound forms will depend on the ability of vegetation canopy to effectively intercept the direct impact of raindrops that strike the soil surface (Iwara, 2011). If the canopy is not dense enough or well developed, little nutrients return to the soil as well as large quantities of nutrient will be removed from the soil surface during periods of heavy rainstorm when the soil is saturated.

Different studies have examined the effects of land use/cover change on physico-chemical properties of the soil (Lal, 1996; Bossuyt *et al*., 1999; Eneji *et al*., 2003; Evrendileka *et al*., 2004; Emadi *et al*., 2008; Agoume and Birang, 2009; Gol, 2009; Offiong *et al*., 2009). These studies nevertheless characterized changes in soil properties in relation to emerging land use/cover change in their respective ecosystems. The conversion of Forest Reserve to other land-uses in recent times has caused many complex changes in the forest ecosystem whose impact raises diverse ecological problems (Henrik *et al*., 2010). Increasing population coupled with urban poverty has exacerbated the migration of people into rural areas especially villages closer or inside the Forest Reserves in Nigeria (Adeofun and Akinsanmi, 1997). This has led to the de-reservation of substantial parts of most of the Forest Reserves in Nigeria (such as Okomu, Omo, Oluwa, and Olokemeji forests) for the establishment of monoculture plantations, while encroachment by landless farmers for agricultural activities has further impoverished many (Ola-Adams, 1996,

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Ogunleye *et al*., 2004). The structural alteration of the potential forest reserves has not been without cost and has resulted in a mosaic of land-uses within the forest reserves. Both forest litters and soil microbes constitute an important resource that makes forests fertile for arable farming in the tropics (Akachukwu, 2006) and the fertility status of a soil is acknowledged to be a reflection of the soil properties and soil texture characteristics (Michel *et al*., 2010). The change in forest cover to other forms of land cover such as plantation and grassland results in the tremendous modification of canopy cover, thereby making the area affected susceptible to soil erosion; this affects the stock of soil organic carbon (SOC). The conversion of forest ecosystem to other forms of land cover may decrease the stock of SOC due to changes in soil moisture and temperature regimes, and succession of plant species with differences in quantity and quality of biomass returned to the soil (Offiong and Iwara, 2012).

The conversion of forest land to tree plantations and food crops plots has been shown to adversely affect soil carbon and nitrogen levels (Michel *et al.*, 2010). There are also strong indications that the conversion of tropical forests into land for agriculture or plantation might have negative impacts on soil properties and the carbon budget (Hertel *et al*., 2009). Hence, a selection of appropriate ecological indicators with well-established sensitivity to disturbances will assist in assessing the extent of these impacts with a view to addressing the associated ecological problems.

Consequently, soil physical and chemical properties have been proposed as suitable indicators for assessing the effect of land-use changes and management (Janzen *et al.*, 1992; Bremer *et al*., 1994; Alvarez and Alvarez, 2000). This approach has been used extensively by several authors to monitor land-cover and land-use change patterns (Schroth *et al*., 2002; Airiohuodion, 2003; Faboya, 2010; Michel *et al*., 2010). Similarly, a lot of studies have been carried out on the soil physiochemical and biological changes (Schroth *et al*., 2002; Tchienkoua and Zech, 2004; Walker and Desanker, 2004) over the humid tropical regions of the world. In spite of the economic importance of plantation forestry and agriculture, previous studies on the effects of different land-use types on soil properties in Nigeria are grossly inadequate, hence this study. The present study assesses variations in soil properties associated with different land-use types within Okomu Forest Reserve, Edo State, Nigeria.

Materials and Methods

Study area

Okomu Forest Reserve is located in Ovia South-West Local Government Area of Edo state and occupied an area of 1082 km^2 within the lowland forest of Nigeria. It is lies geographically between longitudes 5°N to 5°30' E and latitudes 6°N to 6°10'N precisely between the River Osse and Siluko to the East and West respectively and about 40 km from Benin City, the state capital. The reserve derived its name from River Okomu from the Benin word 'Akomu' meaning unity. The reserve was named Okomu during the colonial constitution of the reserve.

Okomu area has well marked rainy and dry seasons. The dry season which lasts from November to March is usually accompanied by northeast trade wind that causes *harmattan* (Azeez *et al*., 2010). It receives a mean annual rainfall above 2500 mm per annum (Akinsorotan *et al*., 2011) falling mainly between March and October with the highest rainfall occurring in June, July and September. The mean monthly temperature is 30 °C. The relative humidity is high and usually not less than 65% during the afternoons in any month of the year.

Collection of soil samples

Five different land use types were identified within Okomu Forest Reserve to include oil palm plantation, cocoa plantation, rubber plantation, secondary forest and cultivated cropland/farmland and each is 0.5 ha in size. Five sampling points were marked out within each land use type and georeferenced using Garmin eTrex X GPS device (Table 1). Soil samples were collected from marked points from 0-15 cm (top soil) and 15-30 cm (sub soil) depths using a Stainless Dutch soil Auger. The soil samples were packed in labelled polythene bags, air dried in the laboratory and passed through 2 mm sieve prior to chemical analysis.

Chemical analysis

Soil pH was determined in 1.0 N KCl employing a 1:1 soil/solution mixture (Thomas, 1996) and read with a digital pH meter after equilibration. Soil organic carbon was determined by the Walkley-Black wet oxidation method (Nelson and Sommers, 1996). Soil nitrogen was determined by the macro Kjeldahl method of digestion, distillation and back titration (Bremmer, 1996). Available phosphorus was determined by the Bray-P1 method (Kuo, 1996).

Table 1. Geo-position of soil sampling points within five land use types in Okomu Forest Reserve, Edo State, Nigeria

Sampling points†	Forest		Farmland		Cocoa plantation		Oil palm plantation		Rubber plantation	
1	N06.41819 E005.46671	178ft	N06.29560 E005.37022	151ft	N06.29569 E005.36821	149ft	N06.35301 E005.35764	241ft	N06.39125 E005.38937	305ft
2	N06.41842 E005.46689	189ft	N06.29567 E005.37030	147ft	N06.29553 E005.36813	142ft	N06.35305 E005.35787	249ft	N06.39172 E005.38954	298ft
3	N06.41878 E005.46704	191ft	N06.29560 E005.37053	137ft	N06.29538 E005.36803	138ft	N06.35314 E005.35797	247ft	N06.39149 E005.38927	304ft
4	N06.41893 E005.46716	182ft	N06.29539 E005.37064	134ft	N06.29528 E005.36827	134ft	N06.35346 E005.35805	223ft	N06.39180 E005.38912	308ft
5	N06.41919 E005.46824	185ft	N06.29520 E005.37088	127ft	N06.29531 E005.36853	134ft	N06.35320 E005.35828	216ft	N06.39175 E005.38872	310ft

†Distances indicated recorded in feet (ft) are height above sea level.

Exchangeable acidity was determined by titration using 1.0 M KCl for extraction (Bertsch and Bloom, 1996). Soil exchangeable cations were extracted using 1.0 N ammonium acetate, NH_4OAc buffered to pH 7.0 (Thomas, 1982). The concentrations of Ca, Mg, K and Na in the filtrate were then determined by spectrophotometry. Na and K concentrations was determined using a flame photometer while Ca and Mg was determined using Atomic Absorption Spectrophotometer (AAS) (Buck Scientific 2.0).

Data analysis

Data on concentrations of soil pH and nutrients were analysed using GLM model in SAS 9.1.3 software for Windows (SAS Institute, 2003). The means were separated using Duncan's Multiple Range test at $\alpha = 0.05$. Bar graphs for the concentrations of soil nutrients were plotted using Microsoft Excel 2013 (Microsoft Corporation, 2012). Bar graphs for deterioration indices were plotted using Origin 8 Pro for Windows (Origin Lab Corporation, 2007). Deterioration/improvement in soil nutrients in the land uses relative to the undisturbed forest was calculated using the deterioration index (DI) of Ekanade (1991) as adopted by Oyedeji *et al.* (2016) where:

$$\boldsymbol{Deterioration\ index, DI,} = \frac{\boldsymbol{X - X_i}}{\boldsymbol{X}} \times \mathbf{100}$$

X = mean value of soil nutrient in the forest soil (reference site); Xi = mean value of soil nutrient in the compared site. Note: a positive value indicates deterioration and a negative value indicates improvement.

Results

Concentrations of soil chemical parameters

There were significant differences ($P < 0.05$) in soil pH, organic carbon, nitrogen, phosphorus, exchangeable acidity and soil cations (Na, K, Ca and Mg) in the different land uses. Significant variations also exist between the levels of the soil parameters in the top soil and sub soil. There were also significant interactions between the land use and soil depth (top and sub soils) for all assessed soil parameters (Table 2).

The soil pH ranged from very strongly acid (4.88) in the sub soil of cocoa plantation to neutral (6.75) in the top soil of Okomu forest. The top soil of cocoa plantation was most acidic (5.05) among the land uses. In all the land uses, pH was significantly higher in the top soil than the sub soil, except in the oil palm plantation (Fig. 1a). Organic carbon was generally highest in the rubber plantation – 1.46% and 1.25% respectively in the top soil and sub soil. The least % OC in the top soil and sub soil were 0.80% and 0.73% in the cocoa plantation and farmland respectively. Soil OC was generally higher in the top soil than sub soil except in the cocoa plantation (Fig. 1b). Nitrogen content in the top soil and sub soil was significantly highest in the forest land – 48.19 mg kg^{-1} and 47.72 mg kg^{-1} respectively. The least N content was in the top soil of the farmland (21.31 mg kg^{-1}). The forest and cocoa plantation had higher N concentration in the top soil than the sub soil (Fig. 1c). Carbon-nitrogen ratio was significantly highest in the top soil of the farmland (555.59). The least C:N was in forest sub soil (212.47). The top soils of the land use types had higher C:N than the sub soils, except in the cocoa plantation (Fig. 1d). Available phosphorus concentration was generally highest in the top soil of the rubber plantation (14.20 mg kg^{-1}) while the farmland had the highest P in the sub soil (10.12 mg kg^{-1}). The least levels of P in the top soil and sub soil were 6.77 mg kg^{-1} and 5.63 mg kg^{-1} respectively in the oil palm plantation and forest (Fig. 1e). Exchangeable acidity was significantly highest in the top soil of cocoa plantation (0.16 meq/100 g). The sub soil of the forest had the lowest acidity (0.05 meq/100 g). Acidity was generally higher in the top soil than the sub soil, except in the oil palm plantation where measure of soil acidity was statistically the same (0.10 meq/100 g) in the top soil and sub soil (Fig. 1f).

Sodium had the highest concentrations among the exchangeable cations across the land use types. Exchangeable Na was highest in the top soil (4.48 mg kg^{-1}) and sub soil (5.01 mg kg^{-1}) of the cocoa plantation. The farmland and rubber plantation had the lowest concentrations in the top soil (3.41 mg kg^{-1}) and sub soil (3.09 mg kg^{-1}) respectively. Na was generally higher in the sub soil than top soil except in the rubber plantation. Exchangeable K was however highest in the top soil of the farmland (0.87 mg kg^{-1}). The

Table 2. Results of analysis of variance and mean squares of soil chemical properties at two soil depths in five different land use types at two soil depths

Sources of variation	df	pH	%OC	N	C:N	P	Ex. acidity	K	Na	Ca	Mg
Land use	4	2.47*	0.28*	738.35*	49318.25*	25.88*	0.006*	0.08*	2.68*	4.15*	0.58*
Soil depth	1	1.56*	0.14*	192.43*	84191.35*	10.77*	0.011*	0.04*	1.47*	0.35*	0.02*
Land use × soil depth	4	1.26*	0.18*	111.72*	76299.59*	36.60*	0.001*	0.10*	1.07*	0.77*	0.12*
Error	40	8.04E-4	3.94E-4	6.10E-4	51.53	2.94E-4	1.92E-4	1.28E-4	1.47E-4	4.25E-5	4.79E-5

df: degrees of freedom, Ex. Acidity: exchangeable acidity and *P<0.05

Table 3. Exchangeable cations (Na, K, Ca and Mg in mg kg^{-1}) at top and sub soil in five different land use types

Land use type	Na		K		Ca		Mg	
	Top soil	Sub soil	Top soil	Sub soil	Top soil	Sub soil	Top soil	Sub soil
Forest	3.93^{c}	4.04^{d}	0.65^{c}	0.58^{e}	2.90^{a}	1.90^{b}	1.17^{a}	0.76^{b}
Farmland	3.41^{e}	4.61^{c}	0.87^{a}	0.71^{c}	0.98^{e}	1.34^{e}	0.39^{e}	0.54^{e}
Cocoa plantation	4.48^{a}	5.01^{a}	0.46^{e}	0.82^{a}	1.10^{d}	1.42^{d}	0.44^{d}	0.57^{d}
Oil palm plantation	4.22^{b}	4.67^{b}	0.71^{b}	0.80^{b}	1.70^{c}	1.49^{c}	0.68^{c}	0.60^{c}
Rubber plantation	3.68^{d}	3.09^{e}	0.55^{d}	0.61^{d}	2.71^{b}	2.39^{a}	0.95^{b}	0.95^{a}

Means with different letter down the column are significantly different at P<0.05

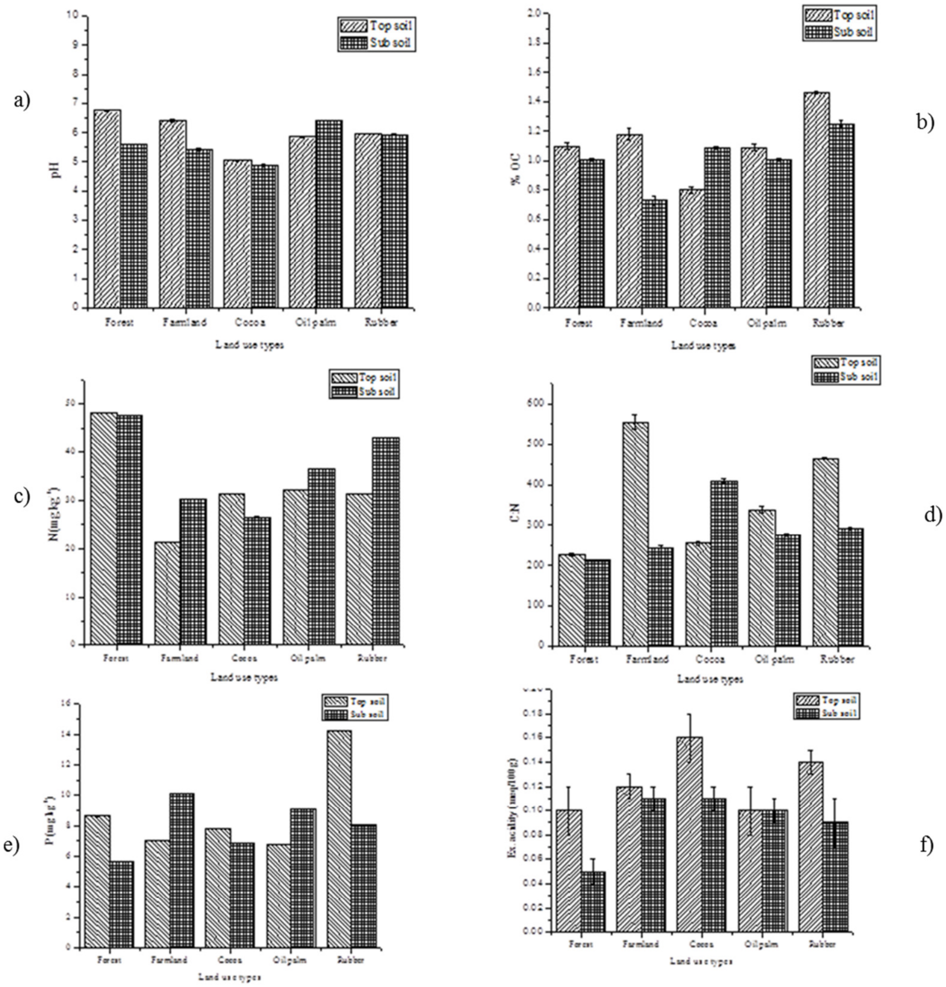

Fig. 1. (a) pH (b) organic carbon (c) N (d) C:N (e) P and (f) exchangeable acidity, in top and sub soil from five different land use types

cocoa plantation had the highest exchangeable K in the sub soil (0.82 mg kg^{-1}) and least exchangeable K in the top soil (0.46 mg kg^{-1}). Soil K in the top soil of the forest and farmland were higher than in the respective sub soils. Soil Ca was highest in the top soil of the forest (2.90 mg kg^{-1}) and sub soil of the rubber plantation (2.39 mg kg^{-1}). The farmland had the least Ca concentrations in the top soil (0.98 mg kg^{-1}) and sub soil (1.34 mg kg^{-1}). Soil Ca was higher in the top soil than the respective sub soils, except in the farmland. Soil Mg was highest in the top soil of the forest (1.17 mg kg^{-1}) and sub soil of the rubber plantation (0.95 mg kg^{-1}). The farmland had the least concentration of Mg in the top soil (0.39 mg kg^{-1}) and sub soil (0.54 mg kg^{-1}). The concentration of Mg in the top soil and sub soil of the rubber plantation were at par (0.95 mg kg^{-1}) (Table 3).

Relationship between soil chemical parameters in the land use types

Pearson correlation index for the soil chemical parameters in the top soils (Table 4) showed a significant positive relationship between pH and OC ($r = 0.51$, $p < 0.01$). Soil pH also correlated positively the soil exchangeable cations, except for Na where a significant negative relationship was observed ($r = -0.71$, $p < 0.01$). Soil pH also correlated negatively with exchangeable acidity ($r = -0.64$, $p < 0.01$). Soil OC correlated positively with C:N ($r = 0.65$, $p < 0.01$), available P ($r = 0.73$, $p < 0.01$), exchangeable Ca ($r = 0.49$, $p < 0.01$) and Mg ($r = 0.44$, $p < 0.05$). Soil OC also correlated negatively with exchangeable Na ($r = -0.75$, $p < 0.01$). Soil N showed a positive correlation with Ca ($r = 0.76$, $p < 0.01$) and Mg ($r = 0.84$, $p < 0.01$), and negatively correlated with C:N ($r = -0.79$, $p < 0.01$). C:N relate positively with soil K ($r = 0.59$, $p < 0.01$) and negatively with Na ($r = -0.81$, $p < 0.01$). Available P correlates positively with Ca ($r = 0.65$, $p < 0.01$) and Mg ($r = 0.53$, $p < 0.01$) but negatively with K ($r = -0.44$, $p < 0.05$). Exchangeable acidity relates negatively with K ($r = -0.48$, $p < 0.05$) and Mg ($r = -0.44$, $p < 0.05$). Na and K are negatively correlated ($r = -0.67$, $p < 0.01$), while Ca and Mg are positively correlated ($r = 0.99$, $p < 0.01$).

In the sub soil, soil pH correlated positively with N ($r = 0.52$, $p < 0.01$) and negatively with C:N ($r = -0.51$, $p < 0.01$). Soil OC correlated positively with C:N ($r = 0.40$, $p < 0.05$), Ca and Mg ($r = 0.75$, $p < 0.01$ respectively) and negatively with Na ($r = -0.58$, $p < 0.01$) and available P ($r = -0.51$, $p < 0.01$). Soil N correlated positively with Ca (r =

Table 4. Pearson correlation for soil chemical properties in the top soil of five land use types

	pH	OC	N	C:N	P	Ex. acidity	Na	K	Ca	Mg
pH	1.00									
OC	0.51^{**}	1.00								
N	0.33	-0.12	1.00							
C:N	0.23	$.649^{**}$	-0.79^{**}	1.00						
P	0.03	0.73^{**}	0.11	0.23	1.00					
Ex. Acidity	-0.64^{**}	-0.18	-0.39	0.10	0.23	1.00				
Na	-0.71^{**}	-0.75^{**}	0.33	-0.81^{**}	-0.30	0.21	1.00			
K	0.66^{**}	0.28	-0.35	0.59^{**}	-0.44^{*}	-0.48^{*}	-0.67^{**}	1.00		
Ca	0.49^{*}	0.54^{**}	0.76^{**}	-0.28	0.65^{**}	-0.37	-0.14	-0.25	1.00	
Mg	0.54^{**}	0.44^{*}	0.84^{**}	-0.37	0.53^{**}	-0.44^{*}	-0.09	-0.20	0.99^{**}	1.00

Values are correlation coefficient *significant at 0.05 level and **significant at 0.01 level.

Table 5. Pearson correlation for soil chemical properties in the subsoil of five land use types

	pH	OC	N	C:N	P	Ex. acidity	Na	K	Ca	Mg
pH	1.00									
OC	0.16	1.00								
N	0.52^{**}	0.39	1.00							
C:N	-0.51^{**}	0.40^{*}	-0.66^{**}	1.00						
P	0.33	-0.51^{**}	-0.46^{*}	-0.13	1.00					
Ex. acidity	-0.24	-0.20	-0.81^{**}	0.55^{**}	0.64^{**}	1.00				
Na	-0.37	-0.58^{**}	-0.75^{**}	0.36	0.17	0.38	1.00			
K	-0.15	-0.22	-0.85^{**}	0.65^{**}	0.38	0.66^{**}	0.81^{**}	1.00		
Ca	0.32	0.75^{**}	0.77^{**}	-0.21	-0.37	-0.45^{*}	-0.97^{**}	-0.76^{**}	1.00	
Mg	0.32	0.75^{**}	0.76^{**}	-0.21	-0.36	-0.44^{*}	-0.97^{**}	-0.76^{**}	1.00^{**}	1.00

Values are correlation coefficient *significant at 0.05 level and **significant at 0.01 level

0.77, $p < 0.01$) and Mg ($r = 0.76$, $p < 0.01$) and negatively with C:N ($r = -0.66$, $p < 0.01$), available P ($r = -0.46$, $p < 0.05$), exchangeable acidity ($r = -0.81$, $p < 0.01$), Na ($r = -0.75$, $p < 0.01$) and K ($r = -0.85$, $p < 0.01$). C:N correlated positively with exchangeable acidity ($r = 0.55$, $p < 0.01$) and K ($r = 0.65$, $p<0.01$). Available P also correlated positively with exchangeable acidity ($r = 0.64$, $p < 0.01$). Soil Na and exchangeable acidity both shared a positive correlation with K and negative correlations with Ca and Mg. Soil K correlated negatively with Ca and Mg ($r = -0.76$, $p < 0.01$ respectively). Ca perfectly and positively correlated with Mg in the sub soil ($r = 1.00$, $p < 0.01$) (Table 5).

Deterioration index for soil chemical nutrients in the land use types

The deterioration index (DI) for nutrient elements in Figs. 2a-b expresses the relative percentage of the chemical parameters in the land uses to that in the forest soil. A positive DI denotes a deterioration of the measured parameter while a negative DI denotes improvement of the parameter over that in the forest soil.

The result of deterioration index revealed positive DI for OC in the top soil of cocoa and oil palm plantations with 27.27% and 0.91% respectively. There was negative DI (improvement) for OC in the farmland (-7.27%) and rubber plantation (-30.00%). There was deterioration (positive DI) in nitrogen in the four land uses with the farmland accounting for the highest (55.78%) in the top soil. Available P deteriorated in the farmland, cocoa and oil palm plantations with 18.66%, 9.85% and 21.55% respectively. There was marked improvement (negative DI) in available P in the rubber plantation (-64.54%). Exchangeable Na improved in the top soil of the cocoa (-13.99%) and oil palm plantations (-7.38%), while K improved in the farmland (-33.85%) and oil plantation (-9.23%). Exchangeable Ca and Mg showed different levels of deterioration in the different land uses (Fig. 2a).

In the sub soil, there was improvement in OC except in the farmland where a positive deterioration was observed (27.0%). Soil N deteriorated in the four land use types with the cocoa plantation having the highest (44.40%). Available P improved (negative DI) in the sub soil of the land use types. Exchangeable Na also improved in the sub soils except in the rubber plantation where deterioration was observed (23.50%). There was improvement in sub soil exchangeable K across the land use types. Exchangeable Ca and Mg deteriorated in land use types except the rubber plantation (Fig. 2b).

Discussion

Soil pH in the acidic range in the cocoa plantation is in line with earlier report by Ololade *et al.* (2010) for cocoa plantation in Ile-Oluji, Ondo State. pH of the top soil in this study tend to increase with exchangeable K, Ca, Mg and organic carbon. Cations are known to increase soil pH through alkalization thereby creating a favourable condition for microbes to act on plant litter (Opala *et al.*, 2012). Juo and Manu (1996) found that pH tend to decrease with decrease in soil nutrient stocks. This phenomenon may be related to cation uptake by plant, with subsequent release of H^{+} ions, organic matter decomposition into organic acids,

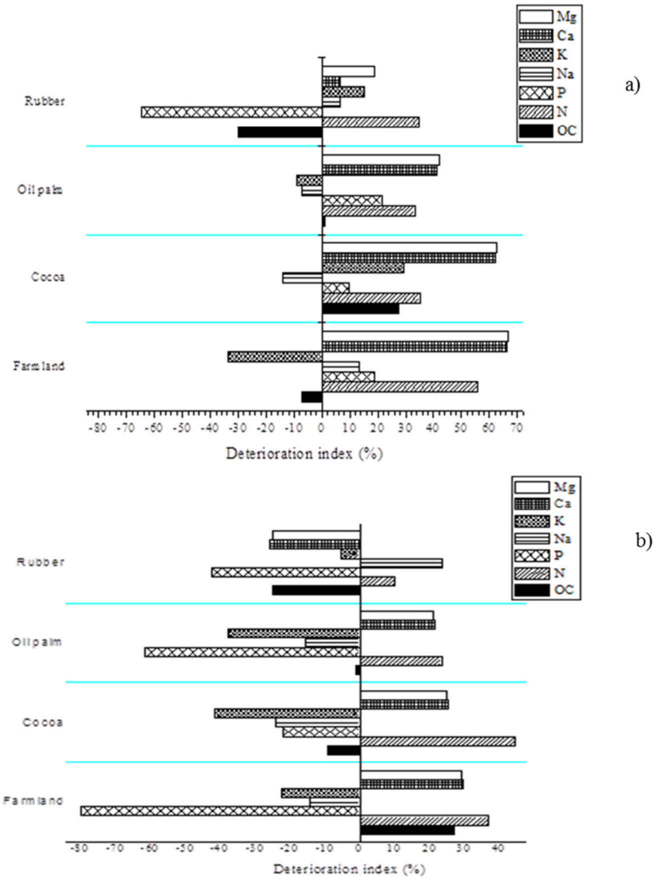

Fig. 2. Deterioration index for soil minerals from (a) top soil and (b) sub soil in four land use types in relation to a forest land

increased CO_2 level through root respiration and nitrification. Conversion of natural forest into monoculture plantations of cocoa and oil palm resulted in a decline (27.3% and 0.9%) in soil organic carbon (SOC). Michel *et al.* (2010) reported significant reduction in SOC in plantations and mixed crop fields compared to natural forest in Cote D'Ivoire, and attributed this to lack of under storey vegetation associated with agricultural lands. High C:N alone, as in the farmland, does not suggest good health of the soil, as low N, pH and CEC in the site will negatively influence the growth of plants. Lewandowski (2002) concluded that high C:N (low soil N) dictates slow decomposition of accumulated biomass and may trigger nitrogen deficiency in plants. Deciduous nature of some trees species in established monoculture plantations (such as cocoa and rubber) build-up of biomass (Abou Rajab *et al.*, 2016) that support the slightest spark of fire, thus accounting significantly in volatilization loss of labile nutrients such as nitrogen (Certini, 2005). Management of such monoculture plantations often eliminate other species including native legumes that contribute significantly to soil nitrogen stock. Although leguminous plants constitute a significant part of conventional cropping system, leaching and volatilization loss limit the availability of the nutrient (Oyedeji *et al.*, 2016). Kutiel and Naveh (1987) in their study of pine forest soil reported 25% decrease in N following burning. The National Wildlife Coordinating Group (2001) also reported that volatilization loss significantly affected N, and to a lesser extent P. The slow mobility of P in soils may be responsible for its low susceptibility to loss by volatilization.

Improvement in soil Ca in the rubber plantation compared to the undisturbed forest in this study supported by the findings of Singh (1998) who reported higher soil Ca in *Tectona grandis* plantation. Improvement in Na and K in the sub soils across the land uses supports the notion of McGrath *et al.* (2001) that soil cation exchange capacity (CEC) increased following conversion of forest to pasture or field crops. According to Blake *et al.* (1999), such improvement often varies with soil chemistry, texture and depth. Such variations possibly accounted for the inconsistencies in the concentrations of the cations across the land uses and with soil depth. In general, decrease in the CEC is reflected in lower pH and organic matter contents in the soils (Owusu-Bennoah, 1997). The resultant low concentrations of Ca and Mg in the top soil and sub soil of the farmland despite high concentration of both cations in the forest soil underscore the need to conserve the forest. Watters (1971) observed that when forest was cleared for cultivation, there was a slight decrease in the cations exchange capacity at all soil depth.

Assessing the impact of land uses on soil organic carbon alone is grossly inadequate since soil organic matter is not chiefly carbon but contains hydrogen, oxygen, nitrogen, phosphorus, sodium, potassium, calcium, magnesium and other micronutrient elements (Gebreyesus, 2013; USDA, 2014). Although soil organic matter can be partitioned conveniently into these fractions, the components and amount of the end product is not static but reflect a dynamic equilibrium influenced by soil properties and by the quantity of annual inputs of plant and animal residues to the ecosystem (Bot and Benites, 2005). There is the need to protect forest cover and regulate conversion of forests to other land uses as to conserve the soil and ensure efficient nutrient cycling. Agro-ecological practices such as no till farming (conservation agriculture), cover cropping, green manuring and intercropping nitrogen-fixing legumes that improve soil organic matter and nitrogen will go a long way to improve productivity in forest converted to agricultural lands and plantations.

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