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ASSESSMENT OF LAND USE PATTERN AND LAND FORM ON SELECTED PHYSICO-CHEMICAL PROPERTIES OF SOILS DEVELOPED ON BASEMENT COMPLEX-SEDIMENTARY TRANSITIONAL ZONE OF SOUTH WESTERN NIGERIA

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ABSTRACT

The effects of cropping practices and soil management on the properties of basement complex-sedimentary transitional zone soils in South Western Nigeria was assessed using soil samples from the pedogenic horizons of ten profile pits dug on two land-use systems (subsistence and experimental farms) and two toposequence. The land use significantly (P<0.01) affected soil pH (in KCl) , Fe and Cu (P<0.05). Topography had significant ((P<0.01) effects on the particle size distribution, Fe, Na (P<0.001) and Cu while soil depth had significant (P<0.001) effects on soil particle size distribution, pH, organic carbon (OC), P, Cu, Zn, Mn (P<0.01), Mg and Fe (P<0.05) contents of the soil studed.

Keywords: Deforestation; Tropical rain forest soils; Sustainability; Integrated soil management; Cropping systems

INTRODUCTION

Conversion of forest vegetation for agricultural land use has been reported as a major cause of soil degradation in most tropical environment such as the basement complex – sedimentary deposit transitional zones of South Western Nigeria (Lal *et al*., 1992). The extent of such degradation depends on the major kinds of agricultural land use and the conservation practices entrenched in the management of such land (Oldeman, 1994). Methods of forest conversion that are not ecologically compatible as well as wrongful allocation of soil resources for agricultural production, and poor soil and crop management systems leads to nutrient mining, accelerate soil erosion and disruption of soil nutrient cycles (C, N, and S) thus reducing the sustainable use of such converted forest soils for cropping.

Given the research information on productive potential and technical know-how available for sustainable management of land resources of this zone, it is technically feasible to manage the land resources intensively for sustained agricultural production without jeopardizing their future potential (Lal, 1986, 1987, 1989).

Several research efforts are on going to evolve land use pattern that will ensure conservation of the agricultural land resources of the basement complex – sedimentary deposit transitional zones of South western Nigeria and to ensure sustainable agricultural production that can guarantee national food security (Ojeniyi, 2010). Among the current research effort is the development of cropping systems that are managed with organo-mineral fertilizers and farm yard manure mixed with chemical fertilizers.

The dominant cropping systems in the transition zone include plantain, cassava, Pawpaw and green (leafy) vegetables based systems. These crops are either grown as sole crop or mixed with other root, tuber or other plantation crops. The present management system encourage fertilizer application based entirely on soil test values which are location specific rather than blanket regional recommendation and are carried out to meet the crop requirements. Bush fallowing period of one to two years may be allowed after continuous cropping for periods ranging between five and ten years before the next cycle of cropping. However in the Peri-urban areas, semi-commercial cultivation of the aforementioned crops has been adopted with improve land management techniques such as the use of organo-mineral fertilizers and soil conservative practices like planted fallow (planting of legume cover crops) and intercropping.

The objective of this paper is to evaluate the sustainability of some land use management systems under experimental and subsistent farming conditions in two toposequence in the basement complex-sedimentary transitional zone of South Western Nigeria.

MATERIALS AND METHODS

Location

Two toposequences were selected for this study within the sedimentary-basement complex transitional zone (Abeokuta geological formation) in Nigeria. Both locations lies within 7°12’30”N - 7°19’5”N and 3°20’30”E - 3°27’30”E and range in altitude from 54 – 130 m above sea level (ASL). The first toposequence was located within the experimental farm site of the Federal University of Agriculture Abeokuta while the second was located within the farms of some subsistent farmers in the same institution.

The experimental sites have humid tropical climate characterized by distinct dry and wet seasons with moderate mean annual rainfall of about 1290 mm and a bimodal rainfall pattern with the first peak in July and the second peak in September. The dry season spans from November to early March while the rainy season takes effect from late March to early November. The average number of rainy days varies between 260 and 290 days per annum. Temperature in this area is almost uniform throughout the year with very little deviations from the mean annual temperature of 27°C. February and March are the hottest months with the mean temperature of 29°C and 28°C, respectively. The mean annual total sunshine hour is about 7 hours with mean daily sunshine of about 8.5 hours.

Soil type

The selected soil had cambic B horizon, ochric epipedon, udic moisture regime in the upper and middle slopes and aquic moisture regime at the toe slope. The soil were classified as udept (cambisol) in the upper and middle slope and aquept in the toe slope. The texture of the epipedon was loamy sand across the slopes while the subsurface horizon had sandy clay, sandy clay loam and sandy loam texture at the upper, middle and toe slope, respectively. The soils had fine sub-angular blocky structure in the epipedon but medium – coarse sub-angular blocky structure in the subsurface horizon. The consistency of the soil was slightly hard in the subsurface horizons while the epipedon had very friable consistency. A unique characteristic of the soil is the gravel content which was high and consisted of coarse, rounded and poorly sorted quartz pebbles with soft gritty sandy clay or sandy clay loam matrix. Also the soil has moderate bulk density (0.95 – 1.48 g cm^{-3}) and generally rapid infiltration rate (> 25 cm hr^{-1}). The fertility status of the soils were low – medium with strongly acid - neutral reaction, moderate organic carbon contents, moderate – high exchangeable bases and low – moderate available phosphorus.

Experimental sites

This research work was carried out in the subsistent and research farm sites of the University of Agriculture Abeokuta, Nigeria. The selected subsistent farms were those of the University staff who have good experience of farm management based on their interaction with the research works of the university scholars. The two farm sites were partitioned into blocks. This was done to check erosion by reducing both the slope angle and slope length. All the blocks were maintained with 5.0 - 10.0 t/ha organo-mineral fertilizer admixed with NPK 20: 10: 10 (200 – 400 kg/ha) and incorporation of remnant crop residues after harvesting. Periodic fertility evaluation of the farms were carried out and the rates and types of fertilizer were usually adjusted to keep the soil fertility level at determined optimum for each crop. Efforts were also put in place to keep leaching losses of applied fertilizers to the lowest possible level. The nutrient content of the mostly used organo-mineral fertilizer is:- 1.09% N, 0.70% P, 1.27% K, 1.48% Ca, 0.58% Mg, 2.75 cmol/kg Na, 95.0 mg/kg Fe, 346 mg/kg Mn, 48.3 mg/kg Cu, 287 mg/kg Zn and 8.97 C/N ratio. The two sites used for this work have been under continuous cropping since 1999.

Field and laboratory studies

Ten profile (TP1 – TP5 and KP1 – KP5) pits were dug on the selected toposequence (subsistent and experimental farm sites). Pedons TP1 - TP5 were located in the experimental farm of University of Agriculture Abeokuta whereas pedons KP1 – KP5 were dug about 5 km Southh-east of the first location within the farms of some subsistent farmers in the same institution. The ten profile pits were dug to include two profile pits each under cassava, pawpaw and fallow while four profile pits were dug under the plantain based cropping systems.

Soils of the pedogenic horizons of each profile were studied morphologically on the field. The soil samples collected from these horizons were air-dried and passed through a 2mm sieve. Particle size distribution was determined by the hydrometer method (Buoyoucos, 1962) after the removal of organic matter with hydrogen peroxide and dispersion with sodium hexametaphosphate (IITA, 1979). The pH was determined with glass electrode pH meter in soil: water and soil: KCl media, each at ratio 1: 1. Exchangeable cations (calcium, magnesium, potassium and sodium) were extracted with neutral normal sodium acetate (NH_4OAc at pH 7.0). Calcium and Magnesium in the ammonium acetate extract were determined by atomic absorption spectrophotometry, while potassium and sodium were determined by flame photometry. The effective cation Exchange capacity (ECEC) was determined by the summation of the exchangeable bases (Ca, Mg, Na and K) and exchangeable acidity.

The organic carbon content of the soils was determined by the modified wet oxidation method (Shamshuddin *et al*., 1995), available P was extracted with Bray-1 solution and P concentration in the extract was determined colorimetrically by the method of Murphy and Riley (1962). Available Zn, Cu, Fe and Mn in the soils were extracted with 0.04M EDTA and their concentrations determined by atomic absorption spectophotometry. The data generated were analyzed using descriptive statistics, analysis of variance and correlation analysis.

RESULTS

Physical Properties of the soils

A distinctive characteristic feature of the soils was high sand, low - moderate clay, low silt and low – high gravel contents. The sand content of the soils ranged from 486.0 – 880.0 gkg^{-1}, with a mean of 733.3 gkg^{-1}. The silt ranged from 20.0 – 174.0 gkg^{-1} with a mean of 74.5 gkg^{-1} in all the profiles while the mean clay content of the soils was 192.2 gkg^{-1} with a standard deviation of 102.7 and ranged from 82.0 – 440.0 gkg^{-1} (Table 1). The gravel content of the soils, especially in the epipedons was high and consisted of coarse, rounded and poorly sorted quartz pebbles with soft gritty sandy clay or sandy clay loam matrix. The gravel content of the soils ranged from 13.17 – 83.04 % (w/w) with a mean of 55.02 % (Table 1).

The sand particle content of the soils decreased in all profile with increase in soil depth whereas the clay content increased with increase in soil depth but there was no evidence of argilluviation in any profile. Expectedly also, the subsurface horizons had higher (245.9 gkg^{-1}) mean clay contents than the surface horizons (106.1 gkg^{-1}). However, the higher clay contents were also associated with higher percentage coefficient of variation of its distribution. Apart from pedons KP2 and KP4 were the silt content of the soils increased with depth, there was no consistent pattern in the profile distribution of the silt sized particle fraction in all other pedons (Data not shown).

The soil texture ranged from loamy sand in the epipedons to sandy clay loam or sandy clay in the subsurface horizons. The soil had structures that varied from crumbs-fine-sub-angular-blocky (fsbk) in the surface horizon to coarse-sub angular-blocky (csbk) in the sub soil. Consistency of the soils ranged from friable (mfr) in the surface horizons to very firm (mvfi) in the subsurface horizons (Table 2). The soils had colours (Table 2) that ranged from brown (10 YR) to gray (2.5Y) in the surface while the sub surface had colour variation between yellow (5Y) and reddish brown (2.5 YR). Pedons TP4, TP5 and KP5 which were imperfectly/poorly drained had subsurface colour in the gray - yellow range (5Y - 2.5Y) with prominent, common and medium, Dark yellowish brown (10 YR 3/4) mottles at the lower horizons. However, the well drained pedon (TP1-TP3 and KP1-KP4) had brown (10 YR) to dark reddish brown (2.5 YR) colour in the subsurface horizons. All the pedons had mottles in the last horizon. However, the degree of mottling, mottle size, abundance and contrast varied widely.

Chemical Properties of the soils

The pH of the soils in water (pHw) ranged from slightly acidic (6.45) - neutral (7.05) (Table 1). As expected the pH in K Cl (pHk) was lower than the pHw and the difference in most cases was more than 15 %. The pHk ranged from very extremely acid (4.40) - neutral (6.75). The organic carbon contents of the soils were low – moderate and decreased with increasing soil depth. The organic carbon (OC) content of the soils ranged from 1.30 - 30.2 gkg^{-1} with a mean of 6.60 gkg^{-1} and standard deviation of 6.9 gkg^{-1}, which is indicative of high variation in its distribution.
The available P was very low in all profile and had values that varied from 0.04 – 3.24 mg kg^{-1}. Like the soil organic C, the soil P distribution was only significantly affected by soil depth being higher (0.91 mg kg^{-1}) in the surface horizons than the sub-surface (0.25 mg kg^{-1}) horizons (Table 1).

The soils had mean exchangeable acidity (EA) of 0.26 mg kg^{-1} with a range from 0.10-0.7 cmol kg^{-1} and standard deviation of 0.14. Similarly to most tropical soils, the exchange sites of the soils were dominated by moderate – high levels of exchangeable calcium and magnesium. While the exchangeable calcium (Ca^{2+}) of the soils ranged from 1.20 cmol kg^{-1} - 12.40 cmol kg^{-1}, the exchangeable magnesium content of the soils ranged from 0.4 – 7.20 cmol kg^{-1}. The mean soil content of

Ca^{2+} and Mg^{2+} were 4.44 and 3.47 cmol kg^{-1} respectively.

Exchangeable potassium (K^+) was low (mean = 0.09 cmol kg^{-1}) and varied from 0.04 - 0.21 cmol kg^{-1} while the mean sodium (Na^+) content of the soil (0.37 cmol kg^{-1}) was moderate, ranged from 0.25 - 0.49 cmol kg^{-1} and accounted for less than 10% (ESP) of the effective cation exchange capacity. The effective cation exchange capacity (ECEC) of the soils ranged from 4.82 -16.70 cmol kg^{-1} with a mean of 8.62 cmol kg^{-1} and the base saturation (BS) of the soil ranged from 85.41 - 98.87%. The sum of Ca^{2+} and Mg^{2+} alone accounted for more than 90% of the TEB and ECEC therefore the pattern of distribution of BS follows similar trends with those of Ca^{2+}, Mg^{2+} and ECEC.

Both Fe and Mn occurred in toxic levels (> 100 $mgkg^{-1}$) while the mean Cu and Zn contents were found to be adequate for most crops grown in the region. The Fe content of the soils ranged from 44.60-480.40 mg kg^{-1} with a mean of 147.90 mg kg^{-1} and SD of 92.30 mg kg^{-1}. The soils

Table 1: Physico-chemical properties of the soils

	Minimum	Maximum	Mean	SD	CV (%)
Sand (gkg^{-1})	486.0	880.0	733.3	110.4	15.06
Silt (gkg^{-1})	20.0	174.0	74.5	32.9	44.13
Clay (gkg^{-1})	82.0	440.0	192.2	102.7	53.45
Gravel (%)	13.17	83.04	55.02	19.61	35.64
pHw	6.35	7.15	6.75	0.20	2.96
pHk	4.40	6.75	5.58	0.56	10.06
Organic C (gkg^{-1})	1.30	30.20	6.60	6.90	104.23
EA (cmol kg^{-1})	0.10	0.70	0.26	0.14	53.53
Ca (cmol kg^{-1})	1.20	12.40	4.44	2.38	53.68
Mg (cmol kg^{-1})	0.40	7.20	3.47	1.72	49.48
K (cmol kg^{-1})	0.04	0.21	0.09	0.04	41.15
Na (cmol kg^{-1})	0.25	0.49	0.37	0.07	19.66
ECEC (cmol kg^{-1})	4.82	16.70	8.62	2.81	31.62
BS (%)	85.41	98.87	94.66	3.63	3.83
P (mg kg^{-1})	0.04	3.24	0.50	0.67	132.70
Fe (mg kg^{-1})	44.60	480.40	147.90	92.30	62.39
Cu (mg kg^{-1})	0.50	3.10	1.44	0.71	49.10
Mn (mg kg^{-1})	48.20	365.40	231.70	95.78	41.39
Zn (mg kg^{-1})	0.75	8.19	2.03	1.70	84.03

pHk = pH in molar KCl; pHw = pH in distilled water

Table 2: Soil morphological properties.

Profile	Depth (cm)	Texture	Structure	Consistency	Colour	Mottle
TP1-A	0 – 24	SL	fsbk	mfr	Dark yellowish brown (10 YR ¾)	
TP1-B1	24 – 64	SCL	fsbk	mfi	Strong brown (7.5 YR 4/6)	
TP1-B2	64 – 110	SC	csbk	mvf	Yellowish red (5 YR 5/8)	Brownish yellow (10 YR 6/8) F, Fn, Ft
TP1-C	110 – 152	SC	csbk	mvfi	Brownish yellow (10 YR 6/8)	Red (2.5 YR 4/8) F, H. M
TP2-A	0 – 12	LS	cr	mfr	Very dark grayish brown (10 YR 3/2)	
TP2-B1	12 – 46	LS	fsbk	mfi	Dark yellowish brown (10 YR ¾)	
TP2-B2	46 – 72	SCL	msbk	mfi	Yellowish red (5 YR 4/6)	
TP2-B3	72 – 128	SCL	csbk	mvfi	Yellowish red (5 YR 4/6)	Brownish yellow (10 YR 6/8) C ,P, M
TP2-C	128 – 138	SCL	csbk	mvfi	Yellowish brown (10 YR 5/8)	Yellowish red (5 YR 4/6) Fn, M, Ft
TP3-A	0 – 8	S	cr	mfi	Very dark grayish brown (10 YR 3/2)	
TP3-B1	8 – 32	LS	csbk	mvfi	Dark yellowish brown (10 YR ¾)	
TP3-B2	32 – 79	LS	csbk	mvfi	Dark yellowish brown (10 YR ¾)	
TP3-C	79 - 148	SCL	csbk	mvfi	Dark red (2.5 YR 3/6)	Yellowish brown (10 YR 5/6) C,Fn, Fe
TP4-A	0 – 10	S	cr	mfr	Black (10 YR 2/1)	
TP4-B1	10 – 25	LS	msbk	mfi	Very dark brown (10 YR 2/2)	
TP4-B2	25 – 140	SCL	csbk	mvfi	Dark red (2.5 YR 3/6)	Yellowish brown (10 YR 5/8)
TP4-C	140 - 160	SCL	csbk	mvfi	Light reddish brown (2.5 YR 6/4)	Pinkish gray (5 YR 6/2)
TP5-A	0 – 20	SL	msbk	mfr	Very dark grayish brown (2.5 Y 3/2)	
TP5-B1	20 – 60	SL	fsbk	mfr	Olive gray (5 Y 4/2)	
TP5-B2	60 – 100	SCL	csbk	mfi	Olive (5 Y 5/3)	Dark yellowish brown (10 YR 3/6) MPC
TP5-B3	100 – 140	SCL	csbk	mfi	Olive (5 Y 5/3)	
KP1-A	0 – 16	LS	Fsbk	Mfr	Dark yellowish brown (10 YR ¾)	
KP1-B1	16 – 48	LS	Fsbk	Mfr	Dark yellowish brown (10 YR 3/6)	
KP1-B2	48 -140	SC	Csbk	Mfi	Yellowish red (5 YR 4/6)	
KP1-C	140 – 159	SC	Csbk	Mfi	Reddish brown (2.5 YR 5/4)	Brownish yellow (10 YR 6/8) PMC
KP2-A	0 – 26	S	Fsbk	Mfr	Very dark brown (10 YR 2/2)	
KP2-B1	26 – 73	LS	Msbk	Mfr	Dark yellowish brown (10 YR 3/6)	
KP2-B2	73 – 121	SL	Msbk	Mfr	Dark yellowish brown (10 YR 3/6)	
P2-C	121 – 160	SCL	Msbk	Mfi	Reddish brown (2.5 YR 4/4)	Yellowish red (5 YR 5/8) Pr
KP3-A	0 – 28	LS	Fsbk	Mvfr	Grayish brown (10 YR 5/2)	
KP3-B1	28 – 74	LS	Msbk	Mfi	Dark yellowish brown (10 YR ¾)	
KP3-B2	74 – 140	SCL	Cfbk	Mvfi	Dark reddish brown (5 YR ¾)	Red (2.5 YR 4/6) m,p,Fn
KP4-A1	0 – 23	S	Msbk	Mfr	Very dark grayish brown (10 YR 3/2)	
KP4-A2	23 – 55	LS	Fsbk	Mfr	Dark brown (10 YR 3/3)	
KP4-B1	55 – 129	SCL	Msbk	Mfi	Dark Reddish brown (5 YR ¾)	Dark red (2.5 YR 3/6) Fe
KP4-B2	129 - 160	SL	Msbk	Mfi	Brown (10 YR 5/3)	Reddish yellow (7.5 YR 6/8) M Fd D
KP5-A	0 – 18	LS	Fsbk	Mfr	Very dark grayish brown (2.5 Y 3/2)	
KP5-B1	18 – 32	SL	Msbk	Mfi	Dark grayish brown (2.5 Y 4/2)	Dark yellowish brown (10 YR ¾) PCM
KP5-B2	> 32	SL	Msbk	Mfi	Olive gray (5 Y 5/2)	Dark yellowish brown (10 YR ¾) PCM

S=Sand; LS=Loamy Sand; SL=Sandy loam; SCL=Sandy clay loam; SC=sandy clay Fsbk=fine subangular blocky; msbk= medium subangular blocky, csbk=coarse subangular blocky; cr= crumb Mfi=firm; mfr=friable; mvfi=very firm; mvfr=very friable; Mottle (abundance, size, contrast, boundary) had mean Mn content of 231.70 mg kg^{-1} and ranged from 48.20 – 365.40 mg kg^{-1} with a standard deviation of 95.78 mg kg^{-1}. Mean soil content of Cu and Zn was 1.44 mg $kg^{-1}$and 2.03 mg kg^{-1}, respectively.

Effects of land use, topography and soil depth on soil physico-chemical properties

The mean distribution of the sand, silt and clay particle sizes (Table 3) were significantly ($P<0.01$) affected by topography while soil depth also significantly ($P<0.001$) affected the distribution of sand and clay particle sizes. The land use pattern and sampling location (subsistent or research farm) had no significant effect on the mean sand and silt contents of the soils (Tables 3 and 4). However, the clay particle size fraction was significantly ($P<0.05$) affected by sampling site.

The middle slope pedon had significantly highest sand contents (781.9 gkg^{-1}) while the sand content of the valley bottom pedons (721.7 gkg^{-1}) was statistically similar to those of the upper slope pedons (695.3 gkg^{-1}). The mean value of silt increased down the slope with the valley bottom pedons having the significantly highest (100.9 gkg^{-1}) mean value followed by the upper slope (75.9 gkg^{-1}) pedons, while the middle slope (60.7 gkg^{-1}) pedons had the lowest (Table 4). Also, the valley bottom pedons had the least CV (26.85 %) followed by the middle slope while the upper slope pedon had the highest CV (49.91%) for the distribution of silt particle size. Thus the highest mean silt contents and the least variability in the distribution of the silt particle size fraction were observed in the valley bottom pedons. The upper slope pedons had significantly higher (236.0 gkg^{-1}) mean clay contents than the middle (151.0 gkg^{-1}) and valley bottom (174.0 gkg^{-1}) pedons, which had statistically similar mean clay contents (Table 4).

The surface horizons had significantly higher mean sand content (823.2 gkg^{-1}) than the subsurface horizons (677.2 gkg^{-1}) whereas the percentage coefficient of variation (CV) of the distribution of the sand particle size fraction was higher in the subsurface horizons (14.44 %) than the surface (5.89 %). This indicates that the variation in the distribution of the sand particle size fraction was lower in the surface horizons. Whereas the subsurface horizons had significantly higher mean clay content (251.0 gkg^{-1}) than the epipedons (98.0 gkg^{-1}), the experimental farm site had higher clay content (212.0 gkg^{-1}) than the subsistent farm site (169.0 gkg^{-1}).

While the pHw did not vary significantly with soil depth, sampling location and land use pattern, the pHk varied significantly ($P<0.001$) with sampling depth, sampling locations and land use ($P<0.05$) pattern (Table 3). The subsurface horizons had significantly lower mean pH (5.29) than the surface horizons (5.83) while the subsistent farm had lower pH (5.31) than the experimental farm (6.02) site (Table 4). Among the various land use patterns, the mean pH value of the soils of cassava based cropping system was significantly lower (4.99) than the pH of the fallowed land (5.48) which was also significantly lower than those of plantain and Pawpaw based land use patterns (5.75 and 5.99, respectively).

There were no significant variation in the distribution of the gravel, organic C and available P contents as a result of variation in land use and sampling location. However soil depth significantly ($P<0.001$) affected the distribution of the gravel, organic C and available P contents.

The surface horizons had significantly higher mean organic C (1.23 gkg^{-1}) and P (0.96 mg/kg) than the subsurface (3.00 gkg^{-1} C) and (0.22 mg/kg P) horizons while the gravel content of the soils was higher significantly in the sub surface (65.50 %) than the surface (38.30 %) horizons (Table 4). In all the profiles, the highest organic C content was observed in the A horizon.

While the quantities of Mg^{2+} in the soils varied significantly ($P<0.05$) with soil depth, those of Ca^{2+}, EA, K^+ and ECEC were not significantly influenced by changes in soil depth, sampling location and land use pattern (Table 3). Similarly, the Na^+ status of the soils varied significantly (P<0.001) with change in topography while the BS of the soils also varied significantly (P<0.001) with land use pattern and sampling location. The soils had higher significant mean Mg^{2+} content (3.67 cmol kg^{-1}) in the subsurface than in the surface (2.67 cmol kg^{-1}) horizons (Table 3). The Na^{+} of the soils was however significantly highest (0.42 cmol kg^{-1}) at the upper slope pedons and lowest (0.32 cmol kg^{-1}) at the middle slope pedons while the Na^{+} content of the valley bottom (0.37 cmol kg^{-1}) pedons was higher than that of the middle slope. The distribution of Na^{+} along the toposequence was probably influenced by lateral leaching losses from the middle slope and accumulation of the Na^{+} each in the valley bottom pedons

Table 3: Mean square for analysis of variance of soil properties

SV	d.f.	SAND	SILT	CLAY	GRAVEL	pHw	pHw
SITE	1	160.16	0.739	182.67*	391.6	0.02089	2.9024***
CROP	3	36.32	8.823	10.23	394.5	0.03343	0.4235*
SLOPE	2	374.43**	55.254**	256.45**	210.3	0.04753	0.3814*
DEPTH	1	2176***	4.316	1986.49***	6321***	0.0003	3.7257***
Residual	31	49.22	8.775	43.65	203.4	0.04239	0.1094
SV	d.f.	Org C	EA	Mg	Na	BS	P
SITE	1	0.0711	0.08074*	2.79	0.000079	276.776***	0.3412
CROP	3	0.2081	0.01325	1.28	0.004584	4.172	0.0569
SLOPE	2	0.1161	0.02314	0.38	0.050609***	2.617	0.2116
DEPTH	1	7.6852***	0.0044	12.907*	0.000276	5.639	4.6674***
Residual	31	0.3088	0.01767	2.951	0.003259	6.484	0.3691
SV	d.f.	Fe	Cu	Mn	Zn		
SITE	1	169	1.7311**	6672	12.976*		
CROP	3	25122**	0.7389*	12247	1.626		
SLOPE	2	32634**	2.2134***	5318	2.488		
DEPTH	1	27273*	3.4566***	59853**	30.305***		
Residual	31	5025	0.232	7604	1.842		

*, **, *** = significant at 5% 1% and 0.1% probability levels, respectively.
pHk = pH in molar KCl; pHw = pH in distilled water

able 4: Effects of land use pattern, topography, sampling site and depth on soil properties.

	SITE			Land Use					Topography				Soil Depth		
	1	2	**s.e.d**	1	2	3	4	**s.e.d**	1	2	3	**s.e.d**	1	2	**s.e.d**
nd (%)	71.50	75.50	**2.25**	72.20	75.10	74.80	71.00	**3.29**	68.90	79.20	71.70	**3.39**	83.20	67.20	**2.40**
t (%)	7.32	7.60	**0.95**	7.81	6.88	6.64	8.78	**1.39**	7.58	5.71	10.88	**1.43**	7.01	7.73	**1.02**
ay (%)	21.20	16.90	**2.12**	20.00	18.00	18.60	20.30	**3.10**	23.60	15.10	17.40	**3.20**	9.80	25.10	**2.26**
avel (%)	52.10	58.40	**4.58**	48.80	64.80	56.60	52.50	**6.69**	52.60	54.40	62.40	**6.90**	38.30	65.50	**4.89**
w	6.77	6.73	**0.07**	6.80	6.68	6.78	6.70	**0.10**	6.71	6.82	6.70	**0.10**	6.75	6.75	**0.07**
k	5.83	5.29	**0.11**	5.77	5.28	5.50	5.72	**0.16**	5.47	5.77	5.44	**0.16**	5.99	5.33	**0.11**
GANIC C (%)	0.70	0.62	**0.18**	0.77	0.49	0.76	0.51	**0.26**	0.57	0.75	0.70	**0.27**	1.25	0.30	**0.19**
A (cmol kg^{-1})	0.21	0.31	**0.04**	0.22	0.31	0.27	0.23	**0.06**	0.30	0.24	0.20	**0.06**	0.27	0.25	**0.05**
(cmol kg^{-1})	4.55	4.31	**0.81**	4.93	3.67	5.00	3.54	**1.18**	4.50	4.59	3.97	**1.22**	4.46	4.43	**0.86**
g (cmol kg^{-1})	3.22	3.76	**0.55**	3.13	4.00	3.60	3.25	**0.81**	3.41	3.38	3.79	**0.83**	2.71	3.94	**0.59**
(cmol kg^{-1})	0.10	0.08	**0.01**	0.09	0.08	0.08	0.10	**0.02**	0.10	0.08	0.07	**0.02**	0.09	0.08	**0.01**
(cmol kg^{-1})	0.37	0.37	**0.02**	0.35	0.40	0.38	0.36	**0.03**	0.43	0.31	0.37	**0.03**	0.37	0.37	**0.02**
EC (cmol kg^{-1})	8.45	8.82	**0.95**	8.73	8.46	9.33	7.48	**1.38**	8.74	8.60	8.39	**1.43**	7.90	9.08	**1.01**
(%)	97.12	91.78	**0.82**	95.31	93.63	94.56	94.82	**1.19**	94.21	95.04	94.92	**1.23**	94.16	94.97	**0.87**
(mg kg^{-1})	0.59	0.40	**0.20**	0.44	0.61	0.54	0.45	**0.28**	0.46	0.64	0.34	**0.29**	0.96	0.22	**0.21**
(mg kg^{-1})	150.00	146.00	**22.80**	185.00	90.00	181.00	95.00	**33.20**	121.00	135.00	241.00	**34.30**	183.00	126.00	**24.30**
(mg kg^{-1})	1.63	1.21	**0.15**	1.65	1.11	1.61	1.17	**0.23**	1.36	1.17	2.19	**0.23**	1.83	1.19	**0.17**
n (mg kg^{-1})	220.00	246.00	**28.00**	267.00	176.00	236.00	224.00	**40.90**	212.00	249.00	245.00	**42.20**	283.00	199.00	**29.90**
(mg kg^{-1})	2.56	1.40	**0.44**	2.18	1.79	2.38	1.46	**0.64**	1.79	1.92	2.84	**0.66**	3.19	1.30	**0.47**

te 1= Subsistent farm; Site 2 = Research Farm; Depth 1= Surface soil (≤30 cm); Depth 2= Subsurface soil (≥ 31cm). Crop 1=Long fallow (> Yrs); Crop 2 = Cassava based system; Crop 3 =Pawpaw based system; Crop 4 = Plantain based system Slope 1= Upper; 2= Middle; 3 = e slope

The distribution of the micronutrients (Fe, Cu, Mn and Zn) were significantly affected by soil depth, Fe and Cu by slope and land use pattern while the distribution of Cu and Zn varied significantly with site (Tables 3 and 4). The epipedon of the soils had significantly higher contents of Fe, Cu, Mn and Zn than the subsurface soils. The Cu contents of the soils of the toe slope (2.19 mg kg^{-1}) was significantly higher than those of the upper (1.36 mg kg^{-1}) and middle (1.17 mg kg^{-1}) slopes that were statistically similar. The Fe content of the upper slope and middle slope were statistically similar. Likewise, the Fe content of the middle slope and toe slope were statistically similar same manner but the Fe content of the toe slope was statistically higher than those of the upper slope. The effect of land use type affected the distribution of Fe and Cu similarly. The Fe and Cu contents of the soils under long fallow and pawpaw based were significantly higher than those under cassava and plantain based cropping systems. Furthermore, the Cu and Zn contents of the soils of the subsistent farm were significantly higher than those of the research farm.

DISCUSSION

The cropping pattern and management practices adopted in the soils used for this study had no significant negative effects on the soil physical and chemical properties, although the cassava and pawpaw based cropping system had significantly lower mean profile pH_K than the long fallow land and the mean Fe and Cu contents of the soils under cassava and plantain based cropping systems were also significantly lower than those of the long term fallow land. The results obtained in this study confirm the report of the reviews on integrated nutrient management for crop production in Nigeria carried out by Ojeniyi (2010). Ojeniyi reported that the integration of crop residue, organo-mineral fertilizer, organic manure and mineral fertilizer in the management of agricultural land will ensure sustainable crop production while minimizing soil acidity, nutrient imbalance, inadequate supply of macro and micronutrients and damages to soil physical properties (bulk density and hydraulic functions).

Although Aweto and Enaruvbe (2010) reported that there were no significant differences between the upper, middle and lower slope segments of the catena in respect of soil particle size composition, the topography (Slope) of the land used for this study had pronounced effects on the soil properties as variation in slope position significantly affected the soil particle size distribution as well as the soil contents of Na, Fe and Cu. The results suggest that the cropping practices and management practices adopted on these soils did not have significant detrimental effects on the soil chemical properties but indicated the possibility of better sustainability of the soils through the management of the soils according to their slope positions (i.e. partitioning the soils into uniform slopes).

The selected sites had similar properties but differed significantly in the soil contents of Cu, Zn, clay, base saturation and pH_K. This observation may have resulted from the differences in the intensification of usage between the subsistent and research farm. The subsistent farm has higher content of clay, Cu, Zn and pH_K than the research farm. The frequency of crop rotation in the research farm is higher than those of the subsistent farm due to the gestation period of some of the experiments carried out on the research farm. These may have placed higher nutrient demand on the soils of the research farm which could also have resulted in the lower contents of Cu, Zn and pH_K.

CONCLUSION

The results obtained from this study suggest that integrated management of the soils of converted tropical rainforest using organic manure, organo-mineral fertilizer, mineral fertilizer, crop residue management and appropriate cropping pattern can be used to maintain the productive capacity of the soils over a prolong period of time without subjecting the soils to chemical degradation.

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