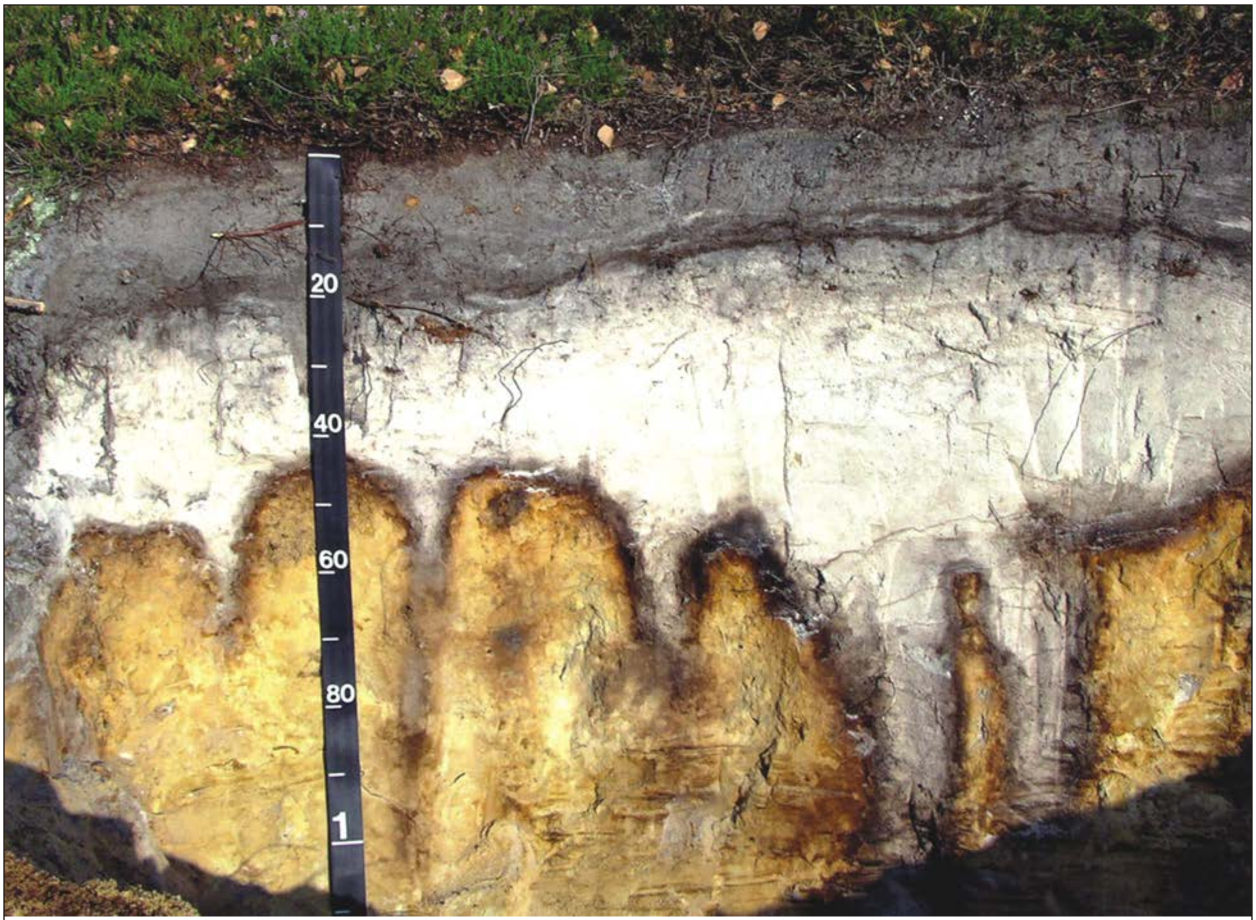

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Availability of Selected Soil Nutrients in Relation to Land Use and Landscape Position

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Abstract: The major aim of this study was to investigate the availability of soil nutrients under different land uses and landscape positions. Three hillslopes were used for the study and soil sampling was guided by the transect technique. The soil samples were collected in May 2004, July 2004 and July 2005. Five soil nutrients, namely Total Phosphorus (TP), Available Phosphorus (AP), Total Nitrogen (TN), Available Nitrogen (AN) and Soil Organic Matter (SOM) were analyzed and used for the study. Data were statistically analyzed using analysis of variance (ANOVA) and mean comparisons were made using Least Significant Difference (LSD). Results showed significant ($p<0.05$) differences in SOM, TN and AN among land uses. Heaviest soil deterioration was recorded in soils under Pineapple Orchard (PO) and least in Grassland (GL) soils. There were significant ($p<0.05$) differences in soil nutrients due to landscape positions especially in Hillslopes B and C. Surprisingly, values of soil nutrients were higher in middle slopes of Hillslope C unlike in the other two where such occurred in the footslopes. The SOM had very great influence on AP and AN.

Key words: Degradation, land utilization, topography, tropical soil, variability

INTRODUCTION

Soil fertility is a major factor in determining soil productivity. This fact necessitates the characterization of the spatial and temporal variabilities of soil nutrients in relation to site features. Such identification of site characteristics such as climate, land use and landscape position helps in predicting rates of ecosystem processes (Schimel *et al*., 1991), assessing the effects of future land use change on nutrients (Kosmas *et al*., 2000) and understanding how ecosystems work (Townsend *et al*., 1995).

Under similar agroecological environments, land use and cultural practices become the dominant factors affecting soil properties and crop production (Nnaji *et al*., 2002). People through their crop production practices influence course of the formation and the physico-chemical status of the soil at any given time (Asadu and Enete, 1997). Akamigbo (2001) observed that at any given time land use is a resultant interplay of available land resources with cultural, social and economic conditions of the past and present development. Ogunkunle and Egghaghara (1992) reported significant differences between land use types in soil pH, extractable P, K, Ca, Mg, total nitrogen, organic matter and bulk density. It was also observed that soils formed over the same parent material and under the same climate and relief had dissimilar bulk densities due to cultivation (Akamigbo, 1999). Land use information is therefore critical for a wide variety of decision-making purposes. Unsuitable land use often leads to sub-optimal use of land and agricultural investments and this triggers processes such as degradation.

Topography expressed as landscape position is a very important factor of soil formation. Esu (2005) noted that topography hastens or delays the work of climatic factors, stating that south-facing slopes in the northern hemisphere are more perpendicular to the sunrise and are generally warmer than their north-facing counterparts. This trend introduces variability in some soil properties especially organic matter, temperature and moisture characteristics. Landscape position in conjunction with land use may be dominant factors in influencing soil properties under a hillslope and small catchment scale. Landscape position creates differences in soil formation and consequently difference in soil properties along a hillslope (Brubaker *et al*., 1993). Landscape positions influence runoff, drainage, temperature and soil erosion. All these affect local carbon and nitrogen processes (Hobbie, 1996) and the variability of soil properties is large in complex hills (Miller *et al*., 1988), especially in organic matter content (Bhatti *et al*., 1991).

Most soil studies on land use are broad-based and on degradation (Mbagwu and Abeh, 1998; Akamigbo, 1999; Dixon and Asadu, 2001). But understanding how much nutrient resources vary across landscapes has become the focal point of much ecological research (Benning and Seastedt, 1995) and land use being an integrator of several environmental attributes which influence nutrients export (Young *et al*., 1996), it becomes necessary to investigate their sole and interactive effects on soil nutrients. The objective of this study was to assess the effects of land use and landscape on the availability of soil nutrients (2) investigate status of soil deterioration and (3) determine the relationship among soil nutrients.

MATERIALS AND METHODS

Study Area

Ohafia in Abia State, southeastern Nigeria lies on latitude 5°52^{1} 29^{11}. 670 N and longitude 7°54^{1}25^{11}. 240 E. The major geologic material in the area is Lower Coal Measures (Mamu formation) of the maestrichtian age, containing sandstones, shale, mudstones and marine intercalations. It lies within the Nsukka-Okigwe Cuesta which swings southwards terminating at Arochukwu where it is characterized by a series of rugged hills. Soils have been characterized as Dystropeptic Tropustults (USDA Soil Taxonomy) (Onweremadu, 2006). Rainfall ranges from 1750-2000 mm annually with a mean annual temperature range of 26-28°C. It has a typical rainforest vegetation which has lost its original nature due to population increase and consequent anthropogenic activities. Farming is mainly practiced at a subsistence level with the traditional slash-and-burn method irrespective of the fragility of the ecosystem. Soil fertility regeneration is by bush fallow, which is fast disappearing due to demographic pressure. Crops are grown in cassava-based mixtures despite the increasing rate of soil degradation by soil erosion.

Field Studies

Three hillslopes, showing typical land use structure were selected for soil sampling. A transect was used to link all land uses and landscape positions. The method of Brubaker *et al*. (1993) guided soil sampling. In this method 6 categories of landscape positions were identified as upper interfluves, lower interfluves, shoulder, upper linear, lower linear and footslope. The study site was divided into 3 landscape positions, namely Upper Slope (US), Midslope (MS) and Footslopes (FS). The US consists of upper and lower interfluves, while the MS comprises shoulder, upper and lower linear units as the FT is the base of the hilly landscape. The land uses for the study were fallow land (FL), Woodland (WL) Oil Palm Plantation (OP), Arable Farm (AF), Pineapple Orchard (PO), Shrub Land (SL) and Grassland (GL).

Thirty plots were delineated for the site and surface soils were collected from them in the months of May and July 2004 and July 2005. Soil samples from Ap horizons (0-20 cm depth) were taken from 5 sampling points within each plot using a soil corer measuring 15×5 cm. These 5 sampling points represented 5 replicates and were homogenized by hand mixing. Non soil materials in the soil samples were separated and discarded. Soil samples were air-dried and sieved using 2 mm sieve.

Laboratory Studies

Total and available phosphorus forms were determined colourimetrically after wet digestion according to the procedure of Olsen and Sommers (1982). Available P was measured by Olsen method (Emteryd, 1989). Total nitrogen was estimated using micro-kjeldahl while available nitrogen was measured using micro-diffusion technique after alkaline hydrolysis (Conway, 1978). Soil organic carbon was measured by wet digestion (Nelson and Sommers, 1996). Values of soil organic carbon were multiplied by a factor 1.724 to obtain Soil Organic Matter (SOM).

Soil Deterioration Index (SDI)

The SDI was calculated according to the procedure of Adejuwon and Ekanade (1988). This index is computed based on the assumption that the level of individual soil nutrients under fallow land, shrubland, pineapple orchard, arable farm, cocoyam farm, grassland and oil palm farm were under woodland before conversion to the present land use. The difference between mean values of individual soil nutrients under 6 land uses mentioned above compared to base values of soil nutrients under woodland was computed and expressed as a percentage of the base values of individual soil nutrients. Therefore, the percentage values were averaged across all soil nutrients under investigation to calculate the SDI.

Data Analysis

Soil data were subjected to one-way analysis of variance (ANOVA) and mean comparisons were made using the Least Significant Difference (LSD) method at $p<0.05$ level. This statistic was used to test the influence of land use and topographic position on soil nutrients. Interactive effect of land use and landscape position was identified using GLM-MANOVA and all statistical analyses were conducted through SPSS program (SPSS Inc. 1993).

RESULTS AND DISCUSSION

Land Uses and Soil Nutrients

The distribution of soil nutrients among the seven (7) land uses are shown in Table 1, indicating significant ($p<0.05$) differences among land uses in soil organic matter and nitrogen forms. Results of multiple comparison of soil nutrients revealed that SOM under grassland woodland and shrubland was significantly ($p<0.05$) higher compared to other land uses. Generally, values of these nutrients were higher in uncultivated lands Similar findings were made by Lepsch *et al*. (1994) that cultivation decreases soil nutrient status. A cultivated land is vulnerable to runoff losses, leaching, eluviation, colluviation and volatilization. All these are in addition to high rate of organic matter mineralization due to high temperatures associated with southfacing slopes in the northern hemisphere.

Table 1: Distribution of soil nutrients among land uses (mean values) soil properties

	Soil nutrients				
Land use	TP (mg kg^{-1})	AP (mg kg^{-1})	TN (g kg^{-1})	AN (mg 100 g^{-1})	SOM (g kg^{-1})
OP	56.0a	1.6a	5.5bcd	3.7bd	8.4b
AF	54.0a	1.1a	3.3a	1.8a	5.1a
PO	50.0a	0.9a	4.2ade	3.1ad	5.4ade
WL	63.0a	2.0a	4.8bce	4.0cd	8.8bcd
FL	60.3a	1.2a	2.9a	2.6ac	4.9a
SL	61.1a	3.3a	3.8ac	2.8ac	6.2ac
GL	59.0a	1.0a	5.1bce	3.9cd	8.9bce
F-value	0.9NS	1.9NS	3.8*	3.0*	4.5**

Values in each column with the same letter are not significantly ($p<0.05$, LSD) different among land uses, OP = Oil Palm, AF = Arable Farm, PO = Pineapple Orchard, WL = Woodland, FL = Fallow Lgrassland, SL = Shrub Land, GL = Grossland, TP = Total Phosphorus, AP = Available Phosphorus, TN = Total Nitrogen, AN = Available Nitrogen, SOM = Soil Organic Matter, ** Significant at 0.01, *Significant at 0.05, NS: Not Significant

Table 2: Temporal variability of nutrients among the land uses

	Soil nutrients					
Sampling date	Land use	TP (mg kg^{-1})	AP (mg kg^{-1})	TN (g kg^{-1})	AN (mg100 g^{-1})	SOM (g kg^{-1})
May 2004	OP	5a	1.30a	06b	3.80bcd	7.1b
	AF	6a	1.98a	0.4ac	2.31a	5.5ac
	PO	6a	2.06a	0.4ad	2.48ad	8.5b
	WL	7a	1.60a	0.6bcde	3.99be	8.8b
	FL	6a	1.58a	0.5bcde	2.44ac	5.1a
	SL	7a	2.06a	0.3a	2.56acd	8.2bcd
	GL	6a	1.10a	0.6b	3.78cde	8.9b
	F-value	0.8NS	2.2NS	0.3.2a	3.9**	3.5**
July 2004	OP	6a	2.9b	3.0ac	2.81a	5.6ac
	AF	6a	0.9a	0.2a	3.31a	4.9a
	PO	5a	0.8a	0.4bd	3.53a	8.7bd
	WL	6a	0.9a	0.5bce	3.81a	10.6be
	FL	6a	0.7a	0.2a	3.03a	5.2ac
	SL	7a	2.6b	0.3ade	2.92a	6.1ac
	GL	6a	0.7a	0.4ade	3.72a	8.3cde
	F-value	1.9NS	4.1**	3.1*	1.2NS	5.88**
July 2005	OP	0.5a	0.9a	0.5bcd	4.3ce	4.6ac
	AF	0.5a	1.1a	0.3a	2.2a	4.7a
	PO	0.5a	1.3a	0.4ac	3.2acd	7.5acd
	WL	0.6a	2.2a	0.5bcd	3.4ace	7.4ace
	FL	0.6a	1.9a	0.4ad	2.2a	8.4ce
	SL	0.5a	0.9a	0.4ac	3.4ace	5.5ace
	GL	0.6a	1.2	0.5bcd	3.8bde	8.8bde
	F-value	1.3NS	0.9NS	2.9*	2.8*	3.2*

Values in each column with the same letter are not significantly ($p<0.05$, LSD) different among land uses, **Significant at 0.01, *significant at 0.05, NS: Not Significant

Table 3: Soil Deterioration Index (SDI) values for the land uses (g kg^{-1})

Land use	SDI
OP	-18b
AF	-26bc
PO	-38d
WL	-8a
FL	-25bc
SL	-13b
GL	-6a
F-value	5.89**

Values in each column with the same letter are not significantly ($p<0.05$ LSD) different among levels of soil deterioration **Significant at 0.01

Soil nutrients varied seasonally among land use types, especially in the distribution of SOM, Total Nitrogen (TN) and Available Nitrogen (AN) (Table 2). Similar patterns of distribution were observed between SOM and nitrogen forms, while mean TP and AP were statistically ($p<0.05$) the same in the study site. The soil nutrients showed similar results of ANOVA and multiple comparison for the three sampling dates. Cultivated land use is related to soil management practices which vary in their tendency to promote soil erosion and this can contribute to the significant variation in nutrients between cultivated and uncultivated land uses. Non-significant difference in TP and AP could be due to the fact that most of the phosphorus are held firmly as insoluble P by sesquioxides. Soils of the study area are acidic and this promotes fixation of P by iron (Fe) and aluminium (Al) oxides. In addition to this, P is chemically bonded to the surface of clay minerals (Chen and Zhang, 1991).

There was significant ($p<0.05$) level of soil determination in the study site, with highest degradation occurring in lands cultivated with pineapple (SDI = -38 g kg^{-1}) and least in grasslands (SDI =-6) (Table 3). All results of the SDI were negative, showing deterioration or loss in value of soils

Table 4: Temporal variability of soil nutrients in relation to landscape positions

		TP (mg kg^{-1})			AP (mg kg^{-1})			TN (g kg^{-1})			AN (mg 100 g^{-1})			SOM (g kg^{-1})		
Hillslope	Position	5/04	7/04	7/05	5/04	7/04	7/05	5/04	7/04	7/05	5/04	7/04	7/05	5/04	7/04	7/05
A	US	5.6a	5.4a	5.2a	0.0a	0.8a	0.9a	0.3a	0.2a	0.3a	2.1a	3.2a	2.2a	0.5a	0.4a	0.4a
	MS	6.0a	5.5a	5.4a	1.8a	1.0a	0.9a	0.3a	0.3a	0.4a	2.2a	3.4a	2.4a	0.5a	0.5a	0.4a
	FS	6.1a	5.7a	5.6a	2.9a	1.9a	1.1a	0.3a	0.3a	0.4a	2.4a	3.9a	2.6a	0.6a	0.6a	0.5a
	F-value	0.7NS	0.8N	0.6NS	2.1NS	2.1NS	2.6NS	0.4NS	0.8NS	0.3NS	0.8NS	1.4NS	0.5NS	0.7NS	0.1NS	0.4NS
B	US	5.5a	5.3a	4.9a	1.5a	0.4a	1.1a	0.4a	0.4a	0.2a	2.7a	2.9a	2.4a	0.6a	0.6a	0.6a
	MS	5.6a	5.3a	5.2a	2.1a	1.0a	1.2a	0.4a	0.4a	0.3a	2.9a	3.09	2.4a	0.7a	0.6a	0.5a
	FS	6.2a	5.5a	5.4a	4.3a	1.6a	1.4a	0.5a	0.5a	0.7a	3.2a	3.2a	3.8b	0.9a	0.8a	1.6b
	F-value	4.5*	0.2NS	0.5NS	2.5NS	1.8N	2.5NS	1.9NS	0.6NS	9.4NS	0.2NS	1.0NS	5.6*	1.6NN	0.5NS	7.2**
C	US	6.1a	5.4a	5.3a	2.8a	3.1a	1.8a	0.3a	0.3a	0.4a	2.6a	2.8a	3.6a	0.6a	0.4a	0.5a
	MS	6.8a	5.9a	5.8a	2.4a	2.5a	6.4a	0.0.4a	0.4a	0.6a	2.9a	4.0a	3.8a	1.1a	0.6a	0.8a
	FS	6.6a	5.9a	5.7a	0.7b	1.8a	6.6b	0.4a	0.4a	0.5a	3.4a	3.9a	3.9a	0.9a	0.8a	0.7a
	F-value	0.5NS	0.6NS	0.5NS	9.8*	1.9NS	3.8*	1.5NS	2.1NS	0.1NS	5.0NS	5.2NS	0.4NS	3.2NS	2.8NS	1.5NS

Values in each column with the same letters are statistically the same ($p<0.05$, LSD) among landscape positions, **Significant at 0.01; *Significant at 0.05; NS: Not Significant; US = Upper Slope; MS = Midslope; FS = Footslope

Table 5: Distribution of soil nutrients among hillslopes (mean values)

	Soil nutrients				
Hillslope	TP (mg kg^{-1})	AP (mg kg^{-1})	TN (g kg^{-1})	AN (mg 100 g^{-1})	SOM (g kg^{-1})
A	6.1b	1.9a	4.1a	3.2a	6.9a
B	5.8a	1.5a	3.5a	2.8a	5.7a
C	6.5b	2.0a	4.1a	3.3a	6.5
F-value	3.98*	1.1NS	1.2NS	1.6NS	0.8NS

Values in each column with the same letter are statistically the same ($p<0.05$, LDS) among hillslopes, *Significant at 0.05, NS: Not Significant

in terms of the measured properties. Grasslands, woodland and shrubland soils exhibited highest loss in soil quality possibly due to better coverage from the erosive impact of rainfall unlike soils under pineapple orchard. Reduced deterioration in these land uses favours soil formation.

Landscape Positions and Soil Nutrients

There was no significant ($p<0.05$) differences in soil nutrients among landscape positions on Hillslope A. Generally, greater values of soil nutrients occurred at the FS, suggesting that overland flow may have moved nutrients to the footslope and other lower topographic positions in the study site. There were similarities in distribution of soil nutrients irrespective of sampling dates (Table 4).

Pattern of distribution of soil nutrients in Hillslope B was similar with that of Hillslope A as values of soil nutrients were highest in the footslope landscape position. Significant ($p<0.05$) differences among landscape positions were observed in soil nutrients of Hillslope B in SOM, TN, AN and TP. The distribution of soil nutrients among landscape positions differed in Hillslope C, showing a tendency for greater values of nutrients at the MS topographic position.

Results suggest that soil nutrient patterns and responses to landscape position were variable. Higher levels of nutrients at the MS in Hillslope C is surprising as one would expect more concentrations at the FS due to downstream movement and deposition. However, land use influences soil erosion on a slope (Dong *et al*., 1998) as sediments may be forced to be deposited. Micro-topographical features such as rills stone bunds old mounds, terraces and water storage depressions on middle slopes can deter further movement downwards.

Results showed that greater mean values of soil nutrients were found in Hillslopes A and C (Table 5). A significant ($p<0.05$) difference in TP was observed between Hillslopes. The results of MANOVA exhibited a significant ($p<0.05$) difference in north and south facing slopes for TP and AP as well as in interactions of land uses and landscape positions.

Table 6: Linear relationship between selected soil nutrients in the studied soils ($p<0.05$; $n = 90$)

Soil nutrients	Correlation coefficient (r)
TP versus AP	0.4**
TP versus AN	0.1NS
TP versus TN	0.3**
TP versus SOM	0.2NS
TN versus AN	0.8**
TN versus SOM	0.8**
AN versus SOM	0.8**

**Significant at 0.01, NS: Not Significant

Relationships among Soil Properties

Significant positive correlations existed among soil nutrients except between TP and AN and TP and SOM (Table 6). The SOM greatly influenced the availability of phosphorus and nitrogen in soils of the study area. The implication of the above is that SOM is important in contributing to the pool of total and potentially mineralizable P and N in soils of the area. Because of the impact of SOM on N and P, Mbagwu and Piccolo (1990) and Oguike and Mbagwu (2001) suggested the application of organic amendments to degraded tropical soils.

CONCLUSIONS

This study evaluated the affects of land use and landscape position on the availability of soil nutrients. It was found that significant differences occurred in soil nutrient distribution and availability among land use types and landscape positions. The SDI values also showed that cultivated land use types were more deteriorated than their uncultivated counterparts. There is need for further and more detailed study in this peculiar ecosystem on soil and soil-related properties to generate sufficient data for modelling soil nutrient changes.

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