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SOIL CHARACTERISTICS AROUND LAKE OPI IN EASTERN NIGERIA AND LAND USE RECOMMENDATIONS

C. L. A. Asadu, A. U. Ekwo and T. K. Udigwe
Department of Soil Science
University of Nigeria
Nsukka, Nigeria

ABSTRACT

In most developing countries including Nigeria basic data on soils and landscape features for proper land use planning are often lacking or scanty. In this study, variations in the properties of soils as well as landscape features around Lake Opi in eastern Nigeria were assessed. The objectives were to characterize the soils, ascertain any effects of the lake on the soils and make recommendations for the sustainable use of the soils and the lake itself. The soils around the lake (≅500-m radius) were sampled at 10-m intervals at approximately three concentric transects around the lake for preliminary information on consistence, texture and colour using auger samples. Based on the information obtained, 5 representative profiles were dug, 3 at ≅7 m from the lake and 2 at ≅200 m from the lake. The profiles were fully described and samples were collected from the pedogenic horizons for the determination of the relative proportions of particle sizes, pH, soil organic matter (SOM), total N, exchangeable bases and acidity, cation exchange capacity and available P.

Comparatively the major differences in the soils that were attributed to the influence of the lake were the thickness of Ap, E/AB, and Bt/BC horizons as well as the contents of clay, SOM, available P, total exchangeable bases and effective cation exchange capacity in these horizons. All, except the thickness of Ap horizon, were relatively higher in the soils 200 m from the lake than in soils proximate to the lakeshore when comparing the mean values obtained from the Ap horizons. Thus, based on the fertility indices in the A horizon, the soils 200 m from the lake were more fertile than those closer to the lake. Again the soils 200 m from the lake appeared to be less variable (lower coefficients of variation) in soil physicochemical properties than those closer to the lake. Thus, the soils 200 m from the lake were generally more developed and were classified as Haplustalfs (Lixisols) using the Soil Taxonomy and FAO/UNESCO systems. Those proximate to the lake were classified as Haplustept (Alisol) and Ustorthent/Ustifluvent (Fluvisols). Based on the soil characteristics and landscape features, an integrated agricultural production system involving vegetable, poultry and fish farming were recommended for the area.

Key words: Lake, soil physicochemical, sustainable land use.

INTRODUCTION

Soil and land constitute the base resources for agriculture, forestry, urban development, industry, communications and other resources of a nation; hence they are among the most vital natural resources to mankind. Berlows (1972) classified land use types under these options: residential lands, commercial and industrial lands, croplands, pasture and grazing lands, forest lands, mineral lands, recreational lands, transportation lands, service area, barren and waste disposal lands.

In line with the recent trends in development, there is need for land evaluation to ascertain capability, suitability and hence effective land use and these should be the ultimate question answered by any soil survey and land evaluation exercise. Cline (1949) categorically stated earlier that the only absolute truths about soils are to be found in the soils themselves, as they exist in nature, whereas our observations and measurements, no matter the number and level of accuracy, are only approximations of the truth. The knowledge of these truths, which are in most cases hidden, could be reached by the acquisition of technical data from the soils themselves. These important technical data on soils can be collected by careful and detailed field surveys and laboratory analysis (Areola, 1974). It has been emphasized that the development of a viable economy in any country relies fundamentally on the soil, which must be allocated judiciously among the major kinds of land use in that country (Ojanuga et al., 1981).

Almost 80% of the land area of eastern Nigeria is of sedimentary geologic deposits made up of shales, coastal plain sand, false-bedded sandstone, and alluvium, while the balance is composed of basement complex and igneous rocks. There exist significant relationships between parent materials and soil properties such as texture, soil reaction, exchangeable bases and acidity, all important to fertility and land use (Akamigbo and Asadu, 1983).

Within regions of uniform climate and geology, the following soil properties are found to be related to topography: depth of solum, colour, degree of horizon differentiation, relative moisture content, thickness and organic matter content of A horizon, reaction, soluble salt content, temperature, the kind and degree of pan development (Craul, 1992). It has been found that the main properties of the soil varying with land use were bulk density and organic matter content and also that forest soils were better nutrient accumulators than grassland soils mainly because forest soils have good potentials for storage of nutrients in biomass (Hall et al., 1977).

Widespread and severe problems of soil degradation in the tropics are not necessarily caused by soil characteristics per se and may be traced to land misuse and soil mismanagement, desperate attempts by resource-poor farmers to grow crops by mining the soil fertility, human greed and short-sightedness, poor planning and cutting corners for quick economic returns (Lal, 2000). Thus, it has been recommended that the steep slopes of soils need to be protected with vegetation, those soils that are flocculated, or are very unstable should be protected and preserved for recreational purpose (Mbagwu, 1977). The physical factors which are of utmost importance to soil erosion in southern Nigeria are rainfall, the degree of vegetative cover, the topographic disposition and lithology (Ofomata, 1975).

Lakes are the most varied features of the earth's surface occupying the hollows of the land surface in which water accumulates. They vary tremendously in size, shape, depth and mode of formation. According to Adeleke and Leong (1979), lakes can be formed by any of the following; earth movement, volcanic activity, erosion, deposition and human/ biological activities. They further explained that lakes vary in salt concentrations and indicated that most lakes in the humid tropics are fresh water lakes. Chemically, a lake would relatively impart its constituent salts on its surrounding soils. Lakes can impart some influence on the surrounding soils through their effect on soil water because precipitation is one of the factors that could affect the chemical composition of the soil solution apart from the characteristics of the soil solids, solute composition, biological activity within the soil matrix and to some extent contact time (Cresser et al., 1993).

Opi Lake in eastern Nigeria has been categorized as a natural lake, which has potential aesthetic value, and there is a widely recognized need to explore and develop it for tourism (Igbozurike, 1975). Good soil management should result from sustainable agricultural systems, that is, one that maintains or enhances the quality of the environment, meets current and future demands of the society and ensures the economic and social welfare of the farming community (CGIAR, 1989; Asadu, 1996a). The usefulness of soil studies lies in land evaluation as it aids in determining suitability and capability of our soils for various uses and eventually as a guide to conservation practices and management of the areas under study (Dent and Young, 1981).

This study evaluated soil characteristics around Opi Lake, and the Lake's effects on the physicochemical properties of the surrounding soils with an ultimate objective to make recommendations for the sustainable use of the soils and the lake.

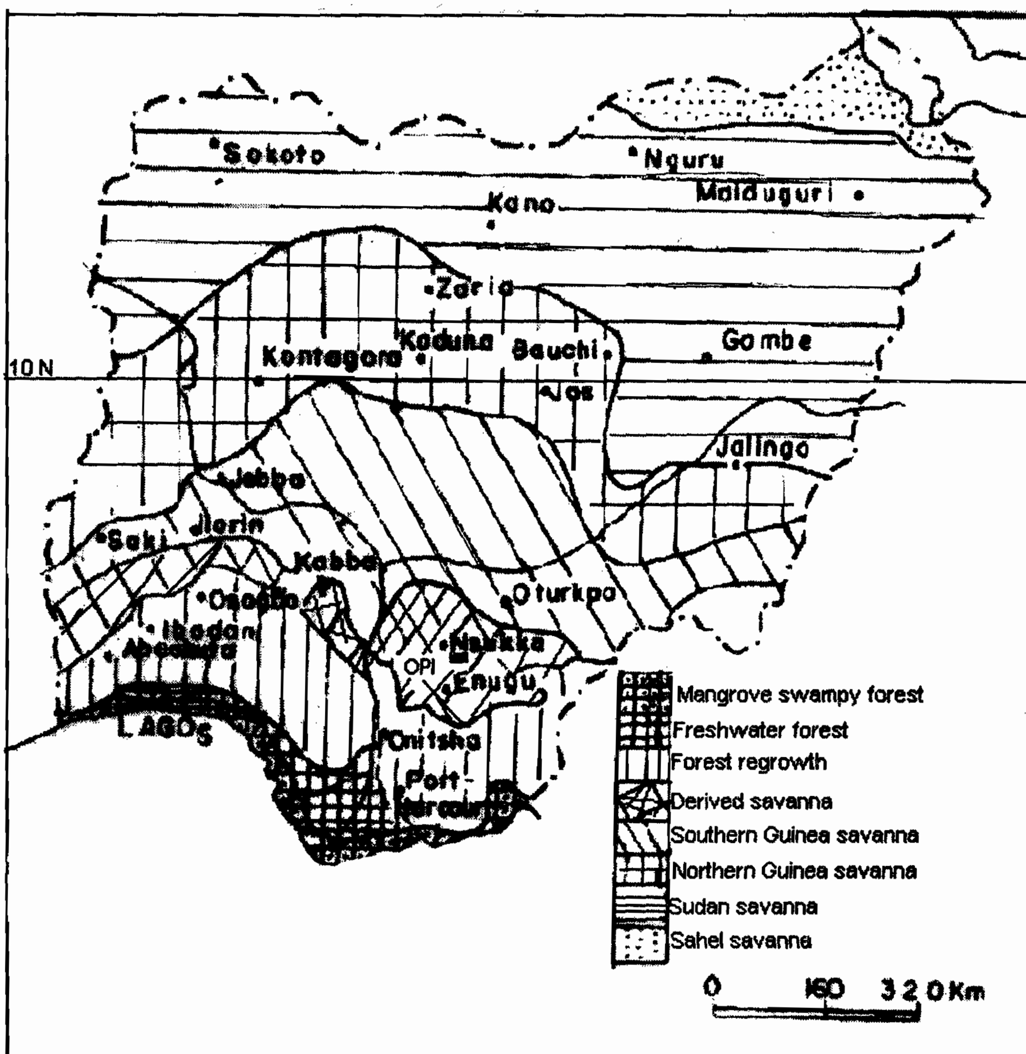

Fig.1. Adapted vegetation map of Nigeria showing Opi location in the Derived savanna zone. (Source: Agboola 1979)

MATERIALS AND METHODS

Location

The area studied was at Uhere Opi, near Nsukka (6^0 52' N and $7^0$24' E) in eastern Nigeria (Fig.1, source: Agboola, 1979). The site is approximately 5 km southeast of Nsukka. There are up to 5 small lakes within the area but the one studied covers approximately 20 ha.

The general climate of the area by Koppen (1936) classification is humid tropical climate, (Koppen's AW). There are usually two seasons, namely the rainy and the dry seasons. The former usually lasts from April to October with a short break normally in the month of August. Average annual rainfall is about 1550 mm and more than 85% of this rain falls within the 7-month rainy season. The average minimum and maximum temperatures are about 22 °C and 30 °C, respectively while the average relative humidity is rarely below 60%. During the short harmattan season (December through January) temperature may fall below 22 °C. The area has an ustic soil moisture regime and an isohyperthemic soil temperature regime (Asadu, 1990).

The soils of the area are generally derived from the residua of either false-bedded sandstone or upper coal measure formations (Asadu, 1990). These geological formations usually give rise to sandy and clayey soils, respectively (Akamigbo and Asadu, 1983). The false-bedded sandstone, with some colluvial materials, is found on the lowland area. On the other hand, the upper coal measures occupy the upper slopes and tops of residual hills in the area. Generally, residua from them are often transported by colluvial and/or erosion processes to the lower plains to form soils of similar characteristics with those of the upper slopes (Asadu and Bosah, 2002).

The Nsukka region has a high central zone, which is generally over 365 m above sea level, with isolated peaks reaching over 545 m (Ofomata, 1975). The highest point in the area lies at 590 m above sea level. The central highland (plateau) section of Nsukka area forms the watershed for some upper course tributaries of the Niger and Cross Rivers (Ofomata, 1975).

The traditional system of agriculture is a rotational bush fallow, under which the soils are left to recuperate during a period of rest between 1 and 3 years. But recently, the area has been subjected to continuous and intensive cultivation due to increases in human populations (Ofomata, 1974). Food crops are grown with major perennial tree crops such as oil palm and Irvengia spp. under intensive systems of land use and occasionally animals are reared.

The native vegetation of the area is largely woody savanna with grassy and herbaceous under growth. The main vegetative cover is secondary due to the influence of man through bush burning, clearing and land cultivation (Asadu and Akamigbo, 1987). It is within the derived savanna zone of the country (Fig. 1). The variety of both tree crops, arable crops and grasses found in the study area include Irvingia spp, *Elaeis guinensis*, *Chlorophora excelsea* (Iroko tree), Agba trees and *Pentaclethra mycrophylla* (ukpaka). The grasses and weeds include *Andropogon gayanus*, *Aspilia africana*, *Imperata cylindrical*, wild species of cocoyam and *Chromolena odorata*. The common arable crops are maize (*Zea mays*), rice (*Oryza sativa*), cocoyam (*Colocasia esculenta*), telferia (*Telferia occidentalis*), amarantus (Amaranthus spp,), yam (Dioscorea spp) and cassava (Manihot spp).

Soil Sampling and Analysis

Following a reconnaissance visit, auger borings were made at approximately 10-m intervals starting from the lake to about 500 m from the lake along 3 transects away from the lake. Augering was done to a depth of 120 cm where there was no restriction and the soils were examined for consistence, colour and texture. From this preliminary study, 5 profiles were dug, three to represent the soils proximate (< 200 m) to the lake and two, $x \geq 200$ m from the lakeshore. Three were located at about 7 m from the lake and 2 about 200 m from the lake. The profiles were fully described and samples were collected from the pedogenic horizons.

Prior to analysis, soil samples were air-dried, gently crushed and sieved with a 2-mm sieve. Particle-size distribution analysis was done by the Bouyoucos (1951) hydrometer method using sodium hexametaphosphate as the dispersant.

The soil pH was determined in duplicate both in water and 0.1N KCl using Beckman's zeromatic pH meter, in a soil: liquid suspension of 1:2.5. Total nitrogen was determined by the macro-Kjedahl wet oxidation method (Bremner and Mulvaney, 1982). Organic carbon was determined by the method of Walkley and Black (1934), and this was converted to soil organic matter (SOM) by multiplying the percentage carbon by 1.724.

Available P was determined by the Bray-2 method (Bray and Kurtz, 1945).

Exchangeable bases were extracted with neutral, 1N ammonium acetate (NH_4OAc), Ca and Mg were determined by atomic absorption spectroscopy while K and Na were determined with flame photometer. Exchangeable acidity was determined by the method outlined by Barnhisel and Bertsch (1982). Effective cation exchange capacity (ECEC) was obtained by summing the total exchangeable bases (TEB) and 1 N KCl extractable Al. Percent base saturation was calculated from 100TEB/ECEC.

RESULTS AND DISCUSSION

Morphological and Physical Properties

The site information and the morphological properties of the five representative profiles summarized in Tables 1 and 2 show that the depths reached in the various profiles varied and were generally limited especially around the lake. The average depth of profiles proximate to the lake (1, 2 and 3) was 90 cm and that of profiles 200 m from the lake (4 and 5) was 124 cm (Tables 1 and 2). Depth of profile 4 was limited due to impenetrable rock layer. All the profiles showed signs of good drainage. Profiles 2 and 3, which were closer to the lake were classified as fairly well drained. This classification was based on the dominant reddish brown colours especially in the A horizons. The profile characteristics observed could be a reflection of both the influence of the lake and the nature of the parent material of the area. Asadu (1982) earlier reported that the soils derived from the colluvial materials of the upper coal measures and false-bedded sandstone in Nsukka area of eastern Nigeria were generally well drained and deep. However, high water table encountered, especially around the lake, may have contributed to the slight changes in colour and the profile depths.

The Ap horizons of profiles around the lake generally had a mean (Table 3) more than twice that obtained 200 m from the lake. However, the former was also more variable, indicating more variability in the thickness of Ap horizon proximate to the lakeshore. These relatively thicker Ap horizons of profiles around the lake than 200 m away from the lake can be attributed to their topographic positions as well as the influence of the lake. Craul (1992) established that the thickness of A horizon depends on topography with other factors being constant. The lake is in a depression and hence soil materials from sites of profiles 4 and 5 were often eroded and moved down by precipitation and surface flow towards the lake, resulting in thicker Ap horizons around the lake. Again, areas 200 m from the lake were more frequently cultivated and hence there was soil loss due to surface and inter-rill erosion caused by surface run off from positions 200 m from the lake to lower positions towards the lake. The lake also supports more abundant undergrowth of vegetation closer to itself and this could have also contributed to slowing down the movement of the transported material into the lake, hence leading to their increased deposition and accumulation towards the lake, thereby increasing the thickness of the Ap horizons.

There were also eluvial-transitional horizons in some of the profiles. Their presence suggest that eluviation/illuviation processes were contemporary soil formation processes in the profiles concerned (Asadu, 1990). However, from the higher mean values of the thickness of these horizons obtained in the soils 200 m from the lake (Table 3) compared with the corresponding values obtained in soils closer to the lake, it is clear that those soils 200 m from the lake were more stable or developed. Thus profiles 4 and 5 were tentatively classified as Alfisols (Lixisols) and those closer to the lakes mainly as Inceptisol (Alisol) and Entisols (Fluvisols) (Tables 1 and 2). The lower values of the coefficients of variation (CV) obtained in both cases (Table 3) support this inference on the greater stability of the soils 200 m from the lake.

Table 1: Summary of morphological properties of the profiles proximate to the lakeshore

Horizon/Depth	Description
	PIT1-General: Oxyaquic Haplustept (Haplic Alisol), approx. 8m from the lake, gentle slope (4%), well drained, used for rice and vegetable production, weak rill erosion, date of sampling: 13/5/2000.
Ap (0-17 cm)	Dark reddish brown (5YR 3/4) moist; sandy loam; weak, fine subangular blocky; non-sticky, non-plastic; friable, hard; no cutans; many, very fine fibrous roots; clear, smooth boundary.
E (17-31)	Brown (7.5YR 4/6) moist; sandy loam; weak, fine granular; non-sticky, non-plastic; friable, hard; no cutans; many, very fine fibrous roots; gradual wary boundary.
B1 (31-55cm)	Dull reddish brown (5YR 4/4) moist; sandy clay loam; moderate, very fine massive; sticky, slightly plastic; firm, very hard; charcoal pieces on surface; many coarse woody roots; gradual wavy boundary.
B2 (55-115cm)	Dark reddish brown (5YR 3/4) moist, clay; strong, very fine massive; very sticky, plastic; firm, very hard; organic matter patches; many coarse woody roots.
	PIT2-General: Oxyaquic Ustorthent (Dysteric Fluvisol), approx. 7m from the lake, sloping (6%), fairly well drained, used for rice and vegetable production, weak rill erosion, date of sampling:13/5/2000.
Ap (0-12 cm)	Brown (7.5YR 4/6) moist; sandy clay loam; moderate, fine subangular blocky; non-sticky, non-plastic; friable, hard; no cutans; common, fine fibrous roots; diffuse, wavy boundary.
A/C (12-43cm)	Bright reddish brown (5YR 5/6) moist; sandy loam; moderate, fine massive; slightly sticky, slightly plastic; friable, hard; no cutans; common, fine fibrous roots.
	PIT3-General: Mollic Ustifluvent (Eutric Fluvisol), approx. 6m from the lake, sloping (7%), fairly well drained, used for cocoyam, rice and vegetable production, weak rill erosion, date of sampling: 13/5/2000.
Ap (0-30cm)	Very dark brown (7.5YR 2/3) moist; sandy clay loam; weak, fine subangular blocky, non-sticky, non-plastic; friable, hard; no cutans; common fine fibrous roots; clear smooth boundary.
AB (30-52cm)	Dark reddish brown (5YR 3/3) moist; sandy clay loam; moderate, fine subangular blocky, slightly sticky, slightly plastic; firm, hard; pieces of charcoal on surface, common medium fibrous roots, gradual wavy boundary.
B (52-112cm)	Brownish gray (5YR 4/1) moist; sandy clay loam; moderate, fine subangular blocky; sticky, plastic; firm, hard; no cutans, common medium fibrous roots.

Table 2:: Summary of morphological properties of representative profiles 200m from the lake

Horizon/Depth	Description
	PIT4-General: Psammentic Haplustalf (Haplic Lixisol), approx. 180m from the lake, very slopy (20%), well drained, used for cocoyam and cassava production, inter-rill erosion, date of sampling: 13/5/2000.
Ap (0-7cm)	Brownish black (7.5YR 3/1) moist; sandy clay loam; weak, moderate, subangular blocky; non-sticky, non-plastic; loose, soft; no cutans; common, medium fibrous roots; clear smooth boundary.
E (7-25cm)	Dull reddish brown (5YR 5/6) moist; sandy loam; moderate, fine massive; slightly sticky, slightly plastic; firm, very hard; no cutans; common, medium fibrous and woody roots, gradual wavy boundary.
Bt1 (25-42cm)	Reddish brown (5YR 4/6) moist, sandy clay loam; strong, very fine subangular blocky; sticky, plastic; firm, very hard; few cutans; common, coarse roots, gradual wavy boundary.
Bt2 (42-98cm)	Bright reddish brown (5YR 5/8) moist, sandy clay loam; strong, fine subangular blocky; sticky, plastic, very firm, very hard; few cutans; few coarse (woody) roots; gradual wavy boundary.
	PIT5-General: Inceptic Haplustalf (Haplic Lixisol), approx. 200 m from the lake, sloping (8.5%), well drained, used for cocoyam and cassava production, incipient gully erosion, date of sampling: 13/5/2000
Ap (0-11cm)	Dark reddish brown (5YR 3/2) moist; sandy clay loam: moderate, medium subangular blocky; non-sticky, non-plastic; firm, hard; thick charcoal coatings; many fine roots; clear smooth boundary.
E (11-37cm)	Brown (7.5YR 4/4) moist; sandy clay loam; moderate, medium subangular blocky; slightly sticky and slightly plastic; firm, hard; no cutans; many fine roots; gradual wavy boundary.
Bt1 (38-63cm)	Bright brown (7.5YR 5/8) moist; clay loam; strong, fine subangular blocky; sticky and plastic, very firm, very hard; few cutans; few, medium roots; gradual wavy boundary.
Bt2 (63-95cm)	Bright reddish brown (5YR 5/8) moist; sandy clay loam; strong, fine subangular blocky; sticky and plastic, very firm, very hard; few cutans; few coarse (woody) roots; gradual wavy boundary.
Bt3 (95-150cm)	Bright reddish brown (5YR 5/8) moist, sandy clay loam, strong, fine subangular; blocky; sticky and plastic; very firm, very hard; few cutans present; few coarse roots.

Table 3: Comparison of selected soil properties across the pedogenic horizons†

Soil property	Horizon	Profile position relative to lake					
		Proximate to lakeshore			Away from lakeshore		
		Mean	SD	CV (%)	Mean	SD	CV (%)
Thickness (cm)	Ap	19.7	9.3	47	9.0	2.8	31
	E/AB	18.0	5.7	31	22.0	5.7	26
	Bt/B	58.3	26.5	46	93.0	28.4	30
Clay (%)	Ap	21.3	3.1	14	24.0	2.8	12
	E/AB	25.0	9.9	40	26.0	2.8	11
	Bt/B	31.2	24.9	80	36.0	12.6	35
SOM (%)	Ap	0.96	1.02	105	2.13	1.55	73
	E/AB	0.60	0.62	103	0.65	0.04	5
	Bt/B	0.96	0.66	69	0.25	0.19	77
Avail. P (mg kg^{-1})	Ap	6.5	0.78	12	8.0	1.77	22
	E/AB	6.4	0.23	4	6.3	0.0	0
	Bt/B	7.0	0.52	7	5.6	0.04	1
TEB (cmol kg^{-1})	Ap	3.09	0.83	27	14.93	7.97	53
	E/AB	3.26	0.53	16	2.67	0.42	16
	Bt/B	4.87	3.03	62	3.83	1.00	26
ECEC (cmol kg^{-1})	Ap	4.83	1.05	22	18.21	7.28	40
	E/AB	5.06	0.73	14	4.17	0.57	14
	Bt/B	7.14	4.01	56	5.71	1.51	26

†SD = Standard deviation, CV = coefficient of variation, SOM= soil organic matter, TEB = total exchangeable bases, ECEC = effective cation exchange capacity.

Table 4: Particle-size (%) distribution

Horizon	Depth (cm)	Sand (2000- 20μ)	Silt (20-2μ)	Clay (<2μ)	Textural class
			Profile 1		
Ap	0-17	76	6	18	Sandy loam
E	17-31	76	6	18	Sandy loam
B1	31-55	72	4	24	Sandy clay loam
B2	55-115	6	2	92	Clay
			Profile 2		
Ap	0-12	76	2	22	Sandy clay loam
A/C	12-43	82	2	16	Sandy loam
			Profile 3		
Ap	0-30	72	4	24	Sandy clay loam
AB	30-52	62	6	32	Sandy clay loam
B	52-112	66	4	30	Sandy clay loam
			Profile 4		
Ap	0-7	70	4	26	Sandy clay loam
E	7-25	68	4	28	Sandy clay loam
Bt1	25-42	62	6	32	Sandy clay loam
Bt2	42-98	38	4	58	Clay
			Profile 5		
Ap	0-11	76	2	22	Sandy clay loam
E	11-37	72	4	24	Sandy clay loam
Bt1	37-63	56	10	34	Clay loam
Bt2	63-95	72	2	26	Sandy clay loam
Bt3	95-150	66	4	30	Sandy clay loam

There was similar soil structure and

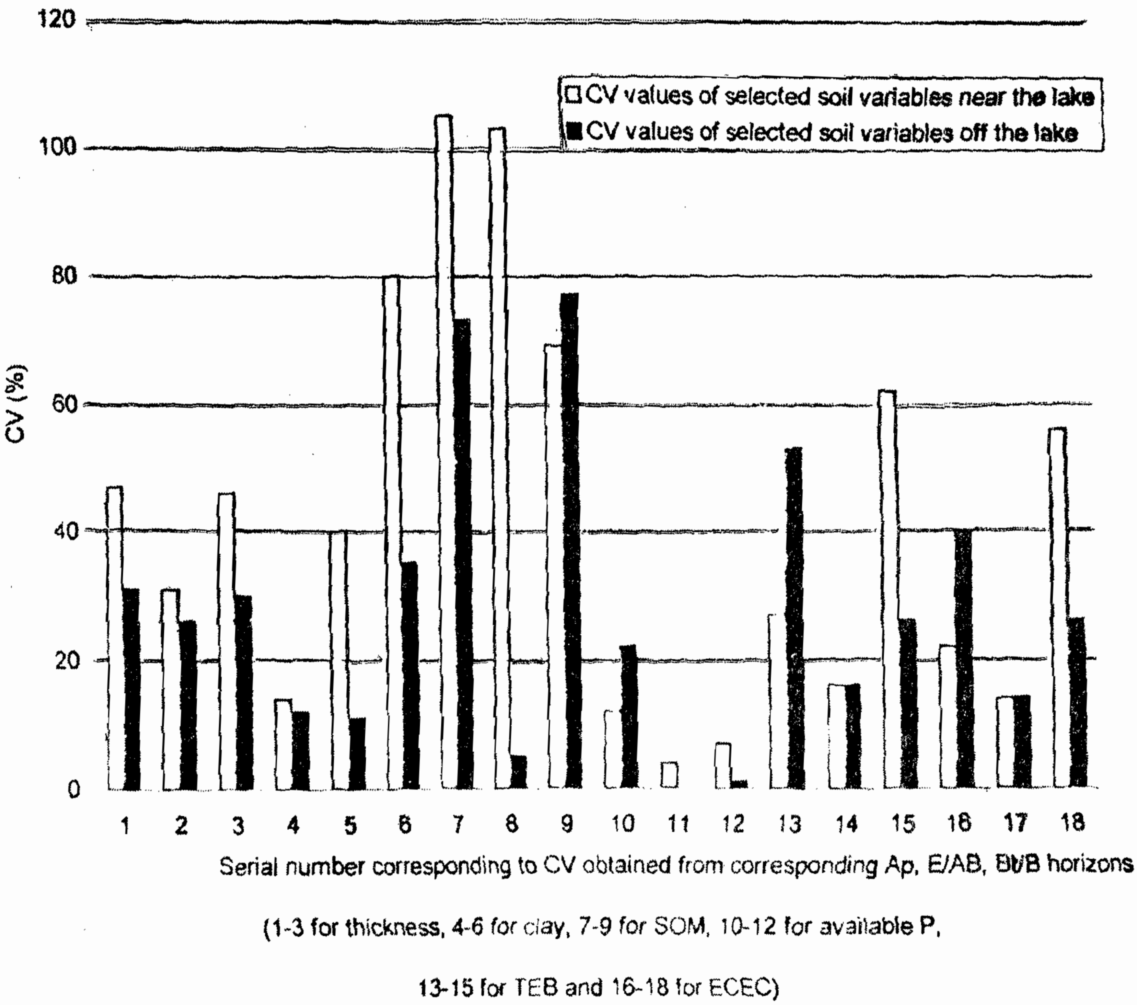

Fig. 2. Variations in the CV values of selected soil variables most affected by the lake

Table 5: Summary of chemical properties of representative profiles†

Horizon	Depth (cm)	pH H_2O	pH KCl	SOM (%)	Total N (%)	Na^+	K^+	Ca^{2+} cmolkg^{-1}	Mg^{2+}	TEB	TEA	ECEC	BS (%)	Av. P (mg kg^{-1})
							PIT 1							
Ap	0-17	5.1	4.2	0.48	0.018	0.09	0.09	2.0	1.8	3.98	3.0	5.98	67	5.6
E	17-31	4.5	4.0	0.28	0.014	0.10	0.10	1.5	1.0	2.70	1.6	4.30	63	6.3
B1	31-55	4.5	4.0	0.48	0.024	0.11	0.12	1.4	1.3	2.93	1.6	4.53	65	7.6
B2	55-115	5.6	4.2	1.72	0.086	0.16	0.20	5.0	3.0	8.36	3.4	11.76	71	6.7
							PIT 2							
Ap	0-12	5.2	4.1	0.28	0.015	0.12	0.05	1.8	1.0	2.97	2.8	4.57	65	7.1
A/C	12-43	5.2	4.1	0.21	0.012	0.14	0.12	2.0	1.5	3.76	3.5	5.76	65	6.3
							PIT 3							
Ap	0-30	4.3	3.7	2.13	0.096	0.12	0.11	1.1	1.0	2.33	2.1	3.93	58	6.7
AB	30-52	4.2	3.7	1.31	0.065	0.12	0.10	1.6	1.5	3.32	3.1	5.12	65	6.7
B	52-112	4.3	3.7	0.69	0.035	0.12	0.11	1.6	1.5	3.33	3.1	5.13	65	6.7
							PIT 4							
Ap	0-7	6.3	5.2	3.22	0.160	0.19	0.27	12.6	7.5	20.56	2.8	23.36	88	9.2
E	7-25	4.3	3.8	0.67	0.035	0.08	0.09	1.2	1.0	2.37	1.4	3.77	63	6.3
Bt1	25-42	4.4	3.8	0.48	0.026	0.09	0.08	1.6	1.4	3.17	1.6	4.77	67	5.6
Bt2	42-98	4.4	3.7	0.41	0.020	0.09	0.07	1.6	1.5	3.26	1.6	4.86	67	5.5
							PIT 5							
Ap	0-11	5.5	4.3	1.03	0.051	0.02	0.27	6.0	3.0	9.29	3.6	13.06	72	6.7
E	11-37	4.5	3.8	0.62	0.031	0.09	0.08	1.6	1.2	2.97	1.6	4.57	65	6.3
Bt1	37-63	4.5	3.8	0.21	0.015	0.10	0.09	2.2	1.8	4.19	1.8	5.99	70	5.6
Bt2	63-95	5.6	4.2	0.07	0.020	0.14	0.20	3.1	2.0	5.44	2.8	8.24	66	5.6
Bt3	95-150	4.9	4.0	0.07	0.019	0.10	0.10	1.6	1.3	3.1	1.6	4.70	66	5.6

†SOM= soil organic matter, TEB = total exchangeable bases, TEA = total exchangeable acidity, ECEC = effective cation exchange capacity

consistence among all the profiles examined, but each profile showed a remarkable trend with depth, especially with respect to textural classes (Table 4). The dominant textural class was, however, sandy clay loam. With regard to soil colour (Tables 1 and 2), the area was dominated by the different shades of brown/red colour of 5YR and 7.5YR hues and more of dark reddish, brown and bright reddish brown colours of 5YR hue. Cutans were not visibly present in most of the soils. Charcoal pieces (< 0.1 mm in diameter) were observed in some horizons like Ap horizon of profile 5 and B1 horizon of profile 1. All surface horizons have fibrous roots. Gradual, wavy boundaries were observed in all the pits (Tables 1 and 2).

Clay content increased with depth in most of the profiles. The higher clay content in the Bt horizons of the soils 200 m away from the lake compared to their respective Ap horizons was an indication of illuviation/eluviation processes to which finer particles (clay) were often more susceptible. The mean clay content of Ap horizons of profiles proximate to the lakeshore was about 21% compared to the slightly higher value of 24% obtained in the Ap horizons 200 m from the lake. However, variability was higher in soils proximate to the lakeshore than in those away from lake as shown by the CV values (Table 3). This can be attributed to fluctuations in the processes of clay removal/additions in these profiles favoured by lake influence on adjacent soils. For example, the higher water table could have been a source of water for the mobilization of clay in the B2 horizon of profile 1 which then helped to enrich the horizon B1 with clay.

There was not much difference in the overall mean values of sand content which was 64% around the lake and 66% 200 m from the lake. The mean sand content of Ap horizons was 75% around the lake and 73% 200 m from the lake. However, an appreciable difference in sand content existed between the two profiles in their B-horizons. The mean sand content obtained in B-horizons around the lake was 54% but the mean was 59% 200 m from the lake. The silt content in all the profiles was very low ranging from 2 to 10% with an average of 4%. This few silt-sized particles in the soils were attributed to the characteristics of the parent materials of the soils (Akamigbo and Asadu, 1983).

Chemical Properties

From the results of the chemical analysis shown in Table 5, the soils ranged from very extremely acid to medium acid with pH values (H_2O) ranging from 4.2 to 6.3 with an average of 4.9. There was no significant difference ($p = 0.6$) in pH values among the soils sampled. Asadu (1990) explained that the generally low pH values and nutrient status of the soils in the area can be partly attributed to the composition of the dominant sandy parent material which is weathered false-bedded sandstone, and partly to leaching losses resulting from intense rainfall which is characteristic of the area.

The soil organic matter (SOM) content ranged from very low to moderately low (< 2.0%). There was no appreciable difference 200 m from and around the lake especially in the subsurface horizons. The values obtained generally decreased downward in all the profiles except in profile 1 which surprisingly gave its highest value in the lowest horizon. The highest value of 3.2% was obtained in the Ap horizon of profile 4, 200 m from the lake. The low organic matter content in the area is an indication of high rate of organic matter degradation made possible by the relatively high temperature and equally good soil aeration of the area, which is made evident by the reddish moist Munsell colours obtained in almost all the profiles. This is an indication of adequate oxidation of iron compounds in the soils. However, indiscriminate burning of plant residues and removal of crop residues through harvest from the fields as earlier observed by Lal (2000) could have also diminished SOM in the soils. The total nitrogen content was equally very low in all the profiles and the trend in distribution was similar to that of organic matter content having its highest value of 0.16% in the same Ap horizon of profile 4. This low value of nitrogen content could be attributed to the low SOM content.

The values of total exchangeable bases (TEB) ranged from relatively low to moderate with the moderate values obtained in the Ap horizons of profiles, 4 and 5 which were 200 m from the lake. From the values obtained, the overall mean TEB for the profiles around the lake was 3.54 cmol kg^{-1} and 6.05 cmol kg^{-1}, 200 m away from the lakeshore. The trend was equally reflected in the CEC values, which were relatively very low to moderate with an overall profile mean value of 6.9 cmolkg^{-1} around the lake and 9.4 cmolkg^{-1} 200 m from the lake. Equally, moderate values of base saturation were obtained with a mean value of 54% around and 58%, 200 m from the lake. The TEB is probably lower around the lake because of the influence of water from the lake, which causes some leaching effects, reducing the quantity of the exchangeable nutrients. Again, water sample from the lake analyzed also indicated low value of TEB (< 2.0 cmol kg^{-1}) of basic cations; hence we attribute little significant addition from the lake to the exchangeable bases of the surrounding soils. The general low TEB and CEC prevalent in the study area was largely due to the effect of parent material; the corresponding low SOM content and the dominance of low activity clays as earlier observed in similar soils around the area (Akamigbo and Asadu, 1983; Asadu, 1990; Asadu and Bosah, 2002).

Total exchangeable acidity (TEA) was low to moderate in all the profiles and had no unique trend down the pit. Moderate values were obtained in Ap horizon of profiles 4 and 5 and virtually all the horizons around the lake. However, the overall mean values did not appear to change significantly as one moved away from the lake. The values obtained ranged from 1.6 - 3.6 cmol kg^{-1} with an average of 2 cmol kg^{-1}. The values of TEA obtained were comparable to those earlier reported for the soils derived from similar parent materials in the area (Akamigbo and Asadu, 1983).

Based on the Bray-2 extraction, available P was relatively low in all the profiles and values ranged from 5.5 - 9.2 mg kg^{-1}. Values obtained (especially in the subsurface horizons) did not change significantly as one moved away from the lake. The low values of available P would have stemmed from the low SOM content and possible lack of abundant native phosphate-bearing rocks in the geological materials of the area.

Generally, the soils 200 m from the lake seemed to be more fertile than those closer to the lake. This can be seen from the comparison of the mean values of 4 major chemical fertility indices presented in Table 3. The mean SOM was generally higher and less variable in the soils 200 m from the lake than in soils closer. This trend in mean values applies to all the indices especially at the Ap horizon. Among the indices, available P exhibited the least variability among the soils while SOM exhibited the most. Except in the case of SOM obtained at Bt/B horizons, the CV values in both of the subsurface horizons were as low as (or lower) in the soils 200 m from the lake (Fig. 2). This trend also shows that there is greater stability in chemical properties in soils 200 m from the lake than in soils closer to the lake, a situation attributable to the influence of the lake.

In general the low values of the nutrients in all the soils are characteristic of the soils of the area, an indication that the use of soil amendments is necessary for their sustainable use in crop production. This applies to most soils in southeastern Nigeria (Asadu, 2000).

Land Use Recommendation

Based on both the soil characteristics and physical features of the land, an integrated agricultural land use system is recommended for the entire area. The system involves year-round vegetable, poultry and fish farming.

The lake water is fresh owing to supplies from some streams and through precipitation, and it is not salty. With the availability of water from the lake, year-round vegetable production is possible in soils around the lake. A small sprinkler system of irrigation with pumps fixed at the edge of the lake is recommend for the dry season planting and for supplementary water supply when necessary. Formation of farming groups can facilitate this where individual farmers cannot afford the cost. Up to 10 ha of suitable land are available for this use. The vegetables recommended are telferia, Nsukka yellow pepper and tomato. These vegetables are always in high demand in the whole of Nigeria and they are particularly scarce during the dry period. This is because most farmers grow them under rain-fed system, which is not very reliable due to the unpredictability of the onset and stability of rainfall in the area (Asadu, 1996b). In rain-fed agriculture in much of the tropics, Lal (2000) observed that soil water management was a crucial factor in enhancing food production. The soils will, however, need some fertilization because of their low nutrient contents (Table 5). This can be obtained from the poultry farm, a component of the system.

A poultry farm of size between 5000-10000 birds is recommended for the eastern part of the lake. With simple treatments (filtration and chlorination), the water from the lake can be used for virtually all the activities in the poultry farm. An area of about 5 ha can be used for this purpose but in addition to poultry houses and a mini-market or farm shop, rest houses for the workers should be sited in this area. The chicken and eggs that will be produced from this farm can minimize the scarcity of animal protein in the zone. The farm will also supply manure to the vegetable farm as stated earlier.

Fishing and fish farms are not common in this part of the country probably due to the absence of large rivers or other water bodies. It will be most interesting to introduce this type of farming in the area. All the lakes can be assessed in more details to find out possible fish species that are most suitable to each for commercial production. This will help to provide animal protein to the inhabitants at affordable cost, as the production will be local.

CONCLUSION

A study of the soils around Opi Lake in eastern Nigeria revealed that the lake influenced the development of the soils around it. The effects were particularly substantial on the thickness of the some pedogenic horizons, clay content, total exchangeable bases (TEB) and effective cation exchange capacity (ECEC) in selected pedogenic horizons. The thickness of the Ap horizon was higher in the soils around the lake but the reverse was the case for the thickness of both the eluvial and Bt/BC horizons. Similarly the contents of clay, TEB and ECEC were all higher in the soils 200 m from the lake than those closer to the lake. Thus, the soils 200 m from the lake were generally more fertile and also less variable than those closer to the lake. They were respectively classified as Haplustalfs (Lixisols) and Haplustept (Alisol) or Ustorthent/Ustfluvent (Fluvisols). An integrated agricultural production system involving vegetable, poultry and fish farming was recommended for the area. These will spark rapid development in this rather obscure rural community in eastern Nigeria.

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