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# Assessment of Properties of Alfisols as Affected by Land use in Minna, Southern Guinea of Nigeria

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***Abstract* – To assess the land use effects on soil properties, this study examined the profile variations in the morphological, physical and chemical characteristics of an Alfisols as affected by land use systems. Soil profiles from arable farmland and teak plantation were described. The surface color of the soils was grayish brown (10YR 5/2) in arable farmland and very dark grey (10YR 3/1) in teak plantation over various shades of brown in the subsurface horizons. Particle size analysis showed that sand particle was the dominant mineral fraction in soils of the two land use types studied and its content decreased down the profiles. Soils of the two land use types showed evidence of clay migration from surface to horizons below with higher contents in teak plantation than arable farmland. The soil pH was moderately to slightly acidic irrespective of the land use type studied. Organic carbon and total nitrogen values of these soils were lower in subsurface horizons and decreased with depth. Available phosphorus was moderate in arable farmland and low in teak plantation with mean values of 11 and 7 mg kg$^{-1}$ respectively. Values for exchangeable bases (Ca, Mg and K) were lower in teak plantation compared to arable farmland and appeared in the order of Ca > Mg > K in terms of abundance. Higher value of exchangeable acidity (1.16-1.80 cmol$_{(+)}$ kg$^{-1}$) were observed in the horizons of teak plantation, thus indicative of the deteriorative effect of trees on the soil properties. The ECEC of these soils were also found to be low.**

***Keywords* – Arable Farmland, Land Use, Soil Properties, Teak Plantation.**

## I. Introduction

The soils of Minna and its environs were derived from deeply weathered basement complex rocks made up of granites, magmatites, gneisses and schists [1]. They are strong brown to red sandy clay, loamy sand or sandy surface layer, deep and weakly to moderately structure with gravelly and concretionary layers in the upper or beneath the surface layers [1], [2]. Soil properties vary in spatial and temporal and such variation depicts systematic changes as a function of soil parent materials and land use [3], [4]. The soils of Minna have been largely exposed to continuous cultivation as a result of increasing human population. [5]Reported that fragile nature of savanna soils predisposes them to degradation rapidly under continuous cultivation. The productivity of such soils declined drastically especially where continuous cultivation is associated with poor land management [6]. Studies on soil properties as affected by different land uses are scanty around Minna. Such exercise is likely to provide rapid information for soil fertility and productivity management. This study was therefore designed to investigate the profile distribution of morphological and physicochemical properties of an Alfisol in Minna in response to land use, that is, arable farmland and teak (*Tectona grandis*) plantation.

## II. Materials and Methods

### *A. Site description*

The study site was lies within the forest plantation and the adjourning arable farmland of the Federal University of Technology, Gidan-Kwano Campus, Minna, Nigeria on latitude 09$^{o}$ 31′ N and longitude 06$^{o}$ 27′ E. Geomorphologically, the site was moderately flat land (< 3 % slope) on elevation of 229.7 meters above mean sea level. The vegetation is southern Guinea savanna with a sub-humid tropical climate. The mean annual rainfall is 1284 mm spread over months of April/May to October [1]. The geology of the area is made up of basement complex. The dominant soil parent material in Minna and its environs are weathered remains (saprolites) of the varied basement complex rocks, which have been deeply and markedly altered for a long time such that bedrock, apart from where it emerges as inselbergs or lower rock outcrops, is several meters below the surface [1].

### *B. Sample collection*

Land use of the study area was arable farmland and teak plantation. Two modal profile pits, one for each land use type were dug and described in accordance with guidelines for soil profile description [7]. Soil samples were collected from each identified genetic horizons for laboratory analysis.

### *C. Laboratory analyses*

Soil samples were air-dried and gently crushed to pass through 2 mm and 0.5 mm sieve. Particle size distribution was determined by the hydrometer method after dispersion with sodium hexametaphosphate according to the procedure described by [8]. pH values of the samples were determined in 1.0 N $CaCl_2$ solution using a soil - solution ratio of 1:2.5 [9]. Organic carbon was determined by the Walkley-Black wet oxidation method [10]. Exchangeable basic cations were extracted with neutral 1N $NH_4OAc$ with potassium (K) and sodium (Na) determined by flame photometry and calcium (Ca) and magnesium (Mg) by atomic absorption spectrophotometry. Exchange acidity was determined by shaking the samples with 1.0 M KCl and titrating them with 0.1 M NaOH. Available P was determined by the Bray P1 method [11]. Effective cations exchange capacity was obtained by summation of the exchangeable basic cations. Total nitrogen (TN) was determined by the micro Kjeldhahl method. Were necessary, data were subjected to paired t-test to compare the means of values from both land use types.

## III. Results and Discussions

### *A. Morphological properties*

The result of some morphological properties of the soils studied is shown in Table 1. Surface color was grayish brown (10YR5/2) in arable farmland and very dark gray (10YR3/1) in teak plantation over various shades of brown in the subsoil. The grayish or brownish coloration in both soils was an imprint of organic matter contents. The surface soils of the two land use types were non-mottled which suggested that they have good aeration. [12]inferred that absence of mottling in soils is an indication of a prevalent non-reducing condition, that is, such soils are in highly oxidized state. Another reason for absence of mottling, especially in arable farmland may be attributed to frequent mixing during ploughing activities. The occurrence of mottling in the subsurface layers may be attributed to poor internal drainage condition caused by presence of massive structure occurring below 50 cm depth in both sites.

Table 1: Some morphological properties of soils of the study sites

| Horizon | Depth (cm) | Colour (moist) | | Structure* | Roots** |
|---|---|---|---|---|---|
| | | Matrix | mottles | | |
| | | **Arable Farmland** | | | |
| Ap | 0-24 | 10YR5/2 grayish brown | - | 2cr | 5mf |
| Bt1 | 24-54 | 10YR4/6 dark yellowish brown | mottled | 2sbk | 3f |
| Bt2 | 54-120 | 7.5YR5/6 strong brown | mottled | Ms | 0 |
| BC1 | 120-157 | 10YR6/3 pale brown | mottled | Ms | 0 |
| BC2 | 157-206 | 10YR7/3 very pale brown | mottled | Ms | 0 |
| | | **Teak Plantation** | | | |
| Ap | 0-19 | 10YR3/1 very dark gray | - | 2sbk | 5ml |
| Bt1 | 19-56 | 10YR4/4 dark yellowish brown | mottled | 2sbk | 5m |
| Bt2 | 56-103 | 10YR5/2 grayish brown | mottled | Ms | 3mf |
| BC | 103-147 | 10YR5/2 grayish brown | mottled | Ms | 1f |
| C | 147-200 | 10YR5/2 grayish brown | mottled | Ms | 1f |

*Structure: 2=moderate; cr=crumb; sbk=sub-angular blocky; ms=massive.
**Roots: 0=null; 1=few; 3=some; 5=many, fine; m=medium; l=large

### *B. Physical properties*

Data on particle-size distribution of the soils studied are shown on Table 2. Particle-size analysis revealed that sand particles dominated the mineral fraction in soils of the two land use types studied probably because the soils were formed from decomposition of granitic parent materials rich in quartz and feldspars. The sand values in both land use types decreased down the profiles. The trend may be attributed to sorting of fine materials, silt and clay, from surface horizon through action of erosion or eluviation and illuviation processes [13]. Sand contents was higher ($P<0.05$) in profile of arable farmland than in teak plantation. Annual cultural operations on arable farmland probably contributed to structural degradation of surface soils and predisposed them to wind and water erosion, hence, explained the differences in the surface textures of both land use types. Unlike sand, the distribution of silt was irregular, however, silt content also differed significantly ($P<0.05$). Soils of the two land use types showed evidence of clay migration from surface horizon (Ap) to horizons below (Bt1 and Bt2). The soils under arable farmland, had 2.37 and teak plantation 1.48 times, higher clay content than the surface horizons. Although, clay contents in teak plantation was higher, both land use types were not statistically different ($P>0.05$) implying that the land use types had no significant effect on clay content of the studied soils. However, the relatively higher clay content within the profile of teak plantation over that of arable farmland may be attributed to further weathering of the soil mineral fractions. [14]observed similar trend in a study of 30 year old teak plantation in which sand-size fractions weathered resulting to clay accumulation in A-horizon and silt in subsurface horizons. Averagely, the silt/clay ratios were 0.35 and 0.43 respectively for arable farmland and teak plantation. These values inferred that the studied soils were highly weathered. According to [15], values below 0.75 indicates old age of soils, between 0.75 and 1.5 indicates moderate pedogenic weathering processes, while high values > 1.5 indicate recent pedogenic processes.

### *C. Chemical properties*

The result of the chemical properties of the soils studied is shown in Table 3. The soil reaction was moderately to slightly acidic in both land use types studied. The result implied that the soil pH was influenced more by parent material, granite which weathered to produce acidic soils, rather than the influence of land use. The pH value ranged from 5.5 to 6.5 for arable farmland and 5.8 to 5.9 for teak plantation. However, [16] reported that slightly acidic nature of the soils of Minna could be attributed to low level of leaching of basic cations and these nutrients will be readily available to crop roots. Generally, the organic carbon content in soils decreased with the soil depth for each of land use studied. The higher organic carbon in the surface horizon was as a result of increased organic matter inputs and its decomposition as reported by [17], [18].

Table 2: Particle-size distribution in soils of the two land use types

| Horizon | Soil Depth (cm) | Particle Size (g kg$^{-1}$) | | | Silt/Clay Ratio | Textural Class* |
|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | |
| | | | **Arable Farmland** | | | |
| Ap | 0-24 | 794 | 90 | 116 | 0.77 | Sl |
| Bt1 | 24-54 | 629 | 95 | 276 | 0.34 | Scl |
| Bt2 | 54-120 | 569 | 55 | 376 | 0.15 | Sc |
| BC1 | 120-157 | 509 | 105 | 386 | 0.27 | Sc |
| BC2 | 157-206 | 529 | 90 | 381 | 0.24 | Sc |
| | | | **Teak Plantation** | | | |
| Ap | 0-19 | 607 | 144 | 249 | 0.58 | Scl |
| Bt1 | 19-56 | 497 | 134 | 369 | 0.36 | Sc |
| Bt2 | 56-103 | 417 | 144 | 439 | 0.33 | C |
| BC | 103-147 | 397 | 164 | 439 | 0.37 | C |
| C | 147-200 | 457 | 184 | 359 | 0.51 | Sc |

***sl=sandy loam; scl=sandy clay loam; sc=sandy clay; c=clay

While the lower organic carbon values in the underlying horizons might be attributed to decreased faunal activities with soil depth as suggested by [19], [18]. The decrease in the content of the organic carbon down the soil profile was an indication of the maturity of the profile developed on a very stable platform. Soil total N was very low irrespective of the land use studied (0.37 and 0.14 g kg$^{-1}$ for arable farm land and teak plantation respectively) and decreased down the soil depth similar to what was obtained for soil organic carbon. Organic matter is the sole source of N in the soil, accounting to between 90-98 % [20]. The organic carbon contents in both land use types were low and the inadequacy needs to be taken into consideration in managing these soils. Available P content of the soils was rated moderate for arable farmland and low for teak plantation, with mean values of 11 and 7 mg kg$^{-1}$ respectively. The lower value obtained for teak plantation relative to that of arable farmland might be attributed to higher nutrient utilization, thus, agreeing with [21] that trees depended on P for biomass production and teak immobilizes P thus depleting soil available P. The underlying horizons of both land use type recorded lower available P values which generally decreased with profiledepth, a trend with organic C (Table 3). This observation was also confirmed by [22].Relatively low to moderate amounts of exchangeable bases were observed in some of the soils studied. However, irrespective of the land use system studied, the exchangeable basic cations in terms of abundance in the soil was in the orderCa> Mg > K**.** Higher values were obtained for arable farmland compared to the values for the teak plantation. The low values of exchangeable bases of these soils may be attributed to the nature of underlying rocks, high rainfall and weathering intensities, leaching and lateral translocation of bases [23]. Also, [24] observed that dry land soils (formed from sedimentary rocks) generally have high levels of total Ca, reaching more than 5 % of the soil by weight and occupied 75 – 85 % of the CEC sites. The dominance of Ca on the exchange sites may also be attributed to Ca being the least easily lost from the soil exchange site [2].The mean values for Exchangeable Acidity (Al and H) were generally low (< 1.0 cmol$_{(+)}$ kg$^{-1}$) in arable farmland and was observed to decreased with profile depth. However, higher values (1.80 cmol$_{(+)}$ kg$^{-1}$) was observed in surface horizon of teak plantation which also decreased with profile depth. This is expected as teak plantation may have higher nutrient utilization, thus depleting the soil exchangeable bases [25]. The ECEC values of these soils were generally low. The low values of ECEC indicate low activity clay characteristics of kaolinite [26].

Table 3: Some chemical properties of soils of the study site

| Land use | Horizon | Depth (cm) | pH ($CaCl_2$) 1:2.5 | Org. C (g kg$^{-1}$) | TN (g kg$^{-1}$) | Av. P (mg kg$^{-1}$) | Exchangeable cations | | | Exch. Acidity (H+Al) | ECEC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $Ca^{2+}$ | $Mg^{2+}$ | $K^{+}$ | | |
| | | | | | | | ← | | (cmol$_{(+)}$ kg$^{-1}$) | | → |
| Arable Farmland | Ap | 0-24 | 6.0 | 22.05 | 0.65 | 9 | 8.00 | 3.50 | 0.15 | 0.89 | 4.35 |
| | Bt1 | 24-54 | 5.6 | 22.05 | 0.61 | 14 | 8.00 | 4.00 | 0.15 | 0.76 | 5.72 |
| | Bt2 | 54-120 | 5.5 | 15.44 | 0.37 | 10 | 6.40 | 3.10 | 0.46 | 0.71 | 6.69 |
| | BC1 | 120-157 | 6.4 | 15.44 | 0.19 | 10 | 7.20 | 2.85 | 0.35 | 0.65 | 5.70 |
| | BC2 | 157-206 | 6.5 | 8.82 | 0.05 | 13 | 10.20 | 4.28 | 0.03 | 0.63 | 6.31 |
| | | **Mean =** | **6.0** | **16.76** | **0.37** | **11** | **7.96** | **3.55** | **0.23** | **0.73** | **5.75** |
| | | *SD = | ±0.45 | ±5.53 | ±0.26 | ±2.17 | ±1.42 | ±0.60 | ±0.17 | ±0.10 | ±0.89 |
| Teak Plantation | Ap | 0-19 | 5.9 | 19.30 | 0.30 | 8 | 2.76 | 0.38 | 0.05 | 1.80 | 13.86 |
| | Bt1 | 19-56 | 5.8 | 14.30 | 0.10 | 7 | 3.68 | 0.98 | 0.04 | 1.20 | 13.74 |
| | Bt2 | 56-103 | 5.8 | 9.30 | 0.10 | 6 | 3.90 | 1.76 | 0.05 | 1.16 | 11.52 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| BC | 103-147 | 5.9 | 8.30 | 0.10 | 7 | 3.84 | 1.06 | 0.03 | 1.36 | 12.14 |
| C | 147-200 | 5.9 | 7.10 | 0.10 | 7 | 4.06 | 1.48 | 0.02 | 1.20 | 15.80 |
| | **Mean =** | **5.9** | **11.66** | **0.14** | **7** | **3.65** | **1.13** | **0.04** | **1.34** | **13.41** |
| | *SD = | ±0.05 | ±5.07 | ±0.09 | ±0.71 | ±0.51 | ±0.53 | ±0.01 | ±0.27 | ±1.67 |

## IV. Conclusion

Soil organic carbon and pH are the main factors influencing the variations in exchangeable bases, total nitrogen, available phosphorus and ECEC of the studied land use system. The moderate soil contents of organic carbon, available Phosphorus and low total nitrogen and ECEC will have implications for sustainable crop production on these soils. The deficient quantity of some of these elements especially in the subsurface horizons indicate the necessity of conscientiously protecting the surface soils from becoming deficient in these elements. Effort must be geared towards improving the soil organic matter through practices such as; planting of cover crops, crop residues management, application of organic manure, avoidance of indiscriminate bush burning, etc. adoption of these practices will not only improve the chemical properties of the soils but also improve microbial activities, water retentioncapacities and textural improvement of the soil. Full recommended rates of nitrogen and phosphorus from inorganic fertilizer may also be advantageous for boosting the fertility of the soil.

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