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# SOME PHYSICAL PROPERTIES OF SOILS OVERLYING LIMESTONE PARENT MATERIAL IN SOUTHEASTERN NIGERIA

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## ABSTRACT

The physical properties of nine (9) pedons of soils derived from limestone parent materials in South Eastern Nigeria were investigated. The percentage of total sand generally decreased with increase in profile depth with total sand for the surface horizons of 61% and 47% for the subsurface horizons. Silt percentage for the surface horizons range between 7.0 % and 48%, for subsurface 7.0% and 48%. The percentage clay generally increased with increase in profile depth in some pedons and fluctuates in some pedon of these soils. The surface layers were generally sandy loam to sandy clay loam in texture. The bulk density of the top soils ranged between 1.20 and 1.62g/cm3, for sub-soils 1.33 and 1.82g/cm3. Particle densities ranged between 2.42 and 3.10g/cm3 respectively and total porosity for the surface and subsurface ranged between 49.7 and 50% respectively for all the soils. Soils with these physical properties may be suitable for the cultivation of arable and tree crops and dry season farming. The erodibility of the soils can be minimized by the incorporation of crop residues.

## INTRODUCTION

Consolidated products of calcareous sands, limy mud and crushed shells constitute limestone (Anatole, 1996). Soils derived from limestone are calcimorphic in nature being formed from calcareous parent materials on uplands and slopes (Bridges, 1970). Soils of limestone origin are usually productive and, in most populated areas have been intensively cultivated (Webster and Wilson, 1980).

Limestone deposits in Cross River State are impure limestone such as marls found at New Netim and pure limestone formation found at Mfamosing. It fringes the sand stones known as Awi formation which again fringes the basement complex. They are found concentrated at the southern part of the state at boundary between the Calabar flank and the Precambrian Oban Massif (Akpan, 1990). These formations represent one of the oldest and major known marine carbonate sequences. They are cenomanian to mid-albian in age (Peters, 1982).

**Keywords:** Physical properties, Soils, Limestone, Parent Material.

## MATERIALS AND METHODS

Nine (9) profiles chosen from limestone deposits area in Cross River State with (Latitude $4^{O}27'$ and $6^{O}45'$N and Longitudes $7^{O}15'$ and $7^{O}28'$E), were dug. Three profiles were dug in each of the following locations (Fig. 1) Odukpani (Od-1, Od-2 and Od-3); Mfamosing (Mf-4, Mf-5 and Mf-6); and Abini (Ab-7, ab-8 and Ab-9). These sites constitute areas with extensive limestone deposits in Southern Cross River State. The mean annual rainfall of the study area ranged between 1,300-3000mm, with uniformity of temperature throughout the year with monthly temperature ranges between 210-320$^{O}$C (Okonkwo and Mbajioru, 2010). The study areas fall into forest eco-climatic region and contain four vegetation zones (Mangrove forest, fresh water, swamp communities, lowland rainforest) with major crops consisting of banana, cassava, pepper, cocoyam, potatoes, pineapple, maize, rice and yam (annual crop) and perennial crops such as pawpaw, bush mango, pears, mango, raphia palm and palm trees. These profiles were dug three (3) in each study site, at the summit, shoulder and backslope/toes position.

**Table 1: Particle size distribution and texture of the sampled soils**

| Profile | Horizon | Depth (cm) | Sand % | Silt % | Clay % | Silt/clay ratio | Texture |
|---|---|---|---|---|---|---|---|
| Od-1 | AP | 0-13 | 67 | 29 | 4 | 7.2 | Sandy loam |
| | AB | 13-40 | 64 | 25 | 11 | 2.2 | Sandy loam |
| | Bt | 40-60 | 63 | 26 | 11 | 2.3 | Sandy loam |
| Od-2 | AP | 0-14 | 52 | 43 | 5 | 8.5 | Sandy loam |
| | AB | 14-45 | 36 | 50 | 14 | 3.6 | Silt loam |
| | Bt | 45-75 | 35 | 48 | 18 | 2.7 | Silt loam |
| | $Bt_2$ | 75-116 | 33 | 46 | 21 | 2.2 | Silt loam |
| Od-3 | AP | 0-13 | 54 | 39 | 7 | 5.5 | Sandy loam |
| | AB | 13-43 | 44 | 40 | 16 | 2.5 | Silt loam |
| | Bt | 43-74 | 47 | 34 | 19 | 1.8 | Silt loam |
| | $Bt_2$ | 74-102 | 35 | 46 | 19 | 2.4 | Silt loam |
| MF-4 | AP | 0-9 | 73 | 24 | 3 | 7.9 | Sandy loam |
| | AB | 9-39 | 59 | 22 | 19 | 1.1 | Sandy loam |
| | Bt | 39-90 | 45 | 14 | 41 | 0.3 | Clay loam |
| | $Bt_2$ | 90-121 | 39 | 17 | 44 | 0.4 | Clay loam |
| MF-5 | AP | 0-10 | 84 | 15 | 1 | 4.4 | Sand |
| | AB | 10-50 | 71 | 13 | 16 | 0.8 | Gravelly sandy loam |
| | Bt | 50-90 | 68 | 9 | 23 | 0.4 | Gravelly sandy loam |
| | $Bt_2$ | 90-151 | 69 | 7 | 24 | 0.3 | Gravelly sandy loam |
| MF-6 | AP | 0-10 | 86 | 13 | 1 | 12.7 | Sand |
| | AB | 10-45 | 74 | 17 | 9 | 1.8 | Sandy loam |
| AB-7 | AP | 0-10 | 52 | 12 | 26 | 0.5 | Sandy loam |
| | AB | 10-28 | 51 | 23 | 30 | 0.8 | Sandy loam |
| | Bt | 28-57 | 51 | 19 | 51 | 0.4 | Gravelly sandy loam |
| | $Bt_2$ | 57-86 | 48 | 25 | 50 | 0.2 | Gravelly sandy loam |
| | C | 86-140 | 44 | 14 | 50 | 0.3 | Gravelly sandy loam |
| AB-8 | AP | 0-14 | 59 | 23 | 19 | 1.2 | Sandy loam |
| | AB | 14-40 | 52 | 19 | 29 | 0.6 | Gravelly sandy loam |
| | Bt | 40-85 | 39 | 14 | 49 | 0.3 | Gravelly sandy loam |
| | $Bt_2$ | 85-99 | 44 | 14 | 41 | 0.3 | Gravelly sandy loam |
| AB-9 | AP | 0-21 | 38 | 15 | 50 | 0.3 | Sandy loam |
| | AB | 21-52 | 46 | 15 | 45 | 0.3 | Sandy loam |
| *ND – Not Determined | | | | | | | |

## LABORATORY STUDIES

Soil samples brought from the field were air-dried and sieved through a 2.00mm sieve for the following analyses. Particles size analysis was determined by methods described by Soil Survey Staff (2002) using sodium hexametaphosphate (Calgon) as a dispersant. The percentage sand, silt and clay were determined by using the Bouyoucos hydrometer by allowing progressive sedimentation of the various separates within intervals.

The total sand was collected, air-dried and sieved into two sizes, coarse sand (250-2000µm) and fine sand (50-250). Using the percentage sand, silt and clay results, the textures were determined using the USDA textural triangle (NSSC, 1995). Bulk density was determined by collecting undisturbed core samples from each horizon using (100cm3) metal rings. These were latter oven-dried at 105$^{O}$C to constant weight and the bulk densities calculated as described by (Black, 1965; Agbede, 2009). Particles density was determined as described by Bowles, (1992); Soil Survey Staff, (2006) using pycnometer. Total porosity was mathematically determined from the result of bulk and particles densities.

$$\text{Porosity} = \left(1 - \frac{\text{Bulk density}}{\text{Particle density}} \times 100\right)$$

## RESULTS AND DISCUSSION

Results of particle size distribution are shown in Table 1 and its summary.The textures of the soils are between sandy loam to sandy clay loam. The total sand contents of the soils decreased with increase in soil depth for all the soil. The surface horizons had total sand fraction result ranging from 36.30% to 86.30% with an average of 61% while the sub-surface horizons values ranged between 33% and 69% with an average of 59% and 47%.

The silt fraction on the whole ranged between 7% and 50% with a mean of 28 %. The topsoil horizons had results between 12% and 50% with an average 28% and the sub-surface horizon ranged from 7% to 48% with an average 24%. Pedon Od-1, Od-2 and Od-3 show high silt content of 50% in top soil and 48% for subsurface soils.

The clay fractions of the soils increased with increase in profile depth in Pedon Od-1 to Od-3 while other pedon fluctuated in clay content. This is an indication of clay migration by lessivage in the process of illuviations. Observation of this clay sequence pariparsu with the total sand suggests that the soil forming sequence in these soils may be from a variety of origins (Esu, 1999). The surface horizons had clay fractions ranging between 1% and 50% with a mean

**Summary of table 1**

| | sand (%) | silt (%) | clay (%) | Silt/clay |
|---|---|---|---|---|
| Surface mean | 59 | 28 | 19 | 4.61 |
| Surface range | 36-86 | 12-50 | 1-50 | 0.3-12.7 |
| Subsurface mean | 47 | 24 | 32 | 1.00 |
| Subsurface range | 33-69 | 7-48 | 11-50 | 0.2-2.7 |

of 19% and subsurface ranged between 11% and 50% with a mean value of 32%. All the soils can be described as high textured because of their predominant clay and sand related textures (Esu, 2010). These clay and sandy texture of the soils account for the moderate permeability of the limestone derived soils. According to Lal (1994) and Ikemefuna (2010), when the silt/clay ratio is 5 (none), 3 (moderate), 2 (high) and 1 (very high), the soil can be rated for degradation and vulnerability potential.All the horizons with silt/clay ratios = 5 have no potential for degradation and vulnerability.

In the study areas, soils with profile (Od-1), (Od-2), Mf-4 and Mf-6 are not prone to degradation and have low vulnerability potential (Vp). Most of the soils are prone to SDR/VP. Such soils represented by profile Od-2 (Bt, Bt2horizon) have high SDR and Vp; also profile Od-3 (AB, Bt and Bt2) have high or very high degradation rate and vulnerability potential. These imply that the soils should be beefed up with a lot of organic materials in order to strengthen the structure and so raise up the silt/clay ratio to possible 3 or more.

The results of bulk density are shown in Table 2 and its summary. The results are for seven (7) profiles during the study. The results show a common trend of increase in bulk density with increase in soil depth. The bulk density of the

## Summary of table 2

| | Bulk density ($g/cm^3$) | Particle density ($g/cm^3$) | Total porosity(%) |
|---|---|---|---|
| Surface mean | 1.30 | 2.67 | 47 |
| Surface range | 1.20-1.62 | 2.42-3.10 | 45-50 |

top soil ranged between 1.20 and 1.62 g/cm3. The subsurface horizon values ranged between 1.33 and 1.82 g/cm3 with a mean of 1.52 g/cm3. The bulk density of the surface horizons is ideal for agronomic practice. This is because top soil containing a good amount of humus with a crumb structure should have a bulk density of 1.2 g/cm3 or even lower as in organic soils. For the subsoil, the bulk density would be 1.5-1.6 g/cm3 in compacted or indurate horizons (Ahn, 1993) and the results of this study are similar to that of Essoka and Esu (2001) who stated that the bulk densities in basement complex soils varies between 1.0 and 2.0 g/cm3 and increase with depth. All the sampled soils have no problems of excessive high bulk densities because bulk densities less than 1.8 g/cm3 may not offer mechanical impedance to root penetration. Even more favourable are results of the top soil horizons that are between 1.2 and 1.62 g/cm3, since soils with values of 1.6-1.8 g/cm3 indicate that aeration and water movement will be too low for

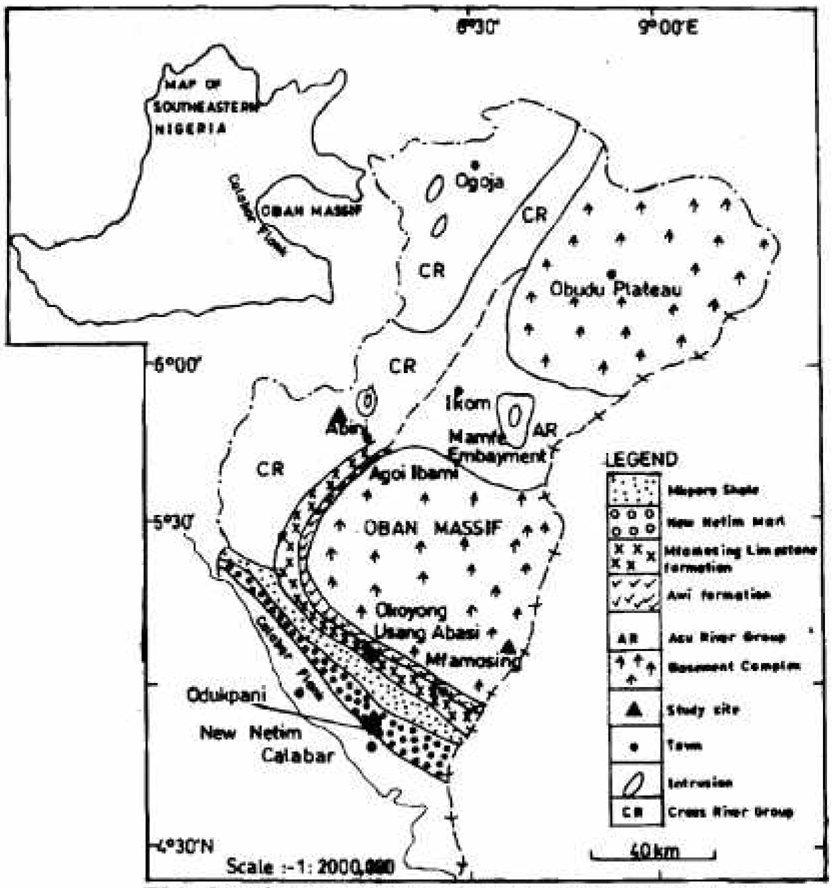


FIG.1: Geological map of Cross River State showing the study areas

optimum root growth (NSSC, 1995; Soil Survey Staff, 2006).

The particle densities of all the soils were between 2.42and 3.10g/cm3 with an average of 2.76 g/cm3(Table 2). These increase with an increase in soil depth for all the pedons. The soil showed minimal particle density of 2.66 g/cm as obtained by Akpan-Idiok and Esu (2009). Total porosity of the soils is shown in Table 2. The soil porosity ranged between 49.7 and 50% and generally increased with increase in profile depth. The surface soils have good porosity values (with a mean of 50.10%). Kachinkii (1965) suggested over 50%for good soils, between 45-50% satisfactory soils, while 40-45% unsatisfactory soils, under 40% and below for poor soils.

## CONCLUSION

The soilsoverlying limestone parent materials are texturally sandy loam to sandy clay loam and would be very suitable for cultivation of varieties of arable crops and tree crops, because of their good structure and abundant pores. Based on physiography of soils of this kind, the soils may be suitable for all year round farming. Irrigation may offer tremendous advantage and soil erodibility may be reduced by the incorporation of the organic matter.

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