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# CHAPTER 39

## AN EVALUATION OF THE EFFECTS OF SHEETWASH ON THE TEXTURE AND AGRICULTURE POTENTIAL OF NIGERIAN COASTAL PLAIN SOILS

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### INTRODUCTION

Erosion is a natural geological phenomenon which takes place at all times irrespective of climatic variations. It involves the removal of soil by the forces of nature for example, running water and wind. Under natural conditions erosion rate is slow such that a soil mantle and vegetation are able to maintain themselves in a state of stable equilibrium (Rowntree 1998). But through the activities of man example deforestation, erosion rate can be increased leading to accelerated erosion (Marker 1988, Wilson 1989). Accelerated erosion starts initially as sheet wash (Weaver 1988, Bulgyin 1993), during which there is slow loss of soil in thin sheets to surface flow and is incipient to rill erosion and gullying (Beckedahl and Dardis 1988, Usman 1994).

The present paper focuses attention on the changes that occur in the textural characteristics of coastal plain soils affected by sheet wash. The study aims to compare the particle size distribution in soils affected by sheet wash with that in relatively unaffected soils, with a view to evaluating the agricultural potentials of the soils. Since the insidious effects of sheet wash cannot be readily discerned until active rills oversteepen drainage divides in poorly consolidated soils. (Wilson 1994) the specific changes in the textural characteristics of affected soils have remained largely undocumented prior to slope retreat (Scoging 1989, Molderhauer and Hudson 1988).

### Study Area

The study area for this investigation is the coastal rainforest belt of Cross River State and Akwa Ibom State, Nigeria, between latitudes 4° 30'N and 5° 30' N, and longitudes 7° 30' E and 9° E. About 90% of the area is composed of moderately acidic ferralitic sandy

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soil underlain by unconsolidated pebble and deeply decomposed Undifferentiated Basement Complex rocks. The area varies in altitude from 55 m. a. s. l. (metres above sea level) at Calabar to 120 m.a.s.l. at Ikot Ekpene. The mean annual rainfall at Calabar is 3978mm while that at Uyo is 3658mm. The vegetation consists of secondary bushes and fallow farmlands dominated by *Elaeis Guinness, Macrolobium macrophyllum, Triumfetta rhombiodeae Cactus afer and Selaginella* spp.

## Materials And Methods

Air photographs were used to delimit the major land facets in Calabar, Uyo, Ikot Ekpene and Etinan area. Within the secondary bushes, exposed surfaces affected by sheet wash appeared as light spots, with grey tones caused by scattered accumulation of leaves. In some cases patterns of recent rills were discernable on the slightly pallid soils. In contrast, unaffected areas had dark tones varying from dark grey at upper slopes to black where the vegetation was dense.

A total of 136 soil samples were investigated: 68 each from the acidic feralitic soils observed to be affected and relatively unaffected by sheet wash. That is, pairs of samples from soils of nearly identical type in areas affected and unaffected by sheet wash were always obtained. To minimize catenary differences in soil properties, sample pits were selected at or close to the upper segments of slopes. Soil samples, taken at 20cm intervals to a depth of 40cm were subject in the laboratory to textural analysis by the Bouyoucos (1962) method. The standard analysis of variance (ANOVA) was used to test for significant differences in particle sizes at the surface soil (0-20cm) and subsurface soil (20-40cm) (Silk 1985).

## Results

The results of textural analysis for soils affected by sheet wash are presented in Table 1 while those for unaffected soils are presented in Table 2:

Table 1: **Mean and SD for particle sizes in soils affected by Sheet Wash**

| Depth (Cm) | % Coarse Sand | % Fine Sand | % Silt | % Clay |
|---|---|---|---|---|
| | | Calabar (20)* | | |
| 0-20 | 24.6±3.3 | 56.4±7.1 | 7.3±3.2 | 11.7±9.2 |
| 20-40 | 26.2±5.8 | 3.7±6.1 | 8.6±3.6 | 12.5±4.2 |
| | | UYO(20)* | | |
| 0-20 | 28.3±2.8 | 62.8±6.5 | 5.2±1.2 | 3.7±2.1 |
| 20-40 | 29.5±5.4 | 58.6±4.1 | 5.9±1.3 | 7.1±4.5 |
| | | IKOT EKPENE (16)* | | |
| 0-20 | 21.5±1.6 | 45.3±8.3 | 8.5±1.8 | 24.7±8.6 |
| 20-40 | 17.6±8.2 | 45.3±8.5 | 9.9±2.4 | 26.2±8.8 |
| | | ETINAN (12)* | | |
| 0-20 | 26.4±2.9 | 57.3±7.3 | 10.5±2.6 | 5.8±3.5 |
| 20-40 | 29.6±3.0 | 51.4±5.0 | 10.7±1.4 | 8.3±4.6 |

*( )* Parentheses indicate number of samples in each site.*

TABLE 2: Means and SD for aprticle sizes in soil profiles relatively unaffected by sheet wash.

| Depth (CM) | %Coarse Sand | %Fine Sand | %Silt | %Clay |
|---|---|---|---|---|
| | | CALABAR (20)* | | |
| 0-20 | 18.2±7.5 | 50.3±5.6 | 14.3±5.6 | 17.2±8.2 |
| 20-40 | 19.5±6.3 | 47.6±6.5 | 15.5±4.8 | 17.4±7.3 |
| | | UYO (20)* | | |
| 0-20 | 27.8±6.7 | 42.8±6.2 | 10.1±3.0 | 19.3±8.7 |
| 20-40 | 20.3±5.6 | 45.2±7.2 | 10.8±3.9 | 23.7±9.8 |
| | | IKOT EKPENE(16)* | | |
| 0-20 | 10.8±5.8 | 38.2 ±7.8 | 17.6±2.8 | 33.4±9.8 |
| 20-40 | 11.6±3.9 | 32.4±6.2 | 21.3±6.2 | 34.7±9.5 |
| | | ETINAN (12)* | | |
| 0-20 | 21.4±8.4 | 50.2±6.0 | 15.5±3.6 | 12.9±7.9 |
| 20-40 | 23.5±4.6 | 44.3±7.3 | 16.2±4.4 | 16.0±7.4 |

( )* Parentheses indicate number of profiles in each site.

## Calabar Area

In Calabar, soils affected by sheet wash have a sandy/loam/sandy clay loam texture. Coarse sand increases from 24.6 ± 3.3% in the surface to 26.2 ± 5.8% in the subsurface (Table 1). Fine sand fractions show a decrease from the surface (56.4 ± 7.1%) to the subsurface (53.7 ± 6.1%). Silt and clay fractions increase with profile depth: silt contents range from 7.3 ± 3.2% to 8.6 ± 3.6% while clay contents range from 11.7 ± 9.2% to 12.5 ± 4.2%.

In the unaffected soils (Table 2), the texture is sandy loam at all depths. The values for coarse sand are comparatively low, ranging from 18.2 ± 7.5% to 19.5 ± 6.3%. The surface fine sand content (50.3 ± 5.6%) and subsurface content (57.6 ± 6.5%) are lower than in the affected soils. However ,clay and silt contents in the unaffected soils are higher than in the affected soil , varying from 154.3 ± 3.4% to 17.5 ± 7.3%.

## Uyo Area

The mean of particle size observations indicate that affected soils in Uyo consist of sand at the surface and sandy loam in the subsurface layers (Table 1). Coarse sand contents range from 28.6 ± 3.2% to 29.4 ± 5.4% while fine sand range from 58.6 ± 4.1% to 62.8 ± 6.5%. Clay and silt fractions are considerably lower than in other sites: clay range from 3.7 ± 2.1% at the surface to 7.1 ± 4.5% in the subsurface while silt shows least variation among the layers. In contrast, unaffected soils have a sandy loam surface layer and sandy clay loam subsurface layers. Coarse sand contents are slightly lower than in the affected soils, rnging from 20.3 ± 5.6% to 27.8 ± 6.7% (Table 2). Fine sand tends to increase with profile depth. Clay and silt contents are much higher than in the affected soils: clay contents range from 19.3 ± 8.7% to 23.7 ± 9.8% while silt shows least variation.

**Ikot Ekpene Area**

Soils affected by sheet wash in this area have a sandy clay loam texture at all depths. Coarse and fine sand contents are relatively lower than in other sites (Table 1). Coarse sand range from 17.6 ± 8.2% in the subsurface to 21.5 ± 1.6% at the surface while fine sand shows low variation. Silt fractions range from 8.5 ± 1.8% to 9.9 ± 2.5% clay while fractions are much higher, ranging from 24.7 ± 8.6% to 26.2 ± 8. 8%.

The texture of unaffected soils is also sandy clay loam/clay loam. Compared with the unaffected soils, coarse sand values are low, ranging from 10.8 ± 5.8% to 11.6 ± 3.9%. Fine sand content is also low, ranging from 32.4 ± 3.9% to 38.2 ± 7.8%. The highest fractions of silt and clay in all unaffected sites occur in these soils, with values ranging from 17.6 ± 2.8% to 34.7 ± 9.5% (Table 2).

**Etinan Area**

The texture of affected soils in Etinan is loamy sand/sandy clay loam. Coarse sand contents range from 26.4 ±2.9% 2.% to 29.6 ± 3.0% while fine sand contents range from 51.4 ± 5.0% to 57.3 ± 7.3% (Table 1). Silt fractions are highest in these soils while clay fractions are the lowest when compared with other sites. Soils unaffected by sheet wash have a sandy loam/sandy clay loam texture. Coarse sand contents which range from 21.4 ± 8.4% to 23.5 ± 4.6% are slightly lower than in the affected soils. Fine sand contents are also lower than in the affected soils (Table 2). Silt and clay fractions are however, higher than in the affected soils; silt contents range from 15.5 ± 3.6% to 16.2 ± 4.4% while clay contents range from 12.9 ± 7.9% to 16.0 ± 7. 4%.

**Discussion**

Variation in soil texture was clearly observed in relationship to individual soil profiles. About 83% of the profiles affected by sheet wash were classified as loamy clay/sandy clay/loamy sand while 71% of the relatively unaffected profiles were loam/sandy clay loam. The data presented (Table 1 and 2) show that whether in affected or unaffected soils, silt and clay contents increase with profiles depth. However, there tend to be a decrease in coarse and fine sand contents of the profiles. High standard errors for fine sand and clay were observed to be related to the occurrence of ferruginous/sandy concretions on some of the profiles. Clearly, no single modal soils could be representative of the characteristics of either the affected or unaffected soils.

Results of this study confirm that sheet wash primarily involves, the removal of clay and silt from the surface layers (Mason and Nater 1994), while sand is redistributed by rain splash. However, an initial exposure of the surface permits discontinuous concretions to be formed from lateritic elements such that sheet wash progresses as surface flow and lateral seepage flushing out mainly the clays and silts (Gardner et. al. 1994). The first rains of April /May, following the relatively long dry season are usually violent with large drops. Falling on hardened concretions that had partially lost superficial permeability, the water spreads uniformly over a wide area. With time, rain drops break down the surface soil aggregates and fine sand formerly held together in the concretions is removed by sheet wash.

Kleiss (1994) observed that with increasing surface permeability mechanical eluviation of the colloids is initiated vertically within the soil profile. However, considering the observed increases in clay and silt fractions with depth in both affected and unaffected soils, it is inferred that the mechanical eluviation of fines is an integral part of normal erosion in the study area and is not exclusive to soils affected by sheet wash.

TABLE 3: Variability in particle size and significance of variation across affected and unaffected soils at two depths.

| Particle Sizes | Affected Profiles | Unaffected Profiles | ANOVA |
|---|---|---|---|
| Texture Layer | Mean ± SDC.V. | Mean ± SDC.V. | P |
| Coarse Sand (%) | | | |
| (SL) | 25.2 ± 2.9 11.5 | 19.6 ± 7.1 36.2 | 0.30 |
| (SSL) | 25.7 ± 5.6 21.9 | 18.7 ± 5.1 27.3 | 0.01* |
| Fine Sand (%) | | | |
| (SL) | 55.5 ± 7.3 13.2 | 45.4 ± 5.9 12.9 | 0.01* |
| (SSL) | 52.5 ± 5.1 9.7 | 42.4 ± 6.8 16.0 | 0.01* |
| Silt (%) | 7.9 ± 2.2 27.8 | 14.4 ± 3.2 22.2 | 0.001** |
| (SL) | 8.5 ± 2.2 25.9 | 15.9 ± 4.3 27.0 | 0.01* |
| Clay (%) | | | |
| (SL) | 11.5 ± 5.9 51.3 | 20.9 ± 8.9 43.0 | 0.001** |
| (SSL) | 13.5 ± 5.5 40.7 | 22.9 ± 8.5 37.1 | 0.001** |

(SL) = Surface soil, 0-20cm
(SSL) = Subsurface Soil, 20 - 40cm
(SD) = Standard Deviation
C.V. = % Coefficient of variation classified as:
< 25%, low variation; 25 - 50%, moderately varied
>50% highly varied.
* = Significant at 1%
** = Significant at 0.1% levels.

Table 3 shows the coefficients of variation in particle size for each site and the results of ANOVA tests between the sites. The large number of samples increases the probability that the correlations established are true. No significant difference in the surface coarse sand content is indicated ($P < 0.30$), although the subsurface content shows significant variation ($P < 0.01$). Find sand varies significantly for both surface and subsurface layers ($P < 0.01$). Silt and clay also vary at significant levels for both layers ($P < 0.01$ - $P < 0.001$). Soil affected and unaffected can therefore be identified with textural classes (Table 4). Loamy clay (36.7%), sandy clay (26.8%) and loamy sand (19.0%) were the dominant texture in the affected profiles accounting for 82.5% of the total sample. Comparatively, loam (44.1%) and sandy clay loam (26.5%) dominated the unaffected profiles, accounting for 70.6% of the total sample.

TABLE 4: Textural classification of profiles affected and relatively unaffected by sheet wash.

| Textural Class | Affected Profiles | | Unaffected Profiles | |
|---|---|---|---|---|
| | No. of Samples | % of Total | No. of Samples | % of Total |
| Loamy Clay | 25 | 36.7 | 8 | 11.8 |
| Sandy Clay | 18 | 26.8 | 6 | 8.8 |
| Loamy Sand | 13 | 19.0 | 6 | 8.8 |
| Loam | 7 | 10.2 | 30 | 44.1 |
| Sandy Clay Loam | 5 | 7.3 | 18 | 26.5 |
| | 68 | 100.00 | 68 | 100 |

According to the FAO (1976) soil fertility rating, loam/sandy clay loam soils are highly desirable for agricultural purposes while laomy clay/clay and loamy sand/sandy clay are of lower value. The present study has revealed that sheet wash is incipient to soil fertility loss through alteration of soil texture. There is predominance of sandy clay loam texture in soils unaffected by sheet wash while the affected soils are loamy clay. Consequently soil conservation should start with appreciation of the effects of sheet wash which are subtle yet damaging to the texture of soils.

The most distinguishing characteristics of Nigerian coastal plain soils affected by sheet wash are the lower contents of clays and silts in the surface and subsurface layers when compared to unaffected soils. Variations in fine sand fractions at the surface are additional indicators of the adverse effects of sheet wash on the texture of coastal plain soils.

It is observed that sheet wash is a process that takes a long period of time, whereas the samples studied were separated in space. No investigations for time were carried out (i.e. what changes would take place, e.g. during a decade in an area affected by sheet wash). Such study would require the use of permanent plots. Hence it is not possible to know what changes in soil texture have taken place in a particular site, although the mechanical composition of the soils in different sites are known. The original heterogeneity of the sites is a factor that could also affect the texture of the soils.

## REFERENCES

Beckedahl, H. R. and G. F. Dardis 1988. The role of artificial drainage in the development of soil pipes and gullies: Some examples from Transkei, Southern Africa. *Proc. Symposium, Transkei, 1988*, (ed) G.F. Dardis and B. P. Moon, PP. 229 - 245 Balkema Publ. Transkei.

Bouyoucos, G. J. 1962 Hydrometer method improved for making particle size analysis analysis of soils *Agron.* J. 54: 464-465.

Bulgyin, S. Yu 1993 Quantitative evaluation of soil erosion hazard. *Eurasian Soil science* 25: 39-47.

F. A. O. 1976 A framework for land evaluation. *FAO Soils Bull.* 32. FAO/UNESCO. France.

Gardner, W. K., M.F. Drendel and G. K. McDonald 1994 Effects of subsurface drainage, cultivation and stubble retention on soil porosity and crop growth in a high rainfall area. *Aust. J. Exp. Agric.* 34: 411-418.

Gleiss, H. J. 1994 Relationship between geomorphic surfaces and low activity clay on the North Carolina coastal plain. *Soil Science* 157; 373-378.

Marker, M. E. 1988 Soil erosion in a catchment near Alice, Ciskei, Southern Africa. In G. F. Dardis and B. P. Moon ed. : *Geomorphological studies in Southern Africa. Proc. Symposium Transkei*, Pp. 267-276, Balkema Publ. Transkei.

Mason, J. A. and E. A Nater 1894 Soil morphology - Peoria Loess grain size relationships Southeastern Minnesota, *Soil Sc. Soc. Am.* J. 58 : 432-439

Moldenhauer, W. C. and N. W. Hudson 1988 *Conservation farming on Steep Lands.* Soil and Water Conservation Society. N. Y. 296 pp.

Rowntree, K. M. 1988 Equilibrium concepts, vegetation change and soil erosion in semi-arid areas ; Some consideration for the Karoo. In G. F. Dardis and B. P. Moon (eds.). *Geomorphological Studies in Southern Africa, Proc. Symposium, Transkei.* pp. 175-185, Balema Publ. Transkei.

Scoging, H. 1989 Runoff generation and sediment mobilization by water, in *Arid Zone Geomorphology.* D. S. G. Thomas (ed.)

Silt, J. 1980 *Statistical Concepts in Geography*, George Allen & Unwind London, 276 pp.

Usman, H. 1994 Soils susceptible to erosion in Northeastern Nigeria. *Arid Soil Research and Rehabilitation* 8; 217-225.

Weaver, A. Van Breda 1988 Factors affecting the spatial variation in soil erosion in Ciskei: an initial assessment at the macroseale. In G. F. Dardis and B. P Moon (ed.) *Geomorphological studies in Southern Africa, Proc. Symposium Transkei*, pp. 215-227, Balkema Publ. Transkei

Wilcox, B. P. 1994 runoff and erosion in intercanopy zones of Pinyon-Juniper Woodlands. *Journal of Range Management* 47: 285 -295.

Wilson, J. P. 1989 Soil erosion from agricultural land in the Lake Sunicoe-couching Basin. *Canadian J. Soil Sc.* 69, 173-151.