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# ASSESSMENT OF SOIL TEXTURE EFFECT ON SOIL EROSION IN NORTHERN SUDAN SAVANNAH ALFISOL OF NIGERIA

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## Abstract

The aim of this study is to assess if silt has a potential effect on the erosion of the soils of Hadejia/Jamaare river basin, along river Kano in Sudan savannah zone, Kano, Nigeria. The research area was split into five slopes using digital elevation model (DEM) map, and in each slope, ten disturbed soil samples were collected at the depth of 0-15 and 15-30cm and replicated ten times in a randomised complete block design (RCBD). Erosion and texture were evaluated using Universal Soil Loss Equation (USLE) and particle size distribution hydrometer method respectively. Results indicated that the percentage silt fraction of the surface soil (0-15cm) was found to have no statistically significant variability among treatments and within blocks between replications (P>0.05). Middle slope recorded the highest silt fraction (33%) compared to valley (26 %). USLE findings however, revealed that middle slope has the highest record of potential soil loss (0.012 t/ha/yr) compared to the lowest slope (0.0013t/h/yr) with no statistically significant variability difference among treatments and within blocks between replications (P>0.05). Correlation analysis suggested that percentage silt and potential soil loss were positively correlated (0.26) and (R2 = 0.056). Overall, this study indicated that silt percentage is an increasing function of soil erosion; hence, rate of soil loss will increase at high silt percentage and that soils that contain high proportion of silt and fine sand are erodible and easily detached and carried away by either wind or water. For this reason, erosion control and management tools such as soil and water conservation praxes are strongly recommended to control the menace.

**Keywords**: Texture, soil loss, erosion, slope.

## Introduction

Soil texture, a physical soil parameter, plays an imperative role in carbon sequestration and greatly affects nutrients availability and their retention. Furthermore, it probably exerts more influence on soil productivity and management requirements than any other physical characteristics of soil (Najmadeen et al., 2010) because it has a great impact on erosion rate due to the removal of top fertile and organic matter-rich soil and deterioration of structure, increasing bulk density, decreasing aggregate stability and soil quality (Yiferu et al., 2018). The capacity of soil to sequester carbon and nitrogen largely depends on the soil texture composition with clay and silt particles greater and better than sandy ones. However, soils with high silt content are easily prone to erosion, leading to slow and gradual wearing away of the silt contents and organic matter with potentially negative impacts on soil structure, nutrients availability and water holding capacity. Eventually, if the soils are not replenished with necessary inputs of soil conservation and improvement, they will be eroded with harmful effects on soil quality, fertility and crop yield (Shih-Hao and Chien-Sheng, 2013).

Several studies reported the soils' ability to infiltrate and retain water is critical for plant production and a function of soil texture (Francisco and Birl, 2003) as limited water retention can lead to insufficient water for plant uptake unless supplemental irrigation is used. Hence, in eroded soils, one should expect decreased water retention because of the preferential removal of clay and silt size particles that occurs with erosion. However, when the lower horizons are composed of relatively high clay contents, the soils retain more water, which are usually unavailable to plants as has been reported by Andraski and lowery (1992) and Fransisco and Birl (2003). Therefore, by improving the physical properties of an eroded soil, particularly silt and clay with organic matter, it may be possible to ameliorate the harmful effects of erosion.

Slope steepness effect on erosion rate is complex and contradicting. Some researchers have shown that the steeper the slope the higher the eroded soils either by wind or water (Abrahams et al., 1996; Fu et al., 2011; Ziadat and Taimeh, 2013) while others reported more than 80% soil detachment and transportation increase as a function of slope percentage variation (Quansah, 1981). Nevertheless, the rate of increase in soil detachment as a result of slope increase depends on soil types (Singer and Black, 1982; Ziadat and Taimeh, 2013).

Population increase, severe land cultivation, poor grazing and deforestation frequently lead to soil erosion increase (Tadesse, 2001; Bewket, 2002), subsequently undermining agricultural productivity and frustrate economic development efforts, especially in developing countries where there is heavy land dependence (Shiferaw and Holden, 2000). Hence, it becomes imperative to protect the soil quality. Furthermore, declining soil productivity due to poor soil quality as result of soil erosion increase has been a major limiting factor to food production in Nigeria (Sanginga et al., 2001).

Many works have been conducted on erosion effects in Northern Sudan Savannah alfisols (Leow and Ologe, 1987; Ofomota, 2001; Shu'aibu, 2002; Buwa, 2003; Birte, 2010) but none has focused on the assessment of the impact of soil texture, particularly silt, on erosion. Therefore, the aim of this study is to evaluate the influence of soil texture on soil erosion of Northern Sudan savannah alfisols and the objectives are to assess the effect of silt fraction on soil loss of Northern Sudan savannah alfisols as well as assess the effect of slope steepness on soil erosion of Northern Sudan savannah alfisols.

## Materials and Methods

### Sample collection

Ten disturbed soil samples from each of the five slopes. The soil samples were collected using auger at the depths of 0–15 cm and 15-30cm, i.e., 10 replications by 5 slopes by the 2 depth levels making 100 total disturbed samples. Samples obtained were air dried and passed through 2 mm sieve for laboratory analysis.

### Particle size distribution

Particle size distribution was determined using the improved standard hydrometer method as described by Bouyocous (1962).

### Erosion assessment

The Universal Soil Loss Equation (USLE) was used to estimate annual soil loss:
USLE equation: A = R K (LS) C P

Where A is the average annual soil loss in t/ha/yr, R is the rainfall-runoff factor [MJ · mm · $ha^{-1}$. $hr^{-1}$ · $yr^{-1}$], K is the soil erodibility factor [t · ha · hr · $ha^{-1}$ · $MJ^{-1}$· mm-1], LS is the topographic factor, C is the cover-management factor and P is the support practice factor.

### Experimental design

Design of the experiment was a randomized complete block design RCBD, were the slopes; crest (C), upper slope (U), middle slope (M), lower slope (L), and valley (V) were assigned as the treatments. Five blocks were made base on the five elevation ranges separated by the digital elevation model DEM, with ten replications within each block. Samples were collected from two depth levels, disturbed samples were collected at 0 – 15 and 15 – 30cm and undisturbed core samples at 0 – 10 and 10 – 20cm.

### Statistical analysis

Data collected was subjected to analysis of variance (ANOVA) to test the variability among treatments and replications at both 5% and 1%. The means were separated using least significant difference (LSD), then ranked and compared for any statistical similarity or differences between the means. The error means square (EMS), coefficient of variation (C.V.), standard error (S.d), range (R), and the overall mean((X )̅) were also determined for each group of data.

### Correlation analysis

Potential soil loss and soil properties were compared by correlation;

$$rxy = \frac{\Sigma xy - \frac{\Sigma x \times \Sigma y}{n}}{\sqrt{\left[\left(\Sigma(x^2) - \frac{(\Sigma x)^2}{n}\right) \times \left(\Sigma(y^2) - \frac{(\Sigma y)^2}{n}\right)\right]}}$$

## Results and Discussion

The percentage silt fraction of the surface soil (0-15cm) at an EMS of 44.64, C.V. of 22.12 % and S.d of 2.988 was found to have no significant variability among treatments and within blocks between replications at both 5 and 1 percent. The means were separated with least significant difference of – and ranked for any statistical similarities and differences; Crest, Upper slope and Middle slope were statistically similar and better, followed by Crest, Upper slope and Lower slope were also statistical similar and then Crest and Lower slope were also statistically similar and least. Middle slope was having the highest percentage silt fraction with a mean 33.4 %, while Valley was the least with a mean of 26.0 %. The range is therefore 7.4. Others are; Upper slope, Crest and Lower slope with means of 32.2 %, 30.2 % and 29.2 % respectively. The overall mean was 30.2%. "The composition of loams on the textural triangle is about 40 percent sand, 40 percent silt, and 20 percent clay. Though generally considered the ideal soil texture, loams only signify the proportion of the separates they contain, which does not necessarily mean that the soils have all the important components especially soil organic matter" (Ngowari, 2016).

The potential soil loss which is strictly a surface property was determined at an EMS of 0.0001044, C.V. of 177.16, and S.d of 0.00457 was found to have no significant variability among treatments and within blocks between replications at both 5 and 1 percent. Middle slope and Lower slope were statistically similar and better, followed by Upper slope, Lower slope and Valley were also statistically similar and Crest; Upper slope and Valley were statistically similar and least. The treatment M was having the highest potential soil loss with mean of 0.012 t/ha/yr, while is the least with a mean of 0.0013 t/ha/yr. The range is therefore 0.0104. Others are; Lower slope, Valley and Upper slope; with means of 0.0082 t/ha/yr, 0.0053 t/ha/yr and 0.0024 t/ha/yr respectively. The overall mean is 0.0058 t/ha/yr. This indicates that the soil loss is very low compared to the recorded average Bettis (2008) showed that rates are generally higher in Asia, Africa and South America; averaging 30 to 40 t/ha/yr, and lower in the United States and Europe; averaging about 17 t/ha/yr.

Table 1: Percentage silt data for 0 -15cm depth

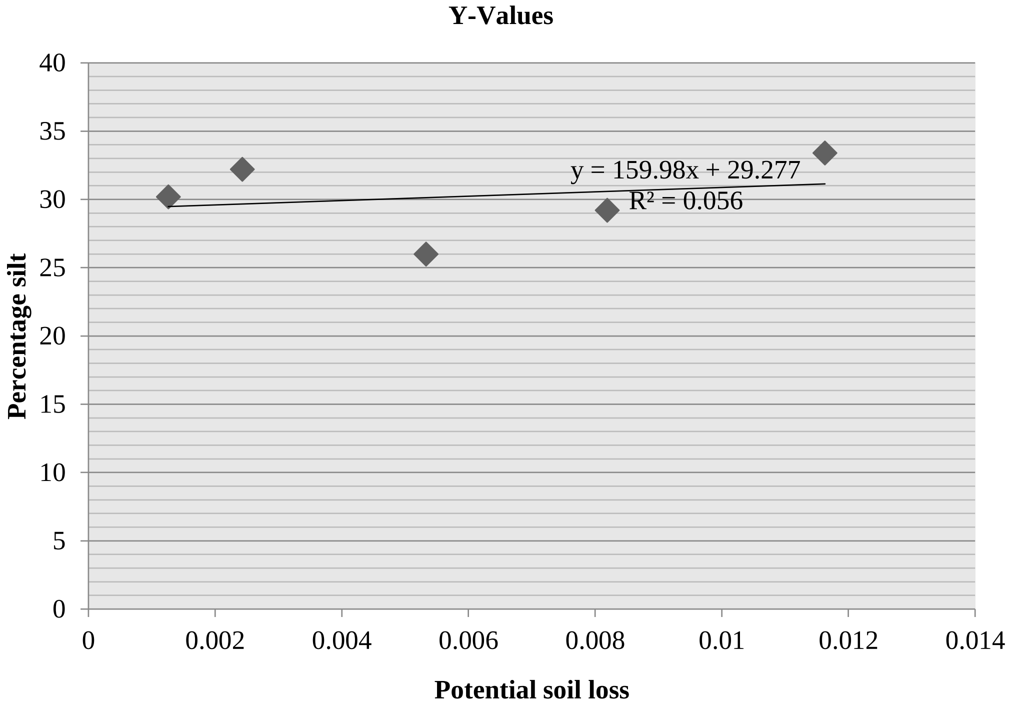
| Slope | I | II | III | IV | V | VI | VII | VIII | IX | X | Σtrt | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | 34 | 28 | 32 | 28 | 38 | 32 | 30 | 30 | 26 | 24 | 302 | 30.2$^{abc}$ |
| U | 28 | 36 | 34 | 30 | 28 | 38 | 34 | 32 | 32 | 30 | 322 | 32.2$^{ab}$ |
| M | 36 | 36 | 28 | 36 | 32 | 36 | 40 | 30 | 34 | 26 | 334 | 33.4$^{a}$ |
| L | 28 | 40 | 34 | 28 | 28 | 36 | 8 | 26 | 30 | 34 | 292 | 29.2$^{bc}$ |
| V | 10 | 20 | 40 | 24 | 22 | 28 | 26 | 36 | 18 | 36 | 260 | 26$^{d}$ |
| Σrep | 136 | 160 | 168 | 146 | 148 | 170 | 138 | 154 | 140 | 150 | 1510 GT | |

C = crest, U = upper slope, M = middle slope, L = lower slope, V = valley, and GT: grand total

Table 2: Potential soil loss data

| Slope | I | II | III | IV | V | VI | VII | VIII | IX | X | Σtrt | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | -0.00157 | -0.0021 | -0.00233 | -0.00052 | -0.00055 | -0.00077 | -0.00323 | -0.00053 | -0.0011 | -0.00096 | -0.0126 | -0.00126$^{c}$ |
| U | -0.00285 | -0.00199 | -0.00455 | -0.00242 | -0.00109 | -0.00144 | -0.00171 | -0.00055 | -0.00555 | -0.00215 | -0.0243 | -0.00243$^{bc}$ |
| M | -0.00347 | -0.0041 | -0.00663 | -0.00398 | -0.00333 | -0.00623 | -0.076 | -0.00601 | -0.00434 | -0.00217 | -0.11626 | -0.011626$^{a}$ |
| L | -0.00742 | -0.01352 | -0.00651 | -0.0066 | -0.00916 | -0.0129 | -0.01164 | -0.00913 | -0.0028 | -0.00222 | -0.0819 | -0.00819$^{ab}$ |
| V | -0.00701 | -0.0006 | -0.001 | -0.00126 | -0.00066 | -0.00094 | -0.01221 | -0.0161 | -0.00328 | -0.01028 | -0.05334 | -0.00533$^{bc}$ |
| Σrep | -0.02232 | -0.02231 | -0.02102 | -0.01478 | -0.01479 | -0.02228 | -0.10479 | -0.03126 | -0.01707 | -0.01778 | -0.2884 GT | |

C = crest, U = upper slope, M = middle slope, L = lower slope, V = valley, and GT: grand total



$r$ = 0.26 NS
Figure 1: Correlation graph for potential soil loss and percentage silt

There is a non-significant positive correlation between percentage silt and potential soil loss, therefore according to this research the higher the percentage silt in the soil the higher the potential soil loss. This was supported by USDA (2018), that; “Silt particles are the most easily detached because they are small and do not easily form aggregates”. Washington State Department of Ecology WSDE, (2018) added that; “soils that contains high proportion of silt and fine sand are the erodible and are easily detached and carried away”. Soils with high silt will be more prone to erosion than less silt soils.

## Conclusion

Silt percentage is an increasing function of soil erosion; percentage silt and potential soil loss were positively correlated with a calculated correlation coefficient of 0.26 NS and a positive linear correlation graph with $R^2 = 0.056$. Therefore, the rate of soil loss will increase at high silt percentage.

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