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Comparing the Macro-aggregate Stability of Two Tropical Soils: Clay Soil (*Eutric Vertisol*) and Sandy Loam Soil (*Eutric Leptosol*)

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Abstract The objective of this work was to compare the macro-aggregate stability of two tropical soils and construe causal relationships between aggregate stability as expressed by both the Coefficient of Vulnerability (K*v*) and Water Stable Aggregates (WSA) with some soil chemical properties. A total of twenty samples were collected, ten from each soil type with two replications were conducted and analyzed. The average values were then used to estimate both parameters. Aggregate stability was measured using both the modified Le Bissonnais wet sieving method and the slaking test that compared the resistance of macro-aggregates to mechanical breakdown. The WSA for the sandy loam soil (E. Leptosol) was about 55.08% as compared to that of the clay soil (E. Vertisol) at 38.07%. Conversely, the K*v* for E. Leptosol was about 1.89 and that of the E. Vertisol was about 2.73. The Kruskal-Wallis test for equal medians [$(chi)^2$=9.14, p-value=0.002] revealed that the effect of wet sieving on macro-aggregate stability for both soils was significantly different. Similarly, the pairwise Wilcoxon rank sum test for E. Vertisol (W=30; p-value=0.799) while for E. Leptosol (W=28; p=0.959) within and between group samples of both soils revealed similar effect of wet sieving on macro-aggregate stability. Noticeable differences were also observed in the degree and rate of slaking. Slaking was faster in E. Vertisol than in the E. Leptosol due in part to the comparatively lower levels of calcium and sulfate in the former. Using the Principal Component Analysis (PCA) as shown by the scatter plot further revealed that both sand and clay components as well as phosphorus (P), magnesium (Mg) and calcium (Ca) had positive effects on macro-aggregate stability for the E. Leptosol whereas only calcium and sulfate had both positive effects on macro-aggregate stability for the E. Vertisol. To a larger extent, pH, humus, sulfate (SO_4), iron (Fe-III) and sand did not favor the K*v* for both soils.

Keywords Coefficient of Vulnerability, Water Stable Aggregates, slaking, Principal Component Analysis, Wet

1. Introduction

Soil aggregate stability may be used as an indicator to express the ability of a soil to sustain mechanical breakdown. It is an attribute that is contingent on the shear strength of a soil [1, 2]; on the amounts and forms of organic matter prevalent in a soil [3] on the biochemical composition of plant residues and influences on soil´s functional properties like soil permeability [4]; on vegetation cover [5]; on root length density [6]; on susceptibility to surface runoff during heavy precipitation events [7]; on soil´s structure [8]; on soil erosion [9]. Tillage practice appears to be one major activity that breaks down soil aggregation and so aggregate stability. It was found out that the aggregate stability decreased due to tillage [10, 11]. There were also significant differences in soil aggregates stability in orchards as well as under perennial cropping; in fallow soils [12]; in soils under annual cropping [13, 14]. In South Sudan and in particular the areas around Juba County, deforestation due to increasing demand for agricultural land, infrastructural projects like settlements, roads and recreational facilities coupled with poor management practices has led to deterioration of the soils functional properties. Though no empirical studies have been conducted on the state of aggregate stability of soils around Juba County, the increasing population pressure caused by the current political crisis has had an adverse effect on the ecosystem. Some of the impacts are increased surface compaction and penetration resistance, susceptibility to erosion especially during the rainy season.

Elsewhere aggregate stability and so good soil structure for sustainable agricultural production as well as preservation of environmental quality has been studied by [15]. Aggregate stability in the topsoil layer (0-5cm) has been closely correlated to susceptibility to soil erodibility [16].

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Invariably, soil aggregate stability has been used to characterize the functional properties of a soil. However, qualifying and quantifying a soil´s aggregate stability often suffers from a number of limitations that are both exogenous (climate, soil temperature, organic matter) and intrinsic (clay minerals, sesquioxides, exchangeable cations) in nature. Main existing problems are laboratory based as most soil samples have to be extruded from their sites and be transported to the laboratory for analysis [17]; scale and spatial variability [18]. Various indices have been used in the estimation of aggregate stability of soils such as the mean weight diameter (MWD) [19]; geometric mean diameter (GMD); Water Stable Aggregates (WSA); Coefficient of Vulnerability (K_v); Aggregate Stability Index (ASItest) [20]. Equally, the stability of micro-aggregates against mechanical breakdown and dispersion may be expressed in terms of Clay Flocculation Index (CFI) and the Aggregated Silt and Clay (ASC) which were both applied to determine soil loss in parts of south-eastern Nigeria [21].

Although much research has been done on estimating the aggregate stability of tropical soils, no much literature reveals the choice of any single stability, instability index or method that is generic for all types of soil micro- and macro-aggregates. According to the hierarchical aggregate stability theory, there are four main mechanisms that cause aggregate breakdown: 1) slaking due to compression of entrapped air during fast/sudden wetting; 2) differential swelling and shrinkage during slow wetting and drying; 3) raindrop impact 4) physicochemical dispersion due to osmotic stress. However, the theory has less applicability depending on: soil age (*highly weathered tropical soils with Al-Fe sesquioxides*), type and composition of organic matter, soil texture, etc. Some studies have measured the aggregate stability using a modified high-energy moisture characteristic method which involved carefully controlling the wetting rate (*whether fast or slow*) of air-dry aggregates under suction and the degree of aggregate break-down measured from the high-energy moisture-release curves [22]. The aggregate stability was then measured as the ratio of fast structural index to slow structural index. Other methods included the wettability of 3-5mm sized aggregates using the water drop penetration time (WDPT) suggested by [23]; the Molarity of Ethanol Droplet (MED) method for soils with low repellence suggested by [24]; modified wet sieving method using atomized spray [25]; and the application of low intensity ultra-sonic vibration on 0.2-2 mm macro-aggregates by [26, 27].

In this research, knowledge on the macro-aggregate stability of both major soil types prevalent in Juba County would deepen our understanding on the ability of these soils in resisting mechanical breakdown due to water erosion especially during the rainy season. The objectives of this paper were to (i) investigate the changes in soil macro-aggregate stability as measured by the both Water Stable Aggregates (WSA) and Coefficient of Vulnerability (K_v) during wet sieving of samples of both tropical soils, (ii) investigate the pertinence of wet sieving as an indispensable method in explaining susceptibility of macro-aggregates to slaking.

2. Materials and Methods

Black Cotton clay soil (E. Vertisol) from a 0-30 cm depth was collected from Lologo 2 village, one of the low areas close to the River Nile, about 5 km south of the University of Juba and on the west bank of the River Nile. The sample site is in front of Central Equatoria State Children's Reformatory Centre about one kilometer west of the River Nile, South Sudan. Sandy loam (E. Leptosol) was collected from the Research and Demonstration farm of the Department of Agricultural Sciences, University of Juba.

2.1. Particle Size Distribution

Determination of the particle size distribution of the two different tropical soil samples was in accordance with the revised procedures described by [28]. Sixty-four (64 gm) of macro-aggregate soil sample (> 2.5 mm) with diameter was placed into a set of well-arranged Eijkelkamp sieves with the uppermost mesh having 2 mm and bottom last 0.063 mm (2.0; 1.0; 0.5; 0.25; 0.125 and 0.063 mm.

The samples were mechanically shaken and sieved and the different fractions collected. Only the >2 mm macro-aggregates were retained for the WSA an K_v test while the rest < 2 mm were then discarded.

2.2. Chemical Analysis

The chemical analyses of soil samples were conducted using the LaMotte Soil Testing Kit STH-4 Outfit (Code 5029). The soil nutrients and parameters analyzed for both soils were: pH, nitrate-nitrogen, phosphorus, sulfate (SO_4), iron (III), humus content, magnesium and calcium.

Table 1. Some chemical and physical properties of the investigated soils

Soil property	(Predominant soil type) Clay soil (*Eutric Vertisol*)	(Predominant soil type) Sandy loam soil (*Eutric Leptosol*)
Sand (%)	24	46.80
Silt (%)	23	41.60
Clay (%)	43	11.60
pH	8.0	7.0
Humus (%)	2.95	1.92
Nitrate-N (kg/ha)	45.36	22.68
Phosphorous (kg/ha)	63.04	170.10
Sulfate (ppm)	100.0	1000.0
Iron (III) (ppm)	4.53	1.36
Magnesium (kg/ha)	172.57	64.5
Calcium (kg/ha)	158.76	396.90

2.3. Soil Aggregate Slaking and Test

To determine the rate of aggregate slaking and dispersion, 15 grams of air dried soil aggregates with diameter >2 mm from each soil types were placed in petri dishes half filled with rain water. Observations were taken using a digital camera after every 20, 30, 40 minutes and then after 24 hours. The rate of slaking was noted and compared for both soil types.

2.4. Aggregate Stability Test

Aggregate stability test for both tropical soils were conducted using the modified method of [9]. 15gm of soil aggregates >2.5mm diameter of either soil samples placed onto a top sieve with mesh of 2mm diameter. The other sieves were stacked together in a column descending in order of mesh size. The entire set up was then lowered into and raised from a bucket containing distilled water several times for 60 sec. The remaining stable soil aggregates in the top 2 mm diameter mesh were then transferred to an oven at 110°C for drying for a period of 10mins and then weighed again to obtain the weight of water stable aggregates (WSA). The percentage weight of the 2 mm water stable aggregates (WSA %) and Coefficient of Vulnerability (K_v) was then calculated.

The percentage weight of macro-aggregates expressed as Water Stable Aggregates, (WSA %) and the Coefficient of Vulnerability, (K_V) excluding sand were calculated as;

$$\mathrm{WSA}(>2.5\mathrm{mm}) = \frac{weight\ of\ dry\ aggregates}{weight\ of\ dry\ soil\ sample} * 100\% \quad (1)$$

$$K_v = 1/\mathrm{WSA} \quad (2)$$

For either aggregate stability index, the Kruskal-Wallis test for equal medians and the analysis of variance (ANOVA) was used to detect any significant differences. Similarly, establishing the relationship between each of the two aggregate stability indices with the soil physical properties and chemical constituents, the Principal Component Analysis (PCA) using the scatter plot and hierarchical cluster analysis (HCA) was applied. All the statistical analyses were done using PAST v3.06 software.

3. Results and Discussion

Whereas the mean WSA values for the sandy loam soil was higher than that of the clay soil (Table 2), it was the contrary for K_v with mean values at 1.89 and 2.73 respectively. The effect of wet sieving on stability of soil macro-aggregate was significant for both soil samples when the Kruskal–Wallis test for equal medians at: $(\mathrm{chi})^2 = 9.143$; df = 1; p-value = 0.003) was used. Considering the one-sample test within and between group samples of both soils, the pairwise Wilcoxon rank sum test also revealed that the effect of wet sieving on aggregate stability was significantly different (W = 55; p-value=1.95×10^{-3}).

Table 2 showed clear differences in the average percentage weight of WSA and K_v in clay and sandy loam soils. The average percentage weight of WSA of clay soil was 38.07% and that of sandy loam soil was 55.08%, implying that sandy loam soil had more stable macro-aggregates than clay. The average K_v in clay soil was 2.73 while that of sandy loam was 1.8892, meaning that the clay soil was more vulnerable to mechanical breakdown due to force of water than the sandy loam soil. There was no significant difference ($p = 0.005$) in the values either WSA (W = 23; p = 0.953 for E. Vertisol and W = 28, p = 0.959 for E. Leptosol) or K_v (W = 28, p = 0.959 for E. Vertisol and W = 28, p = 0.959 for E. Leptosol) within each soil data set when the Wilcoxon rank sum test for one-sample was used. However, there was significant difference ($\mathrm{chi}^2 = 9.143$, p = 0.002) in the WSA and K_v within soil samples of both soils when the Kruskal-Wallis test for several samples was used.

According to [29], the percentage weight of WSA was used an estimate to measure the extent to which soil aggregates resist falling apart when wetted by water or hit by rain drops. High WSA values indicated stable aggregates whereas low WSA indicated unstable soil aggregates. Similarly, the K_v was also used to measure vulnerability of soil aggregates to mechanical force of water. A high K_v value indicated weak and unstable soil aggregates while a low K_v value indicated strong and stable soil aggregates.

The average percentage difference of WSA was higher in sandy loam (17.0%) than in clay soil and showed that sandy loam soil had more stable soil aggregates. The K_v in sandy loam soil was 0.84 lower than in clay soil similarly suggesting a higher vulnerability of the clay soil to mechanical breakdown during wet sieving. Our results especially for E. Leptosol with clay content (11.6%) are contrary to earlier findings by [30] who showed that aggregate stability was relatively low for coarse-and medium-textured soils (<25% clay) with low organic matter.

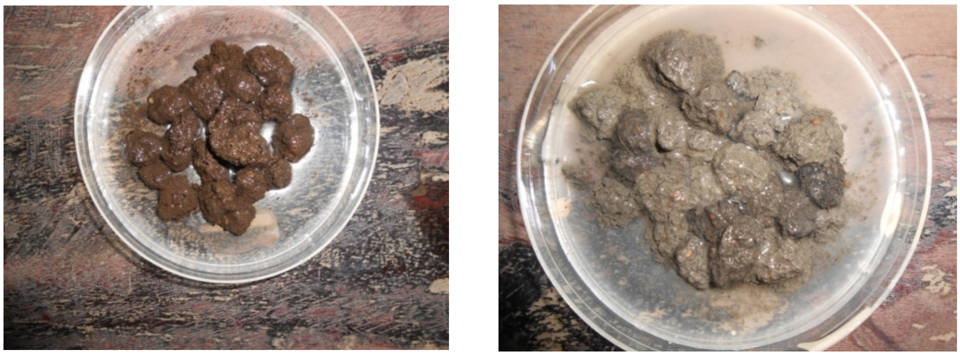
Table 2. Statistical moments of n=20 soil samples of sandy loam soil (E. Leptosol) and clay soil (E. Vertisol)

	Water Stable Aggregates (WSA %)						Coefficient of Vulnerability (K_v)					
	Mean	std	var.	$r^‡$	CV%	W(p)	Mean	std	var.	$r^‡$	CV%	W(p)
Sandy loam soil	55.08	1.15	2.85	0.40	20.4	28(0.96)*	1.89	0.40	0.16	0.37	21.35	23(0.95)*
Clay soil	38.07	1.67	1.32	0.25	20.1	28(0.96)*	2.73	0.58	0.33	0.29	21.10	28(0.96)*

*W(p) where W = Wilcoxon value (p) = equal median indicating not significant at the 0.05 confidence interval;

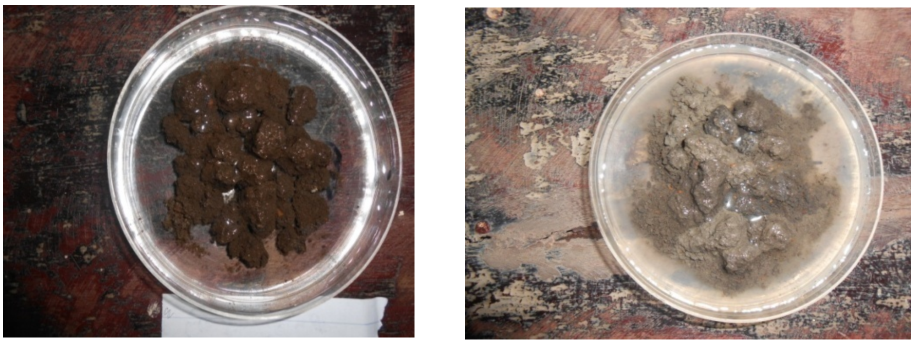
$r^‡$ =Pearson linear correlation; std=standard deviation; CV=Coefficient of Variation

(a) E. Leptosol (b) E. Vertisol



Slaking process of E. Leptosol and E. Vertisol after 20 mins

(a) E. Leptosol (b) E. Vertisol



Slaking process of E. Leptosol and E. Vertisol after after 30 mins

(a) E. Leptosol (b) E. Vertisol

Slaking process of E. Leptosol and E. Vertisol after after 40 minutes

(a) E. Leptosol (b) E. Vertisol

Slaking process of E. Leptosol and E. Vertisol after 24 hours

Figure 1. Photos showing slaking process of E. Leptosol and E. Vertisol during a 24 hour persiod

Hypothetically, the E. Leptosol with low clay content would show a comparatively lower WSA and hence higher K*v* than the E. Vertisol indicating therefore a higher predisposition to slaking and dispersion. This however, was not the case as shown in our study.

Differences in the rate of slaking and dispersion of the two soil samples is shown (Figure 1). More slaking was observed in the first 20 minutes in the petri dishes containing aggregates of clay soil while there was less or hardly any discernible slaking in the petri dishes containing soil aggregates of sandy loam soil. The slaking rate and aggregate disintegration of clay soil samples rapidly increased after 40 minutes compared to that of sandy loam soil. After 24 hours, complete dispersion of aggregates of clay soil had occurred while those of sandy loam soil were not completely dispersed. This indicated that the clay soil aggregates were more susceptible to mechanical disintegration and slaking than the sandy loam aggregates. This was due to rapid uptake of water causing differential swelling of clay minerals as well as aggregate rapture due to volumetric increase of entrapped air [9] contained in the clay soil than in the sandy loam soil.

Though the humus content was comparatively higher in the E. Vertisol than in the E. Leptosol, this was not determining factor in reducing slaking.

Furthermore, our results underscore the significance of WSA and K*v* in assessing the disposition of either soil samples to slaking and therefore surface sealing. Slaking often precedes dispersion, [31] then sealing and eventually crust formation especially of micro-aggregates which ultimately can reduce both water infiltration and saturated hydraulic conductivity [32]. [33] reported that larger formation of soil crust was caused by higher content of water-stable micro-aggregates and smaller size fractions of water-stable macro-aggregates. Implicitly, the low WSA of clay (38.07%) and therefore high content of water unstable aggregates (61.93% of <2.5 mm) would suggest a higher predisposition to slaking or dispersion and therefore crust formation.

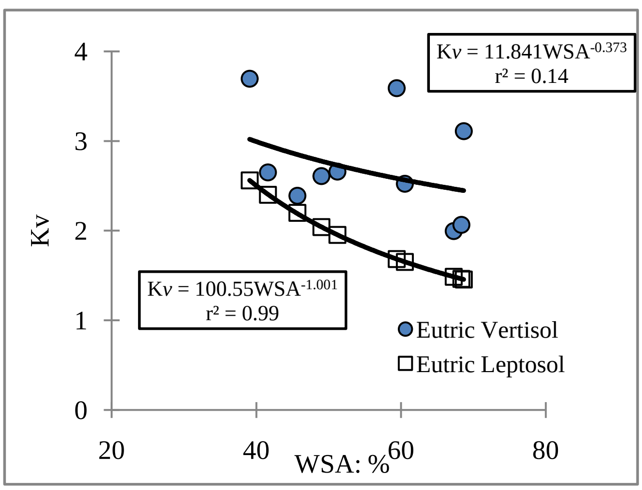


Figure 2. Relationship between Coefficient of Vulnerability (K_V) and Water Stable Aggregates (WSA) of two tropical soils

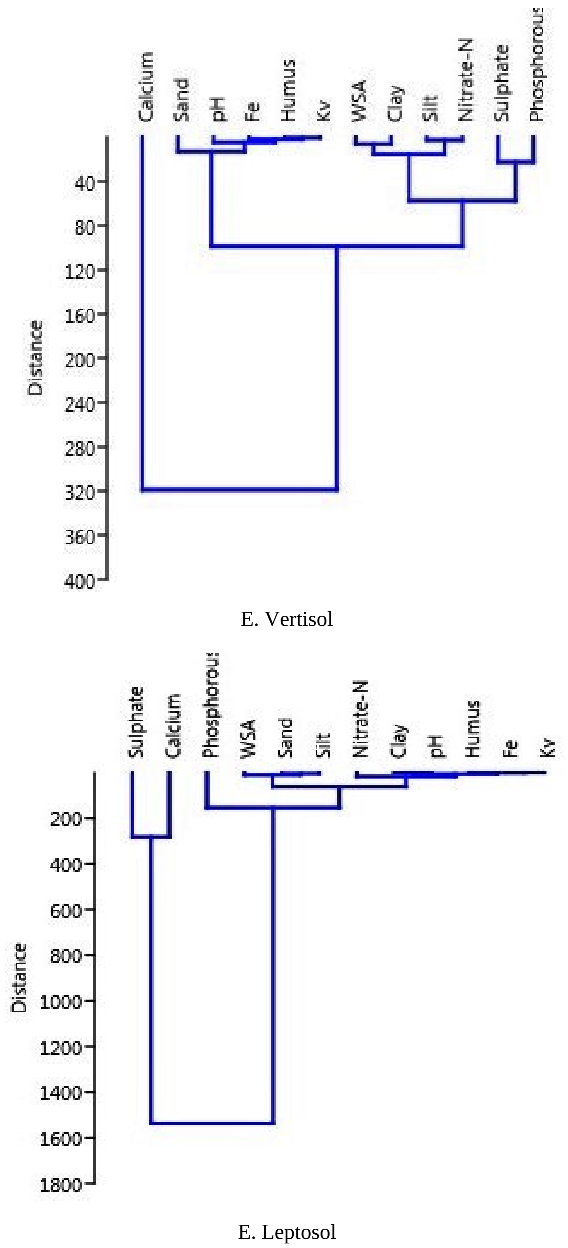


Figure 3. Hierarchical dendrograms showing dissimilarity in both *E. Vertisol* and *E. Leptosol* as influenced by chemical and physical properties

Increasing WSA with decreasing K*v* is shown to be negatively correlated (Figure 2) suggesting vulnerability of the macro-aggregates of either soil samples to mechanical disintegration upon wetting. The linear regression for E. Leptosol was $r^2 = 0.14$ as compared to E. Leptosol at $r^2 = 0.99$. The E. Vertisol gave comparatively higher K*v* values than those of the E. Leptosol indicating its macro-aggregates predisposition to breakdown during wetting. This higher vulnerability to mechanical breakdown during wetting would be attributable to the interacting effects pH, Fe, sand and humus (Figure 3). Although free Fe in soil solution are known to have a cementing effect especially in soils with low contents of organic matter [34] it was not the case in this study. Similarly, the high pH values for both soils at 7 and 8 for E. Leptosol and E. Vertisol respectively, and contrary to the findings of [35], most acidoids present in the soil solution did not peptize 0H-ions which would have otherwise enhanced soil particle aggregation. Different aggregate coatings and their fillings of organic matter and clay are known to influence aggregate stability differently [36]; or aggregate permeability [37-38], the role of such coatings which would otherwise enable water repellency [39, 40, 41, 42] and hence increase aggregate stability was here insignificant. Presumably, during wetting especially for the E. Vertisol, water was able to infiltrate into the inter-aggregate spaces with relative ease thereby reducing the inter-particle contact and hastening mechanical breakdown. By implications therefore, increase in clay content in E. Vertisol did not necessarily lead to aggregate stability, rather this increased its disposition to faster slaking and thus dispersion.

Looking at the hierarchical dendrograms of both soils (Figure 3), shows that each soil had two larger clusters with calcium (as outlier) in the E. Vertisol at cut-off level > 120 and fused with the rest of the soil chemical and physical components at much lower distance. The first minor cluster at cut-off level 80 was made up of sand, pH, Fe, Humus and K*v*; the second with WSA, clay silt and NO_3-N and the third with sulfate and phosphorus all of which showed a more or less equal dissimilarity. It can be assumed that aggregate stability of the E. Vertisol, when considering the cut-off level at >120 was more a function of both calcium on one hand and the combination of the three clusters on the other.

On the other hand, E: Leptosol showed a higher dissimilarity with two larger clusters at cut-off level >400. The first minor cluster was made up of calcium and sulfate with phosphorus as an outlier. The second with WSA, silt and sand, the third NO_3-N, clay, pH, humus, iron (III) and K*v*. Macro-aggregate stability for this soil was more a function of Ca and sulfate on one hand and the rest on the other but with a comparatively higher dissimilarity. Irrespective of the dissimilarity or distance between the individual clusters in both soils, the clustering of both Ca and sulfate in the E. Leptosol as compared to Ca as an outlier in the E. Vertisol accounted for the varied macro-aggregate stability in both soils. The clustering of Ca and sulfate in the E. Leptosol would be the major factor for the comparatively higher WSA and K*v* and therefore more stable macro-aggregate stability. For the relationship between WSA and K*v*, (Figure 4) significant correlation coefficients for E. Leptosol with r^2=0.978; *t*-test = 14.46 and for E. Vertisol with r^2 = 0.961; *t*-test = 13.58 at $p < 0.05$ were obtained. The variation in macro-aggregate stability and the significance of these correlations was due, in part, to variations in the calcium and sulfate levels in both soils. For comparative purposes, the use of WSA and K*v* macro-aggregate stability indices in this study was pertinent. The indices indicated the predisposition of E. Vertisol to mechanical breakdown and therefore slaking than E. Leptosol. The erodibility and crusting potential of either E. Vertisol or E. Leptosol could as well be inferred from both WSA and K*v* indices. However, these indices did not suggest nor indicate any quantitative threshold values from which such inferences could be made. They were simply descriptive and attempted to rank the behavior of either soil to the effects of water. The influence of sand [43], silt [44] and clay fractions [29] have each been cited as soil constituents that have major roles on the stability of soil aggregates. Whilst this is certainly the case in this study, the correlation coefficients calculated between WSA and K*v* should not be construed as entirely dependent on the textural differences only, but also on the variations in chemical properties for both soils. Although the textural range of the soils used in this study was not significantly wide, there are nonetheless substantial variations in the amounts of sand, silt and clay.

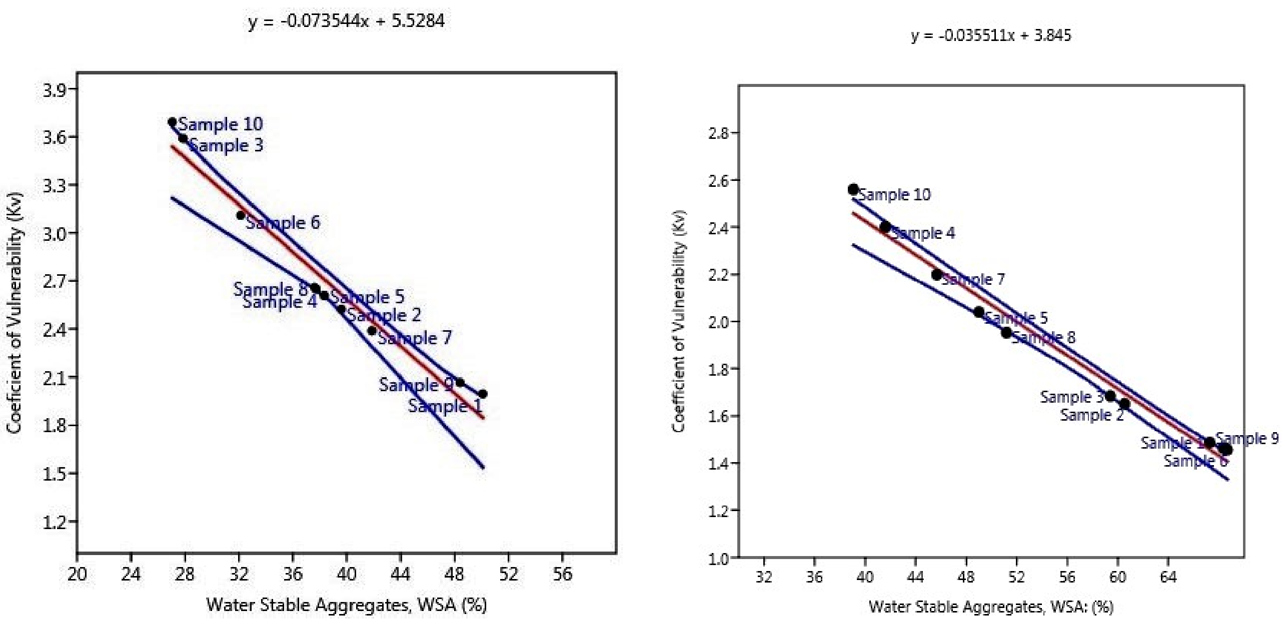


Figure 4. Relationship between Water Stable Aggregates and K_V of samples of E. Leptosol (left) and E. Vertisol (right) with blue lines showing 95% confidence level

3.1. Significance of Soil Chemical and Physical Properties

The significance in terms of antagonistic or synergistic effects of either one or several factors on WSA and K*v* was studied using the scatter plot (Figure 5). Both Ca and SO4 had positive loadings on the E. Vertisol, whereas all physical properties such as pH, Humus, WSA, K*v*, sand, silt and clay contents as well as chemical elements such as Mg, Fe and P had negative loadings. Conversely, NO3-N, clay, silt, WSA, Mg, P and Ca had positive loadings whereas humus, pH, sand, Fe and K*v* had negative loadings on E. Leptosol. Similar results on the effects on silt and clay contents of *Orthic Luvisol* on aggregate vulnerability to destruction during wetting were reported by [45]. However, both clay and silt contents showed negative influence on macro-aggregate stability in E. Vertisol, this was on the contrary for E. Leptosol which showed increased macro-aggregate stability with both clay and silt contents and low macro-aggregate stability with sand. The findings in our study are in line with earlier works of [31, 44] who showed that both soil constituents had major influences on soil aggregate stability. According to *Harmonized World Soil Data (HWSD) Viewer 1.2*, the Cation Exchange Capacity (CEC) is comparatively high at about 68 cmol/kg and the E. Vertisol may be classified as a “high activity clay” (HAC) [46] soil consisting of 2:1 expansible montmorillonite and smectite clay minerals. However, the comparatively easy dispersive nature of E. Vertisol during slaking test would suggest that much of the clay mineral was illite containing high amounts of Mg, [47, 48]. On the contrary, [49] argues that increase of clay contents does not always lead to soil aggregation especially that smectites have a more dispersive tendency than illite or kaolinite. The use of the Principal Component Analysis (PCA) as shown by the scatter plot in Figure 5, further showed that both silt and clay components as well as P and NO3-N did not favor macro-aggregate stability for the E. Vertisol whereas they favored macro-aggregate stability for the E. Leptosol. To a larger extent, the pH, humus, SO4 Fe and sand did not favor the K*v* for the E. Leptosol. Several other similar studies on the relationship between the percentage of water-stable aggregates and soil organic matter have been reported by [50, 51, 52]. The NO3-N had positive effect on aggregate stability which is in agreement with earlier and similar studies of [29, 43, 53]. In our study, the type, amounts and fraction of organic matter may have not been sufficient enough to enhance aggregate stability especially in E. Vertisol. No measurement of the relative quantities of oxidized humic substances or polysaccharides (*microbial gums*) contained in the organic carbon as well as N-amino acids and ammonium ions in the humus were conducted. However, the negative loadings of humus at both pH values of 7 and 8 for E. Leptosol and E. Vertisol respectively would suggest that the levels of binding organo-complexing humic and N-aminated compounds was significantly low to warrant soil aggregate stabilization. Magnesium tended to favor aggregate stability in E. Leptosol than in Vertisol and no concrete reasons were attributable to this phenomenon. Presumably, high levels of Mg in the E. Vertisol tended to bind with more carboxylic, hydroxyl and amine functional groups thereby increasing the susceptibility to dispersion during wetting.

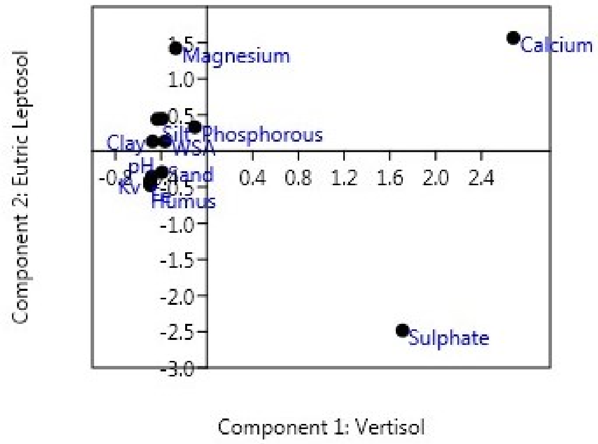


Figure 5. Scatter plot with Eigenvalues showing soil chemical and physical properties of both tropical soils

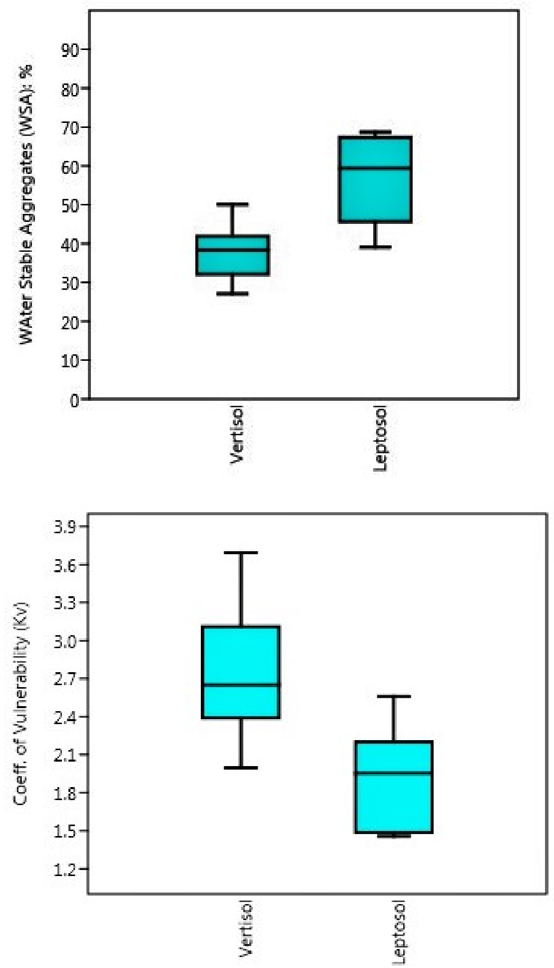


Figure 6. Water Stable Aggregates (WSA) and the Coefficient of Vulnerability for both tested soils

Equally, the hydration energy of Mg, [54] that is greater than that of Ca should have led to larger separation distance within the clay mineral layers thereby enhancing lesser attraction and so flocculation. Similar studies on flocculation as a result of high Mg contents in Midwestern soils of the USA were reported by [55].

Results of WSA and K_v for both soils have been presented (Figure 6). The E. Vertisol showed a small range of WSA of between 33 to 40% whereas the E. Leptosol showed 45 to 68%. The WSA value of the E. Vertisol of less than 50% suggested a low degree of macro-aggregate stability and therefore higher predisposition to mechanical breakdown during wet sieving than the E. Leptosol. Conversely, the K_v of the E. Vertisol was comparatively higher, between 2.4 to 3.2 while that of the E. Leptosol, was between 1.5 to 2.2.

4. Conclusions

1. Use of Water Stable Aggregates (WSA) and the Coefficient of Vulnerability (K_v) as aggregate stability indices for both soils: sandy loam and clay soils showed differences resulting from wet sieving.
2. The aggregate stability index WSA and K_v expressed as a linear function, allowed for establishment of significant differences between both tropical soils. The E. Leptosol showed greater macro-aggregate stability, WSA and lower K_v than the E. Vertisol with a lower WSA and higher K_v.
3. The use of hierarchical cluster analysis and the scatter plot of the PCA revealed differences in aggregate stability due to variations in the physical properties as well as chemical constituents of either tropical soil. The aggregate stability index WSA for E. Leptosol exhibited mainly a strong relationship with sand and silt components whereas for the E. Vertisol was with clay and silt. The K_v by E. Leptosol was influenced to a greater extent by Fe whereas this for the E. Vertisol by humus.

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