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ASSESSING AGGREGATE SIZE DISTRIBUTION IN SOILS FORMED ON SANDSTONE/SHALE PARENT MATERIAL IN SOUTHEASTERN NIGERIA

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ABSTRACT: Disintegration of Soil aggregate increases with poor Soil Management practices, to achieve Stability of Soil aggregate, the understanding of aggregate-size fraction of the soil management practices that will enhance Soil Stability is necessary. The study was carried out to evaluate aggregate-size distribution in Akwa Ibom State, Southeastern Nigeria. Twenty-four Soil Samples were collected from twenty-four locations in the study area. The Soil Samples were air dried and Sieved through a 4mm sieve for aggregate size fractionation with a nest of four sieves; 4-2.0, 2.0-0.25, 0.25-0.053 and < 0.053mm, using the wet-sieving method, air-drying plus capillary wetted and air-drying plus slaked pretreatment, while 2mm sieved sample was used for physical and chemical analysis. The results show that the values of large macroaggregates were significantly ($p < 0.05$) less than the small macro – aggregates, micro aggregates and mineral fractions. The results show differences in aggregate size distribution and could be used to plan soil management in the study area.
Keywords: Aggregate size distribution, soil management and conservation.

INTRODUCTION

Soil aggregates are important in the stabilization of land surfaces and the ability of soils to remain productive. Aggregate are secondary particles formed through the combination of mineral particles with organic and inorganic substances. The complex dynamics of aggregation are the result of the interaction of many factors including the environment, Soil management factors, plant influences and Soil properties such as mineral composition, texture, organic carbon concentration, pedogenic processes, microbial activities, exchangeable ions, nutrient reserves, and moisture availability (Kay, 1998 and Bronick and Lal, 2005), and which also determine the stability of aggregates when disruptive forces are applied (Angers et al, 1993). Soil aggregate occur in different sizes, but are broadly classified as macro aggregates (> 0.25mm) and micro aggregates (< 0.25mm) (Oades and Waters, 1991; Edwards and Bremner, 1967 and Oades, 1993). Macro aggregate stability can be measured using wet Sieving techniques (Salako et al., 1999), while micro aggregate stability is often described by measuring dispersion of aggregates (Salako, 2001). Soil aggregation is important for crop establishment, water infiltration rather than runoff and the associated Soil erosion and compaction (Franzlubers et al., 2000). Aggregate Stability on the other hand, is an indicator of Soil structural condition as well as erodibility (Chan and Mead, 1988; Coote et al., 1988; Six et al., 2000), and can be used to evaluate or predict the effects of agricultural techniques on soil surface integrity (Angers et al., 1993). For instance, stable soil aggregates are important in maintaining favorable soil physical, Chemical and biological quality. Several methods have been proposed for determining soil aggregate – size distribution. Matkin and Smart 1987) compared Six tests of stability. Kemper et al. (1985) separated aggregates by wet – sieving air – dried soil through a series of three sieves (2.0, 0.25 and 0.053mm) by quickly submerging the soil in deionised water or slaked on top of the 2.0mm sieve to simulate the natural stresses involved in the entry of water into the soil.

Elliott)1986); Six et al., (1998) used capillary wetted and slaked pretreatments as a means of differentiating stable macro aggregates from unstable macro aggregate based on their resistance of slaking. Soil quality index by crop growth and yield has declined in Akwa Ibom State reportedly, due to mainly rainfall erosivity and soil erodibility, aided by poor or improper land use and management. However, defining limits for assessing aggregate – size distribution that represent a desired level of aggregate stability and risk of erodibility, as well as defining means of guiding soil aggregate stability management in the area have not been developed. This study evaluates Soil aggregate – size distribution using Capillary – wetting and slaked pre-treatment in order to determine the technique which simulates field conditions and guide the selection of Soil Management practices that would improve soil structural stability in the area.

MATERIALS AND METHODS

The study was conducted in soils formed on Sandstone/shale parent materials in Akwa Ibom State. Sandstone/shale is located between latitudes 5° 00^{I} and 5° 27^{I} N and longitudes 7° 27^{I} and 8° 03^{I} E. the climate of the study areas is hot humid tropical, characterized by two seasons, the wet and dry season. The wet seasons, last from the month of April to October, while the dry season occurs between the month of November to March. Rainfall varies from 3000mm along the coast to about 2,000mm on the northern fringes. Ogban and Essien described the area as in ecology, where relatively high proportion is lost as runoff and where rainfall exceeds the evapotranspiration for at least 8 months in the year, with the difference contributing to the high runoff and potentially high soil erosion. Mean annual temperature varies between 21 and 29°C, and relative humidity ranged 95% (Petters et al., 1989), while evapotranspiration ranges from 4.11 to 4.95mm, partly because of the high insolation and temperature (Enwezor et al., 1990). In sandstone/shale parent material evidence of varying degrees wetness (hydromorphic properties) due either to a periodically high water – table and / or slow infiltration of surface water due to the high clay content, is seen in all the flood plain Soils, most of the terrace soils and some of the soils on the lower slopes. The properties show either as grey colours throughout, grey mottles or self reddish concretions and staining in the soil profiles.

Geology of the area are Sandstone/shale soils. The soils vary in texture from sand to loamy sand and mostly brownish in colour. The soils have low water retention capacity and content of Organic matter (Petters et al., 1989) and are susceptible to soil erosion and leaching loses which can lead to the depletion of basic cations, rapid decline in productivity and low yield (Udo and Sobulo, 1981 and Scholes et al., 1994.). The sandstone/shale sand geological imprint shows the relative clayey nature of the soils and moderate to high inherent fertility of many of the soils. This is because the shales and the colluvium and alluvium (Quartnary Deposits) derived from it have a high base status and weather to regolith containing little residual quartz sand. The terrace soils commonly have clay horizons. Soils in the nearly flat floodplain and depressional areas are clayey throughout. The flat floodplain is dominated by poorly to vary poorly drained, Organic – rich sandy clay loam or silty clay loam topsoil over clayey subsoils. They have excellent physical properties (Ibanga et al., 1989). The vegetation is generally, the rainforest belt which has been reduced in most places completely to farmlands of short duration fallow, < 4 years and to secondary forest of oil palm (Ogban , et al., 2004). The vegetation is characterized by high species diversity. Ogban and Essien (2016) explained that the type of farming practiced is the traditional land rotation with the associated bush fallow system; a form of shifting cultivation which relies on inherent soil quality and resilience to restore the productive capacity of the soil. A variety of tree and food crops are grown, including oil palm, cocoa yam, rubber, maize, cassava, plantain/banana and yam with assorted vegetables.

Field and Laboratory Methods

Soil samples were collected in twenty-four locations, three random soil samples were collected from 20cm topsoil depth and bulked for particle size and chemical analyses. Another set of twenty-four disturbed soil samples were collected with a spade for aggregate – size distribution analysis. Also, twenty-four core soil samples were collected for the determination of bulk density and hydraulic conductivity. The bulked soil samples were air-dried and sieve through a 2mm sieve while the samples for aggregate analysis were sieved through a 4mm sieve. The first set of samples were used in the following analyses: The sample for particle – size analysis was done, after the destruction of organic matter, using the Baouyoucos hydrometer method as described in Dane and Topp (2002). The clay and silt fractions obtained by chemical dispersion. (Sodium hexametaphosphate solution). Aggregate-size fractions were isolated by wet sieving using air – dry 4mm sieved soil. Two 100g Sub-samples of air-dried soil were used to analyze the aggregate-size distribution. Two pretreatments were applied before wet sieving: air drying followed by rapid immersion in water (Slaked) and air drying plus capillary rewetting (Six et al., 2004). Aggregates were physically separated in four aggregate size fractions:

i. Large macroaggregate (> 2.00mm in diameter)
ii. Small macroaggregate (between 0.25 and 2.00mm)
iii. Micro – aggregates (between 0.053mm and 0.25mm) and
iv. The mineral fraction (, 0.053mm in diameter).

After wet sieving, all the fractions were oven – dried, except the large and small macroaggregates obtained by the capillary – wetted pretreatment. These macroaggregates were air – dried and later used for the separation of large and small stable macro aggregates. Sand corrections were performed by subtracting the total sand content of each size fraction from the amount of sample retained on each size fraction. The total sand content of each aggregate – size fraction was determined by weighing the material that was retained on the sieve with a 0.053mm screen upon dispersal of the aggregates with sodium hexametaphosphate ($5gL^{-1}$).

Definition of slaked pretreatment variable

The total amount of aggregates collected in fraction 1 are labeled as T_{1s}; These are stable large macro aggregates (S_1); i.e. $T_{1s} – S_1$……………………………..(1)

The total amount of aggregates collected in Fraction 2 are labeled as T_{2s}, and are the small macro aggregates that were in Fraction 2 before slaking (S_2) and

the stable small macro aggregates that result from the fragmentation of unstable large macro aggregates upon slaking (G2),;i.e,T2s = S_2 +G_2........ (2)
The total amount of aggregates collected in Fraction 3 are labeled as T3s and they are micro aggregates with two different origins; micro aggregates that were in fraction 3 before slaking (S_3) and micro aggregates that result from the disruption of unstable macro aggregates upon slaking from all previous Fraction 1 and 1 or 2, are labeled G_3; i.e. $T_{3s} = S_3 + G_3$..........................(3)
Finally, the materials collected in Fraction 4 is the mineral fraction T_{4s}, with two different origins; mineral fraction that was in Fraction 4 before slaking (S_4) and mineral fraction that resulted from the fragmentation of unstable macro aggregates upon slaking from all previous Fractions are labeled (G_4); $T_{4s} = S_4 + G_4$.. (4)
The summation of the amount of aggregates collected in each size fraction after slaking is equal to the total amount of soil (T) used for this study;$T = T_{1s} + T_{2s} + T_{3s} + T_{4s}$... (5)
Definition of capillary – wetted pretreatment variables. The total amount of aggregates collected in Fraction 1 are labeled as T_{1cw} and they are the stable large macro aggregates (V_1); i.e $T_{1cw} = S_1 + V_1$.................................... (6)
The total amount of aggregates collected in Fraction 2 are labeled as T_{2cw} and they are stable small macro aggregates (S_2) and the unstable small macro aggregates in this Fraction (U_2); i.e. $T_{2cw} = S_2 + U_2$.............................. (7)
The aggregates collected in Fraction 3 are labeled as T_{3cw} and they are the macro aggregates that were found in this Fraction before major perturbation of Fractions 1 and 2; $T_{3cw} = S_3$... (8)
The mineral fraction collected in fraction 4 are labeled as T4cw and they are the mineral fractions that were found before major perturbation of fractions land 2;$T4_{cw} = S_4$... (9)
The total Summation of the amount collected in each size class after the capillary – wetted pretreatment was equal to the total amount of Soil (T) used for this study; $T = T_{1cw} + T_{2cw} + T_{3cw} + T_{4cw}$.................................. (10)

Definition of subsequent – slaked variables in addition to the slake and capillary – wetted pretreatment, physical separation was done on the amount of stable macro aggregate in Fraction 1 and 2 from the unstable macro aggregates by performing a second slaking treatment, this was referred to as subsequent – slaked to differentiate this treatment from the slaked treatment (air – dry soil). The subsequent slaked treatment was performed based on the protocol suggested by the USDA (the slake test) to assess stability of the soil when exposed to rapid wetting (USDA, 1998; Herrick, 1998), similar to the field situation under the intense rainfall that characterize the study area. In addition, the amount of aggregates that remained in the sieve after subsequent slaking was weighed. The total amount of aggregates collected in Fraction 1 after the subsequent slake was labeled as T_{1SS} and was the stable large macro aggregates (S_1). The total amount of aggregates collected in Fraction 2 after the subsequent slake was labeled as T_{2S} and referred to as the stable small macro aggregates (S_2).

Statistical Analysis

The physical and chemical properties of the soil were summarized using descriptive statistics namely, range, mean, median, and standard deviation and coefficient of variation. To decide whether or not data follow the normal frequency distribution the coefficients of skewness and kurtosis were also examined.

RESULTS AND DISCUSSION

Soil Physical and Chemical Properties Related Soil Structure

The data of some physical properties and their descriptive statistics are presented in Table 1. The mean and median values of these properties serve as estimates of central tendency, while standard deviation (SD), coefficient of variation (CV), skewness and kurtosis serve as measures of variability. Particle size distribution showed that the values of coarse sand ranged from 427 to 779 g kg^{-1}, with a mean of 655 g kg^{-1}, coefficient of variation was 11% with skewness and kurtosis of 0 and 12 g kg^{-1} respectively. The range for fine sand is from 80 – 400 g kg^{-1} with a mean value of 193 g kg^{-1}, standard deviation of ±75 g kg^{-1}, coefficient of variation of 36% and skewness and kurtosis of 0 and 2 g kg^{-1} respectively. Total sand content of the soil varied between 752 – 927 g kg^{-1}, with a mean value of 848 g kg^{-1}, standard deviation of 47 g kg^{-1}, coefficient of variation 6 g kg^{-1} skewness and kurtosis were zero, these results indicated that total sand had a normal distribution. Silt content varied between 10 – 92 g kg^{-1}, standard deviation of ±20 g kg^{-1} and coefficient of variation 54% with a mean value of 37 g kg^{-1}. The clay content ranged from 53 – 187 g kg^{-1}, standard deviation of ± 38 g kg^{-1} and coefficient of variation 33% with skewness and kurtosis of 0 and -1 g kg^{-1} respectively.

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Table 1: Physical Properties of 20 cm Depth of Soil on Sandstone/Shale Parent Material

Location	CS	FS	TS	Si	CL	Texture	Ks	ϱb	f
		←	gkg^{-1}	→		Texture	$(cm\ hr^{-1})$	$Mg\ m^{-3}$	m^3m^3
01	727	170	897	15	88	Sand	2.08	1.46	0.45
0	738	160	898	25	77	Sand	8.61	1.05	0.604
03	779	98	877	53	70	Loamy sand	1.65	1.08	0.591
04	597	220	817	70	113	Loamy sand	0.86	1.65	0.378
05	657	120	777	49	174	Sandy loam	35.89	1.35	0.49
06	614	138	752	92	156	Sandy loam	40.20	1.24	0.531
07	618	227	845	53	102	Loamy sand	25.84	1.25	0.528
08	673	218	891	33	76	Sand	7.18	1.08	0.594
09	724	120	844	42	144	Loamy sand	21.53	1.56	0.413
10	706	180	886	30	84	Sand	19.38	1.23	0.556
11	717	140	857	10	133	Loamy sand	7.90	1.26	0.526
12	427	400	827	10	163	Loamy sand	14.36	1.74	0.345
13	593	160	753	60	187	Sandy loam	9.33	1.15	0.566
14	687	150	837	33	130	Loamy sand	0.60	1.82	0.313
15	697	140	837	20	143	Loamy sand	1.72	1.45	0.454
16	653	210	863	39	98	Loamy sand	7.90	1.18	0.555
17	627	260	887	40	73	Sand	2.18	1.45	0.548
18	707	220	927	20	53	Sand	21.53	1.39	0.47
19	685	208	893	32	75	Sand	23.69	1.31	0.507
20	645	260	905	23	72	Sand	11.48	1.35	0.492
21	575	270	854	37	118	Loamy sand	14.36	1.23	0.538
22	585	250	835	20	145	Loamy sand	5.17	1.10	0.584
23	583	230	813	30	157	Loamy sand	7.18	1.66	0.373
24	713	80	793	62	145	Loamy sand	10.77	1.62	0.389
$\bar{x}$	655	193	848	37	114		12.56	1.36	0.492
Min	427	80	752	10	53		0.60	1.05	0.313
Max	779	400	927	92	187		40.20	1.82	0.604
Median	665	194	845	33	114		8.97	1.33	0.517
Sd (±)	75	70	47	20	38		10.92	0.22	0.085
CV (%)	11	36	6	54	33		86.96	16.32	17.2
Skewness	0	0	0	1	0		0.99	0.42	0.880
Kurtosis	2	2	0	1	1		0.69	-0.72	0.680

Key: CS = Coarse Sand, FS = Fine Sand, TS = Total Sand, Si = silt, CL= Clay, Ks = Saturated Hydraulic Conductivity, ϱb = Bulk Density, f =Total Porosity

The results showed a decrease in silt content throughout the underlying sandstone parent material. CS = 6, SI = 54, C = 33 in sand, silt and clay may be due to the associated parent material which may be less uniform in the area, may be due to the associated parent material (sandstone/shale) and the extent of weathering and clay mineralogy. The result shows that the texture of the soil is sandy to loamy sand. Saturated hydraulic conductivity shown on Table 1. Ranged from 0.60 – 40.20cm hr^{1} with a mean vale of 12.56 cm hr^{1} standard deviation 110.92 $cmhr^{1}$ and coefficient of variation 86.96% skewness and kurtosis values of 0.99 and 0.69$cmhr^{1}$ means that those with slow hydraulic conductivity has high fine textured soils, due to high viscosity and tortuosity in water flow, resulting in low conductivity of the soil, while those locations with rapid conductivity had higher coarse textured soils which made the conductivity easier, due to the presence of organic matter content that maintained a high proportion of macropores and stabilizes soil structure.

Soil bulk density varied from 1.05 – 1.82 Mg m^{-3} with a mean value of 1.36 Mg m^{-3}, standard deviation of ± 0.22 Mg m^{-3}, coefficient of variation of 16.32% with skewness and kurtosis values of 0.42 and -0.72 Mg m^{-3}. Generally, soil in the study area possessed a fairly favorable bulk density, except in few areas that have relatively high bulk density that could hinder plant root penetration and growth of plants. Total porosity ranged between 0.313 – 0.604 m^3m^{-3} with a mean value of 0.492 m^3m^{-3}, with standard deviation and coefficient of variation of ± 0.085 and 17.249%. the porosity of these soils was moderate, rated as satisfactory for agricultural practices, since porosity values above 0.400 m^3 m^{-3} is classified under satisfactory soils (Kachinskii, 1970).

Soil Chemical Properties: As shown in Table 1, the chemical properties of soils in the study area revealed that, soil pH in water ranged from 6.64 – 7.25, with a mean value of 6.92, standard deviation of ± 0.13, coefficient of variation 1.94%, with skewness and kurtosis of 0.21 and 0.86. Soil pH of the area is slightly acid to relatively weakly alkaline. The reactions of the soil in the area are lightly suitable for most of the beneficial soil microorganisms in discharge of mycolin fluid that binds the soil aggregates together. Organic carbon varied between 14.03 – 26.48 g kg^{1} with a mean value of 18.39 g kg^{1}, with standard deviation and coefficient of variation of 14.26 g kg^{1} and 23.18%, with a skewness value of 1.37 g kg^{-1}, which shows that the distribution was positively skewed, within the study area. The result indicated that organic carbon contents of the soils were high. It helps to cement flocculated clay particles into stable macroaggregates.

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Exchangeable calcium varied between 4.30 – 8.46 cmol Kg^{-1} with a mean value of 5.60 cmol Kg^{-1}. The exchangeable calcium was statistically uniform in some areas while in other areas, exchangeable calcium carbonate. The condition enhanced flocculation of the soil and improve aggregates stability. Exchangeable magnesium ranged from 1.13 – 3.84 cmol Kg^{-1} with a mean value of 2.09 cmol Kg^{-1}. With standard deviation and coefficient of variation of ± 0.84 cmol Kg^{-1} and 40.37%. Exchangeable potassium ranged between 0.41 and 0.63 cmol Kg^{-1} with a mean value of 0.49 cmol Kg^{-1}, standard deviation of 0.07 cmol Kg^{-1}, and co-efficient of variation of 16.68%, with skewness value of -0.91cmol Kg^{-1}, which indicated that, it was negatively skewed, because the value for median was greater than the mean. The result shows that sodium content will help in peptization of aggregates that result in impermeability. The result of exchangeable Ca, Mg, Na and ECEC showed that their values can support good crop production in the area Landon (1984) reported that tropical soils with calcium level as low as 0.2 cmol Kg^{-1} can effectively support crop growth.

Table 2: Chemical Properties 20 cm Depth of Soil on Sandstone Parent Material

Location	pH (H_2O)	EC	OC	TN	Ca	Mg	Na	K	EA	EC	EC	TEB	Fe	Al
		← dSm^{-1}		g kg^{-1} →		Exchangeable Bases	← (cmol			mg kg^{-1}	———	Kg^{-1}) →		←
01	6.82	0.22	24.45	1.05	5.33	2.20	0.41	0.41	8.84	17.19	8.35	2.11	0.53	
02	6.98	0.61	14.09	0.61	8.41	3.62	0.44	0.52	5.76	18.75	12.99	3.12	0.61	
03	6.95	0.42	15.21	0.66	8.46	3.84	0.45	0.52	8.48	21.75	13.27	3.20	0.64	
04	6.98	0.18	23.59	1.02	5.36	2.22	0.41	0.42	6.6	15.01	8.41	2.12	0.61	
05	6.95	0.55	15.58	0.67	4.30	1.34	0.32	0.42	4.68	11.06	6.38	2.02	0.46	
06	6.96	0.90	16.38	0.71	4.30	1.37	0.32	0.42	6.28	12.69	6.41	2.11	0.46	
07	7.02	0.17	24.39	1.05	5.38	2.27	0.41	0.42	6.48	14.96	8.48	2.12	0.68	
08	7.04	0.40	16.50	0.71	5.18	1.39	0.32	0.43	7.04	14.36	7.32	2.12	0.46	
09	6.90	0.85	15.50	0.68	5.28	1.44	0.33	0.44	6.24	13.73	7.49	2.12	0.48	
10	6.80	0.27	14.50	1.08	5.42	2.27	0.42	0.52	5.07	13.10	8.63	2.20	0.68	
11	6.87	0.11	25.26	1.09	5.44	2.29	0.42	0.52	5.12	13.79	8.67	2.23	0.72	
12	6.80	0.14	16.50	0.71	5.28	1.44	0.33	0.44	6.50	13.99	7.49	2.12	0.53	
13	6.76	0.13	26.48	1.41	6.16	2.33	0.42	0.61	2.88	12.40	9.52	3.23	0.75	
14	6.64	0.63	24.78	1.37	6.19	2.35	0.43	0.62	5.45	15.04	9.59	3.33	0.79	
15	6.87	0.11	16.50	0.71	5.32	1.47	0.33	0.44	8.62	16.18	7.56	3.11	0.55	
16	6.96	0.11	17.22	0.74	6.23	2.38	0.52	0.62	10.01	19.76	9.75	3.34	0.83	
17	6.80	0.18	24.28	0.35	6.25	2.38	0.52	0.63	9.80	19.58	9.78	3.35	0.87	
18	6.99	0.45	16.20	0.70	5.34	1.49	0.44	0.52	3.24	11.03	7.79	3.11	0.57	
19	7.25	0.83	16.20	0.70	6.72	3.55	0.44	0.52	7.51	18.74	11.23	3.11	0.59	
20	7.02	0.54	16.10	0.70	6.76	3.58	0.44	0.52	8.32	19.62	11.30	3.12	0.59	
21	6.92	0.87	15.35	0.66	4.35	1.13	0.31	0.42	8.11	14.32	6.21	6.01	0.37	
22	7.16	0.69	15.72	0.68	4.37	1.18	0.32	0.42	4.12	10.41	6.29	2.01	0.39	
23	6.85	0.15	16.52	0.71	4.30	1.22	0.32	0.42	5.02	11.28	6.26	2.02	0.42	
24	6.74	0.21	14.03	0.62	4.35	1.38	0.33	0.43	3.47	9.96	6.49	2.23	0.71	
$\bar{x}$	6.9	0.41	18.39	0.81	5.60	2.09	0.39	0.49	6.40	14.95	8.57	2.57	0.60	
Min	6.64	0.11	14.03	0.35	4.30	1.13	0.31	0.41	2.88	9.96	6.21	2.01	0.37	
Max	7.25	0.90	26.48	1.41	8.46	3.84	0.52	0.63	10.01	21.75	13.27	3.35	0.87	
Median	6.93	0.34	16.44	0.71	5.35	2.21	0.41	0.44	6.38	14.34	8.38	2.22	0.59	
Sd (±)	0.13	0.28	4.26	0.25	1.15	0.84	0.07	0.07	0.12	4.50	2.05	0.56	0.14	
CV (%)	1.94	68.58	23.18	31.20	20.59	40.37	16.68	15.43	1.88	22.10	23.90	21.70	23.26	
Skewness	-0.21	0.76	1.37	1.17	0.66	-0.43	-0.84	1.82	-0.11	-0.01	0.28	1.89	0.12	
Kurtosis	0.86	-1.17	-1.00	0.78	1.29	-0.28	-0.91	-0.68	-0.78	-0.74	0.22	-1.91	-0.71	

EC – Electrical conductivity, OC – Organic carbon, TN – Total nitrogen, TEB – Total exchangeable bases EA – Exchangeable acidity ECEC – Effective cation exchange capacity.

Exchangeable iron varied from 2.01 – 3.33 mg Kg^{-1} with a mean value of 2.5 mg Kg^{-1}, standard deviation of ± 0.56 mg Kg^{-1} and coefficient of variation of 21.70% the coefficient of kurtosis was -1.19 mg Kg^{-1} and that of skewness was 1.89 mg Kg^{-1}. This indicated that it was positively skewed. Exchangeable aluminum ranged from 0.37 – 0.87 mg Kg^{-1} with a mean value of 0.60 mg Kg^{-1}. Few areas had low values. The result shows that the negative hydroxyl ions being replaced from positively charged aluminum ions in the crystal while other areas had highest values. This result indicated that, at high pH values, the hydroxyl ions tend to dissociate from the oxygen, leaving a negative charge on the surface.

Evaluation of Stable and Unstable Aggregate – size Distribution

The amount of stable aggregates in the study area, shown in Table 3 below indicates that large macroaggregate (>2.0 mm) has a mean values of 3.958 mm (slaked) and 6.792 mm (capillary-wetted). Large macroaggregates has the smallest amount of aggregate. There was significant differences among other size classes. Small macroaggregates (0.25 – 2.0 mm) has the largest mean values of 14.167 mm (slaked) and 21.208 mm (capillary-wetted) among the size classes. There was non-significant trend of the distribution of microaggregate (0.053 -0.25 mm, <0.053 mm), but statistically different from large macroaggregate (> 2.0mm). The amount of unstable macroaggregates (0.053-0.25 mm, < 0.053 mm) has the mean values of 11.208 mm (slaked) and 16.750 mm (capillary-wetted) and 12.914 mm (slaked) and 18.875 mm (capillary-wetted) respectively. Capillary pretreatment has larger values than slaked pretreatment, and the reduction of large and small macroaggregates in these soils as a result of slaked pretreatment, which produces an artificial redistribution of the unstable macroaggregates constituents that later are accounted for in the smaller fractions and that the capillary – wetted pretreatment gives only partial information abouth the distribution of the stable aggregates in line with the result of (Marquez et al., 2004).

Microaggregates (0.053-0.25 mm) has a slaked mean value of 11.208 mm and capillary-wetted mean value of 16.750 mm microaggregates showed significant different from large macroaggregates. There were no statistical differences between small macroaggregates and mineral fraction within the study area. Mineral fraction (< 0.053 mm) has mean value of 12.914 mm (slaked) and 18.875 mm (capillary-wetted) and was significantly different from large macroaggregate, but statistically not different from small macroaggregate and microaggregates. The result shows that large macro aggregates as the lowest mean value of 3.958mm (slaked) and 6.792 mm (capillary-wetted). These results support the hypothesis that, water erosion with slaked pre-treatment method disrupt the stability of aggregate within the study area. According to the work of Marquez et al (2004), cool-season grass would produce the highest level of macro aggregation. Also, Haynes and Francis (1993) demonstrated that a short-term (5-years) pasture could provide more soil organic matter and increased aggregate stability.

Table 3: The Aggregate-size Distribution on Twenty-Four Locations of Sandstone Parent Materials

	MEAN	
Treatment	Slaked	Capillary-wetted
>2.0 mm	3.958 b	6.792 b
0.25-2.0 mm	14.167 a	21.208 a
0.053-0.025 mm	11.208 a	16.750 a
-0.053 mm	12.914 a	18.875 a

Different letters in column indicate differences ($p<0.05$) between the sieve/size classes.

CONCLUSION

The amount and distribution of stable and unstable aggregates in the soil can be used as an indicator of the stabilization and destabilization of the soil aggregates. From the methods used for aggregate separation, it was observed that the wet sieving followed by air-drying plus slaked pretreatment was the best method suitable for separating Soil aggregates. This produces an artificial redistribution of the unstable macroaggregates constituents. Soil aggregate stability have great influence on the stability and productivity of the soil and should be enhanced by practices that are soil conserving which will help in the stabilization of the Soil aggregates.

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