International Journal of Scientific Engineering and Science
Volume 3, Issue 8, pp. 14-18, 2019. ISSN (Online): 2456-7361

Effect of Sand Mixing on Clay Structural Parameters

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***Abstract*— *Clay-sand mixing experiment was conducted in order to assess the effects of sand mixing on the structural parameters of clay soil (vertisol) obtained from Lake Geriyo, Yola, Adamawa state. Five levels of sand-mixing using 250g, 150g, 100g, 50g and 0g sand per kg of clay soil were used. Saturated pastes of the mixtures were allowed to dry in tray for three weeks after which the cracking pattern and the number of cracks of the dry clay-sand mixture were observed qualitatively. Quantitative determination was made of the aggregate size distribution, clod bulk density and aggregate stability. The results of these determinations have showed that fine sand mixing has no significant effect on the number of aggregate larger than 2mm, while the aggregate size less than 0.5mm was influenced by the coarse sand-mixing. Clod bulk density decreased with increase in the levels of sands mixed. Aggregate stability as assessed by wet sieving method increased with increase in sand addition. Moisture content of sand-mixtures at field capacity decreased with increased in both fine and coarse sand additions while significant ($p<0.05$) treatments effect was observed due to coarse sand addition on saturated moisture content of the soil as 50 and 100g coarse sand followed (0g sand) no sand addition treatment. With this, it can be deduced that, additions of sand materials influences structural parameters and water retention properties of clay soil and should therefore be encouraged in clay soils of semi-arid environments*.

***Keywords*— *Clay-sand mixture, Coarse sand, Clod Bulk Density, Field Capacity, Structure and Saturated moisture content*.

I. INTRODUCTION

Plant requires soil to obtain water and nutrients for growth, and for anchorage and stability. For efficient crop production, it is important to understand the soil environment in which plants grow, to recognize the limitations of that environment and to ameliorate where possible without damaging the soil quality. Thus, soil fertility is not a stable property, but is rather a dynamic one. Fertility status of a soil is a natural inherent gift bestowed within the layers of soil which are governed and regulated under various Physico-chemical, Geo-microbial and Hydro-climatic processes eventually subjecting the soil in to stage of depletion from its inherent nature (Sadiq et l., 2019). Soil is one of the most important natural resources for crop production. Soil in its natural state rarely provides the most favorable physical conditions for crop growth. Management of soil physical conditions to ameliorate the constraints for plant growth will not only preserve the quality of soil for future but also contribute to the mitigation of soil degradation. Georgiannou (1988) made an investigation on the behavior of clayey sands under monotonic and cyclic loading. He concluded that the fine content has a remarkable influence on the stress-strain response of the soil mass. As the fines content increases, the dilatant behavior of the soils is suppressed, and the response gradually becomes controlled by the fine matrix at about 40% fine content.

However, different studies have been conducted on the effect of mixing sand-clay on the geophysical properties in relation to different field of studies. Thus, Wasti and Alyanak (1968) have worked on sand-clay mixtures and stated that when clay content is just enough to fill the voids of the granular portion at its maximum porosity. Similarly, studies of soils continued over the years as clean sands and pure clays define distinct boundaries of a wide spectrum of natural soils and thus set limits on expected performance (Mohammad and Ali 2012).

Soil texture indicates much about the possible limitation to crop production in a given soil. However, the limitations arise predominantly from the manner and degree to which the particles are bound together with organic materials to form aggregates, between and within which a network of interconnecting voids of a wide range of sizes is present. Though a lot of work has been done to ameliorate the soil structural stability such as incorporation of organic matter, farmyard manure and much other incorporation, little work has been reported on mixing of soil of different textural class with the aim of stabilizing it. Munsuz and Rasheed (1971) suggested that various natural processes may modify soil structure ultimately leading to equilibrium porosity that is a function of compacting, loosening and compacting processes. Rasiah and Aylmore and (1998) reported that comparison between natural soils and corresponding homogenous sand-clay mixtures show that many of the soils have considerably higher proportions of intra-aggregate pores. It is particularly noticeable in soil with high sesquioxide.

Disruption of the structure of the aggregates by puddling or dispersion, generally removes most of the enhanced macro porosity compared with the sandy-clay mixtures (Shiel *et al*., 1988). Report has also shown that in mixing natural sand with a suspension of silt and clays, packing voids decreases as the fine content increased and was replaced partly with fissures. Other report has pointed out the influence of silt and clay on the physical performance of sand-soil mixtures. They observed that as the silt/clay ratio increased from 0.2 to 4.8 in a soil sample with a sandy content of 88%, shear strength decline from 34 to 20. This study therefore was set to determine the effect of addition of coarse and fine sand on clay structural parameters of a vertisol in Lake Geriyo, Yola, Adamawa State, Nigeria.

II. STUDY AREA

Soil Sample used for the study was collected from Lake Geriyo located in Jimeta, Adamawa state, Nigeria. It is situated at latitude 9.30^0N and Longitude 12.43^0E. The climate of Yola is semi-arid, characterized by unimodal rainfall pattern with erratic distribution; a long dry season followed by a short wet season. The average rainfall is 650 mm per annum ranging from 500-800mm with the length of 3-4 months. The mean temperature is 26^0C (79^0F), wind of 5.8km/h East to North-east. The land is used for cultivation of arable crops like rice and wheat. The vegetation is covered by some few trees including neem (*Azardirachta indica*), Acacia (*Acacia albida*), Baobab (*Adansonia digitata*), Tamarind (*Tamarindus indica*), and shrubs scattered around the site (Adebayo, 1999).

III. Materials and Methods

3.1 Collection, Preparation and Analyses of Soil Samples

Four (4) kg of surface vertisol sample (0-15cm) was collected from Lake Geriyo. Sandy soil material was also obtained from a nearby site for the purpose of testing its effect on the clay structural parameter if mix together. The sand was then separated into two groups according to their sizes, the coarse sand and the fine sand. The fine sand was obtained by the used of 0.02mm sieves. For the coarse sand, the sand was sieved using 0.5 mm. After sieving, the sand that remains on the sieve i.e. the ones that do not pass down were collected as coarse sand. The fine sand was equally obtained through the same procedure (after sieving with 0.5 mm sieve before passing it through 0.02 mm sieve) and the soil that did not pass through the 0.02 mm sieve was collected as fine sand. The coarse sand lies within the range of 0.5mm-2mm while the fine sand lies within the range of 0.02mm-0.5mm. The clay samples were crushed and sieved using 2mm sieve. They were labeled appropriately in polyethene bags and stored in the laboratory for subsequent experiments. The sand for mixing was assumed to be inert.

Particle size distribution (PSD) was determined using the hydrometer method (Bouyoucos, 1962). Soil pH was measured electrochemically by the use of glass electrode pH meter. The EC was measured with EC meter. Organic carbon was also determined using wet oxidation method by Nelson and Summers (1982). Exchangeable cations (i.e. potassium, calcium, magnesium and sodium) were extracted by using 1N ammonium acetate solution adjusted to pH 7.0 and exchangeable acidity (Hydrogen and Aluminum) were determined by titration method after extraction with 1N KCl.

3.2 Clay-Sand Mixture Experiment

The clay-sand mixture experiments were carried out in two stages. One for coarse sand (CS) mix and the other for fine sand (FS) mix. Five levels of sand particle mixing were applied in both cases viz: sand addition of 250g, 150g, 100 g, 50g and 0 g per one kg of clay soil. These treatments were designated as CS0, CS1, CS2, CS3, CS4, and FS0, FS1, FS2, FS3, FS4 for coarse sand and fine sand mixtures, respectively. Each treatment was replicated three times for both the coarse and fine sand mixtures.

The clay-sand mixtures were prepared in special trays (plastic) 1.0 kg of clay soil was first soaked in sufficient quantity of water to make a paste. After 24 hours, the content of the trays were thoroughly mixed and the required quantity of sand mix was added. Then the clay-sand mixture was again turned to make paste. More water was added to saturate the entire mixture. The mixtures in the trays were placed on the floor and allowed to dry at room temperature (25-37^0C) for a period of six (6) weeks in a laboratory. Cracks and cracking patterns were observed for both the coarse and fine sand.

3.3 Determination of Structural Parameters

Aggregate size distribution was determined from the dried sand-clay mixture without crushing or breaking them into pieces. The entire content of the trays was used to determine the aggregate size distribution. The dry sieving was carried out using the rotary sieve as described by Chepil (1962).

Dispersion ratio was determined by gentle dispersion of the samples in water and by complete dispersion with water alkaline sodium hexametaphosphate (calgon) solution at room temperature. The dispersion ration was calculated from the expression

$$\text{Dispersion ratio} = \frac{B}{C-A} \times 100$$

Where:
A = Correction factor
B = Gentle dispersion in water
C = Complete dispersion in alkaline sodium hexametaphosphate (calgon).

Other parameters determined include aggregate stability determined using wet sieving method and clod bulk density obtained from air dried peds of considerable sizes 8-16mm using melted paraffin wax at 60 degrees. Field capacity was determined using column method. Data obtained were subjected to descriptive (mean) and inferential {analysis of variance (ANOVA)}analyses and the difference between the means were separated using least significant difference (LSD) test at 5 % level of probability.

IV. Results and Discussion

4.1 Particle Size Distribution of the Mixtures

Result of the particle size distribution of the mixture showed clay content decreased with increase in sand proportion (Table 1). The result indicates a decreasing trend in the clay proportion and increased proportion of sand, while silt remains fairly constant. These alter the original structure of the soil and hence the physical condition. It was reported by Ibanga *et al.* (1980) that soil strength was directly related to percentage clay, less to percent sand and inversely to percent silt. Similar work had been done by Whitmyer and Blake (1989) who reported that increase in silt/clay ratio had markedly altered the physical performance of sand. They also observed that it increases the silt/clay ratio, increase shear strength and air field porosity.

4.2 Field Capacity of the Mixtures

Table 2 shows comparison between the water field capacity of the two samples studied. The result showed that fine sand additions at various levels have higher water field capacity than that of the coarse sand. These indicate that coarse sand has less influence on water retention of the soil. The control also shows a higher water field capacity which was due to the high clay content of the vertisols. This is in line with the findings of Krishnamothy and Ramanthan (1977) in which they observed that, clay content had predominant influence on fine sand and coarse sand.

Table 1: Particle size distribution of the sand-clay mixtures

Sample	Sand (%)	Silt (%)	Clay (%)
Find sand (g kg^{-1})			
0	12.400	38.600	49.000
50	20.280	32.830	46.890
100	25.370	36.970	37.660
150	27.680	35.820	36.500
250	36.060	34.260	29.680
Coarse sand (g kg^{-1})			
0	12.400	38.600	49.000
50	18.970	34.550	46.48
100	24.960	30.900	44.140
150	31.330	28.560	40.110
250	41.010	35.25	23.740

Table 2: Water field capacity of sand-clay mixtures

Level of addition (g)	Fine sand mixture FC (%)	Coarse sand mixture FC (%)
0	23.92	23.25
50	23.92	19.62
100	22.68	19.12
150	19.18	17.12
250	16.64	13.55
MEAN	21.148	18.53

4.3 Aggregate Size Distribution of the Mixtures

The aggregates of both the size mixtures (Table3) were in decreasing order. However the proportion of the aggregate size of 0.25mm was larger than expected, which could have been as a result of the contribution of the actual soil particles that remained un-aggregated. Comparison between the mean of fine- and coarse-sand mixtures shows that, fine sand field capacity is higher than that of coarse sand.

It was also observed that, the aggregates greater than 2mm are higher per kilogram of clay. Clay, fine sand soil- sand mixture showed a trend of increase in aggregate weight as the additions were made. Also comparison between the fine and coarse sand addition in Table 3 below shows greater or larger lumps in 2mm fine sand than that of coarse sand. This is in line with the visual observation made pointing out greater lumpiness in the fine sand additions than in the coarse sand additions. Therefore, the sand additions reduced the number of cracks and increased the lumpiness of aggregate with greater uniformity in coarse sand mixture.

It is evident that the uniformity of the peds in the coarse sand mixture gives more improved structural aggregate which is in line with the findings of (Donnan and Schwab, 1974) in the development of soil structure. Smaller cracks of the control are an indication of rapid loss of water from the surface and on wetting there is rapid saturation of the surface and decrease infiltration leading to erosion. The additions of sand at various clay weights may possibly reduce the susceptibility of soil to erosion and would likely increase the infiltration rate of the water which is in line the findings of Whitmyer and Blake (1989) on infiltration of vertisols.

Since uniform structural condition is required for crop production, in these additions, coarse sand additions would likely be preferable over fine sand additions.

Table 3: Aggregate size distribution of fine and coarse sand after additions

Treatment	>2mm	1mm	0.5mm	0.25mm
Fine Sand (g)				
0	9.2667	0.5000	0.1000	0.1000
50	9.2667	0.4000	0.2000	0.1000
100	8.2000	0.9667	0.6333	0.0667
150	6.9000	2.7333	1.4000	0.2000
250	6.6333	1.8000	0.6333	0.1000
Coarse Sand (g)				
0	9.3000	-	0.1000	0.1000
50	9.5667	-	0.1000	0.0677
100	8.7667	-	0.2667	0.1000
150	8.7667	-	0.2333	0.1000
250	9.03	-	0.1667	0.0667

4.4 Aggregate Stability of the Mixtures

Table 4 shows comparison between the stability of 2mm mesh size of both fine and coarse sand. The Result indicate a high stability in coarse sand than in fine sand which is due to the fact that coarse sand tend to bind or have high binding or aggregating capacity on clay than fine sand. Another reason is due to the fact that smaller particles built up smaller structures comprising smaller parcels of clay and other colloidal material which is in line with the research work of Oades (1993).

Comparison at both 1mm and 0.5mm of fine sand and coarse mixture shows that, there are higher mean values of 5.400 and 3.733 of fine mixture at 1mm and 0.5mm respectively indicating high stability than that of the coarse sand which decreases as the mesh size reduces.

From the foregoing discussion, it is deduced that the increase of both the fine and coarse sand will influence aggregation and stability. Therefore there is a need to improve or reduced the destructive effect of water in natural soil mixtures of sand which could be overcome by the use of cover crops and surface mulch which will reduce the rain drop impact on soil.

Table 4: wet sieving method for aggregate stability in fine and coarse sand mixtures

Level of addition	2mm	1mm	0.5mm
Find sand (g)			
0	39.000	4.000	3.000
50	81.000	4.667	2.000
100	84.000	2.667	3.000
150	66.667	6.000	5.333
250	64.667	9.667	6.333
Coarse sand (g)			
0	39.000	4.000	3.000
50	88.000	2.333	1.667
100	78.00	3.333	1.667
150	81.667	7.667	3.333
250	79.000	4.000	2.333

4.5 Clod Bulk Density of the Mixtures

There is no significance difference ($p>0.05$) between the various addition as attributed by the fine nature of the sand and the surface area turn out to be large. This was also discussed by Hartman and De Boodt (1974). They reported that capillary depression is inversely proportional to the particle size and that water content will increase as bulk density decreases. The decrease in bulk density as sand was added also agreed with the work of Summerfeldt and Chang

(1982) who reported that increasing manure application has decreased bulk density and increase water retention.

It is therefore evident from the results that the coarse sand had more influence on the bulk density of vertisols than the fine sand. Since bulk density when high impedes root penetration and water infiltration, the reduction in bulk density is an improvement of the structural condition of the vertisols.

Table 5: Average clod bulk density (Mgm^{-3})

Sand addition (g)	Fine sand mean	std	Coarse sand mean	std
0	1.730	0.039	1.690	0.029
50	1.703	0.037	1.510	-0.007
100	1.670	0.027	1.583	0.008
150	1.510	-0.005	1.477	-0.069
250	1.060	-0.095	1.468	-0.016
$LSD_{(0.05)}$	1.562	-	0.508	-

4.6 Saturated Moisture Content of Clay-Sand Mixtures

It was observed from the gravimetric moisture content (Table 6) that as the proportion of fine sand and coarse sand increase, the gravimetric moisture content decreased. The decrease was not however linear. Comparison between the two revealed that, the rate at which the moisture content decreased was higher in coarse sand than in fine sand addition. Analysis of variance revealed that there was no significant difference ($p>0.05$) in fine sand addition, however, significant treatments effect ($p<0.05$) of coarse sand addition on saturated moisture content was observed. Control (no sand addition) gave highest saturated moisture content followed by 50 and 100 g coarse sand additions (Table 6).

The change in proportion of the clays in the mixture and increase in sand content was therefore responsible for the reduction of water content at saturation.

Table 6: Saturated moisture content of soil mixtures

Addition (g)	Fine sand mean	std	Coarse sand mean	std
0	0.632	0.0922	0.757a	0.173
50	0.631	0.0912	0.648b	0.064
100	0.501	0.0612	0.600b	0.016
150	0.451	0.0888	0.495c	0.089
250	0.384	0.1558	0.420c	0.164
LSD (0.05)	0.250	-	0.105	-

V. CONCLUSION

An experiment was carry out in the physic laboratory, Faculty of Agriculture, university of Maiduguri to determine the effect of sand mixing on clay structural parameters (vertisols).The sample used was from Lake Geriyo, Adamawa State. Vertisols are attributed by shrinking and swelling upon drying and wetting, because of their high smectite contents. These pose problems of drainage and infiltration of water down the profile as a result of which its workability is reduced. Various result obtained at the cause of these research work proves that mixing or addition of sand at various level altered the structural conditions of the vertisols. It was observed that the cracking pattern was reduced with increase in level of sand addition. It is evident from the results obtained that sand additions have influence in clod bulk density as it was observed to decrease giving rise to adequate aeration and possible water penetration for the coarse sand addition treatment. However it was fairly constant in fine sand addition. Aggregate stability increased due to sand addition at various level of addition of both the fine and coarse sand. But low stability increase was observed in coarse sand mixture.

Water retention is another property of the vertisols that was affected by the sand addition. There was no significant difference of fine sand addition on the clay content, at the saturated moisture content of the treatments. In the coarse sand, there was significant difference due to coarse sand addition. This shows that coarse sand have much influence on clay soils than fine sand. It was observed therefore that, natural soil active clay had strong influence on the structural parameters of vertisols. Soil-sand mixing of vertisols had reduced the bulk density of the vertisols. It can be deduced that mixing clay soil with sand can have effects on bulk density, aggregate stability, aggregate size distribution, water field capacity and saturated moisture content of the clay soil of Lake Geriyo. Therefore, it is recommended that, sand fractions addition should be encouraged in vertisols of semi-arid environments.

ACKNOWLEDGMENT

We would like to extend our profound gratitude to the Gerio Lake Management for their support towards realization of the research work.

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