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ORGANIC CARBON CONTENT AND DRY AGGREGATE STABILITY INDEX OFSOME TROPICAL SOILS ATYOLA, ADAMAWA STATE, NIGERIA

[*1]Ibrahim Emmanuel Vahyala, [2]Saminu Hamisu Aliyu and [3]Zainab Suleiman Mohammed
[1,2,3]Modibbo Adama University of Technology, Yola Adamawa State, Nigeria
E-mail: ievahyala@gmail.com ([*]*Corresponding Author*)

Abstract: Food production in Yola and environs, involves continuous cultivation of areas immediately outside the townships by many peasant farmers. A common complaint by the farmers these days is that the soils are dead and no longer productive, which is consistent with the negative effects of continuous tillage and cultivation on soil aggregates. Soil aggregation and organic carbon contents are important parameters that influence the physical, chemical and biological properties of soils. Literature shows that soil organic carbon favors aggregation and stability of the aggregated units. Stability of aggregated units is a good indication of soil structure and soil health, therefore a sustainable cultivation system must ensure conservation of desirable soil structure and health. This study sought to examine the nature of this problem by evaluating dry aggregate stability and organic carbon contents of soils from three areas that have been under continuous cultivation for a very long time (at least 20 years). These include; Sangere Numan road, Girei road and Chuchi-Jippujam along Yola road. Soil samples were collected at two depths 0-20 and 20-50cm, from 10 randomly selected points that were at least 50m apart from each of the three sites listed above. Mean weight diameter (MWD) was computed overa range of five aggregate-size classes(10-4.75mm, 4.75-2.0mm, 2.0-1.0mm, 1-0.6mm and 0.600-0.002mm), using dry sieving method. Soil organic carbon contents were determined by wet oxidation method of Walkley and Black. Analysis of variance for a two-factor with replications was carried and means were tested using t-test pair-wise comparisons. The result showed that soils from Sangere Numan road hada significantly greater dry aggregate stability (MWD >3mm) than soils from either Jippujam (MWD≈2mm) or Girei (MWD≈1.5mm), and this pattern was consistent for surface and sub-surface horizons. Organic carbon contents of the soils were generally low. In both surface and sub-surface horizons, Girei had a significantly lower organic carbon and clay content (Organic carbon=0.99%; Clay = 8%), than Sangere (Organic carbon = 1.45%; Clay = 20%) and Jippujam (Organic carbon =1.33%; Clay = 21%), however, the difference between Jippujam and Sangere, were not significant for these parameters. This study showed that the soils of Sangere along Numan road hada better physical condition than soils of Jippujam and Girei. In fact, soils along Girei road may be the most impacted by continuous cultivation and tillage operations.
Keywords: Tillage, continuous cultivation, aggregate stability, soil organic carbon, mean weight diameter (MWD).

Introduction

Food production in Yola and environs, involves continuous cultivation of areas immediately outside the township by many peasant farmers along three roads leading in or out of town. A

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common complaint by the farmers these days is that the soils are dead and no longer productive, which is consistent with the negative effects of continuous tillage and land cultivation. Peasant farmers in Yola have attempted to address the problem by emphasizing inputs such as fertilizers and herbicides, however, the response to fertilizer application has not been satisfactory. This suggests that there is another problem beyond fertility and fertilizer applications. Deterioration in physical condition of soils is known to manifest as a “hidden-stress” [1], which may not be easily recognized and identified by the farmer. Deterioration in physical condition can be typically attributed to loss in soil structure. Soil structure refers to the aggregation and arrangement of aggregated units of various sizes made from sand silt and clay fractions of the soils, as well orientation of the network of pore spaces within and between the aggregated units. These pores spaces are usually responsible for storage and movement of water, air, and heat in the soil system, therefore, loss in soil structure implies significant alterations to the natural and healthy configuration of soil aggregates and pore spaces.

Soil aggregation and organic carbon contents are important parameters that influence the physical, chemical and biological properties of soils. Literature shows that soil organic carbon favors aggregation and stability of the aggregated units. Soil aggregate stability is widely recognized as a key indicator of soil quality [2-3]. Soil aggregate stability has been used to indicate soil resistance to erosive agents and soil quality [4]. Higher soil organic carbon is known to improve the soils aggregation and stability of aggregated units. It increases the cation exchange capacity (CEC) and water holding capacity of sandy soils, and it contributes to the structural stability of clay soils by helping to bind particles into aggregates [5]. Globally, the amount of carbon stored in soil is equal to amount stored in vegetation and in the atmosphere combined [6]. Natural variation in soil organic carbon occur as a result of climate, organisms, parent material, time and relief [7]. A sustainable cultivation system must ensure conservation of desirable soil health and structure, and structural. Structural stability describes the ability of the soil to retain its aggregates and pore-spaces when expose to external forces like winds, water, and mechanical manipulations such as tillage. Continuous tillage cultivation is one of the major factors that breaks the defensive measure of the soil structural aggregates.

The objectives of this study were to:

i. Measure the aggregate stability and organic carbon content of soils from the three different areas in this study

ii. Evaluate the levels of deterioration associated with each particular of three the sites
iii. Identify which is the best amongst the three sites.

Materials and Methods

Yola, the capital of Adamawa State, the town is situated in the semi-arid belt of Northeastern Nigeria. It lies along the Benue River with 9^0 10' N to 9^0 15' N and 12^0 20' E to 12^0 30' E, the area is generally flat to gently undulating. The elevation ranged from 160 to 190 m above sea level. The area receives an annual rainfall of 700 to 1600 mm. Rainfall distribution is unimodal, with much of the rain falling between May and October. The rainy season is followed by a long dry season, during which the area comes under the strong influence of the Northeast trade winds (winds that originate in the Sahara and blows across the Sahel region), locally referred to as Hammattan. Maximum temperature can exceed 40°C March-April, while minimum temperature can be as low as 18°C between December and January [8].

Site characteristics and soil sampling:

Three (3) farm lands located on the outskirts of Yola were selected for sampling. These include:

I. Farm lands near Jippu jam junction along Yola road
II. Farm lands at Sangere along Numan road
III. Farms along Girei road

Field observations showed that Girei soils had loose surfaces when dry with low activities of micro and macro-organism like earthworm, insects, and termites. They were yellowish brown to dark brown in color. The dominant field crop in the area was Maize, and has a long history of cultivation. Sangere soils were observed to feel like sandy loams in the surface horizons and loams to clay loams in their sub-surface horizons. They were generally firm when dry with low presence of soil organisms like earthworms and insects. However, they also have a very long history of cultivation, where Rice and Maize were dominant field crops. Jippujam soils had loamy to clay loam and clay textured feel. They were very firm and heavy when dry with common presence soil organisms like earthworms and insects. Dominant field crop observed was rice, with a very long cultivation history.

Soil auger was used to collect samples at two depths (0-20cm and 20-50cm) and 10 randomly selected sampling points that were at least 50m apart from each of the three study sites. Each sampling point was geo-referenced using a GPRS (Garmin eTREX 10). A total of 60 soil samples were collected for Laboratory analysis (3 sites x 10 sampling points x 2 depths). An additional 10 core samples were collected from each of 3 study sites using core samplers for bulk density determination. Details of reference coordinates for all 30 sampling points are provided in Table 1.

Laboratory analysis

The soil texture was determined using the Bouyocus hydrometer method as described by [9]. The soil pH was measured in a 1:2 soil to water ratio using a glass electrode (H19017 microprocessor) pH meter. Similarly, the EC was measured using Jenway 4320 EC meter [9]. Organic carbon (O.C.) content of the soils was determined using the wet oxidation methods of [9]. Potassium dichromate was used as an oxidizing agent. The filtrate was titrated with ferrous ammonium sulphate in the presence of diphenylamine indicator to a dull green end point. The percentage organic matter was calculated by multiplying percentage O.C. by a factor (1.724).

Data analysis

Dry aggregate size index was determined using set of sieves to separate the soil into four aggregate size group representing 10-4.75mm, 4.75-2.0mm, 2.0-1.0mm, 1.0-0.6mm, and 0.6-0mm respectively. The method assigned an appropriate weighing factor to each class size range of aggregates, based on weighing the masses of aggregates of various class size ranges.

Mean Weight Diameter (MWD) of the sample was calculated according to [10];

$$MWD = \sum_{i=1}^{n} xiwi$$

Where x = class mean diameter, w=weight of aggregate in class size range.

Descriptive statistics and graphical procedures were used for data interpretation. Analysis of variance for 2 factors with replications (3 study sites, 2 sampling depths and 10 sampling points on each study site) was employed and means were separated using a student’s T-test for parameters that indicated significant effects ($p \leq 0.05$).

Result and Discussion

Soil reaction (pH) and electric conductivity (EC)

Soil reaction expresses acidity or alkalinity of soils. Detailed results for laboratory analysis of pH and EC are presented in Table 2. The soils of the study sites were all observed to be slightly acidic, both at surface and sub-surface horizons, with mean pH values of 6.07, 6.04 and 6.10 for Girei, Sangere and Jippujam respectively. Slight acidity in soils (pH 5.9 – 6.5) is desirable according to [11], however, there is a need for careful management of chemical inputs, especially fertilizers to avoid development of acidic conditions. When pH approaches a value of 8.0 or greater, then there is a risk of dispersion of colloidal materials like clay and subsequent loss in structure [3], which usually leads complete loss in water permeability and internal drainage. Electrical conductivity (EC) value of 0.61 dSm^{-1} was observed in Girei, while values of 0.62 dSm^{-1} and 0.54 dSm^{-1} were observed for Sangere and Jippujam respectively, suggesting that there are no risks from freely dissolved salts in these soils.

Soil texture and organic carbon

Results for textural analysis are presented in Figure 1. The results showed that Girei had highest sand fraction followed by Sangere and Jippujam. The textural classes show that soils of Girei were predominantly Loamy sands, with and average Sand content of 82%, 8.7% Clay and 9.3% Silt. Sangere soils were predominantly Sandy loam textured with 67.4% Sand, 15.6% Silt and 17% Clay. Jippujam soils had a Sandy clay loam to a Loamy texture with means of 58% Sand, 19.4% Silt and 22% Clay. At Girei and Sangere, sand fractions were consistently higher in surface horizons than in sub-surface horizons, while at Jippujam higher sand fractions occurred in sub-surface horizons. Jippujam sites were all flood plains and spill plains of River Gongola, which is a tributary of the River Benue at Yola, Adamawa State. Jippujam being a flood/spill plain, alternate horizons formed from layers Sand and Clay were commonly observed, hence may explain the large variances (>100%), observed for sand and silt fractions at this site (Table 2). Such large variances suggest several data points may have values that are far from the reported mean values [12].

Results for Organic Carbon content of the soils are presented in Table 2 and Figure 2. Sangere had highest organic carbon content (1.43%), followed by Jippujam (1.36%) and analysis of variance showed no statistically significant difference for these two site at ($p \leq 0.05$), as shown by common alphabetical notations in Figure 2. Gireisoils had the least organic carbon (0.98%), which was also observed to be significantly lower than either Sangere or Jippujam soils. It is desirable to have organic carbon contents of 2% or higher, which would favor and encourage activities of soil organisms according to [11]. The greater the biodiversity of soil organisms, the healthier the soil becomes and this would increase nutrient cycling potential, improve soil aeration and water holding capacity.[13], had earlier observed that an increase of 0.01 kg kg^{-1} organic carbon would result in an increased available water capacity from 0.02 to 0.04 m^3 m^{-3} in a coarse-medium textured calcareous illitic soils at Ontario in Canada. The difference in organic carbon content between Girei (9.8 kg kg^{-1}) and Jippujam (13.8 kg kg^{-1}) or Sangere (14.3 kg kg^{-1}) is about 4 kg kg-1, which is much larger than reported in literature cited above, and therefore it’s expected that water holding capacity of Girei soils would be significantly lower than the soils at Sangere or Jippujam.

Aggregate class size distribution and mean weight diameter (MWD)

The results for aggregate class size distribution at both surface and sub-surface horizons are presented in Figures 3 and 4.The aggregates class size distribution data showed a higher proportion (>35%) of aggregates in 0.60-0.002mm interval class for both Girei and Jippujam soils, while Sangere soils dominated the two interval classes with the largest aggregate size units (10.00-4.75mm and 4.75-2mm). It is difficult in any study to separate fine aggregate units from medium to fine sand grains within the 0.06-0.002mm interval class size, because the upper limit of 0.06mm closely represents upper limit of silt fraction, while the lower limit 0.002mm describes finest fraction referred to as colloidal, [3]. The almost linear trend exhibited by Girei soils in which proportion of aggregates in class size interval increases as the aggregate class size decreases for both surface and sub-surface horizons suggest that the sand fraction which was observed to be over 82% may account for the pattern in Girei soils rather than actual aggregated soil units. Soils from all the three sites converged within interval class size of 2.00-1.00mm, having almost equal proportion of 15-17% in each case at the surface horizons. The pattern was slightly different at the sub-surface because Girei had proportions slightly over 20% for the 2.00-1.00mm interval class.

[4], measured the impact of water splash on soil aggregates sizes corresponding to 0.50-2.00mm, 2.00-8.00mm, and 8.00-30.00mm with varying organic carbon contents. They found that the material that was removed after a period of 90 minutes were highest on the largest size range of 8.00-30.00mm, and this size also had the least tensile strength compared to the smaller size ranges. They also observed that losses from samples with higher organic matter content were lower than losses from samples with low organic matter contents. This suggests that one would expect greater resistance to erosive forces of water splash in soils of Sangere and Jippujam in addition to greater water holding capacity reported earlier as observed by [13].

The mean weight diameter (MWD) is used as an index of soil structural development and stability [10]. Greater value indicates higher degree of larger aggregated units, while lower values suggest lack of aggregated units of larger sizes, and this is particularly applicable in medium and fine textured soils. Soils with high proportion of coarse sand fraction, or gravelly materials may lead to a biased representation because the fractional diameter of these larger sand grains and gravels show up as aggregated units. Fortunately, the soils in these study were free of such materials. The data indicate that Sangere soils were better aggregated than those of either Girei or Jippujamas shown in Figure 5.Sangeresoils had a MWD of about 2.50mm and 3.00mm at the surface and sub-surface horizons respectively. At Girei however, MWD were less than 1.50mm for both surface and sub-surface horizons; Similarly, Jippujam soils had MWD values 1.90mm and 1.80mm. Statistical analysis showed that the MWD of Sangere soils were significantly larger than those of Girei and Jippujam soils (Figure 5), however, no significant difference was observed in the latter two soils, and this trend was consistent for surface and sub-surface horizons.

Conclusion

This study evaluated an important physical property of the soils (soil structure), which has a direct impact on soil health and productivity. Often times farmers in this part of the world only emphasize fertilizers as the major input responsible for high yields and productivity, however, little attention is paid to management of soils physical deterioration which eventually manifests as a hidden stress. Researchers have pointed to this problem long time past, for instance [14]stated that "our understanding of damage due to badly timed cultivations or to compaction by too frequent passage of heavy machinery will be very unsatisfactory until we have succeeded in measuring such changes, and determining on what soils real problems exists". This study has revealed that soils along Girei road may have the greatest limitations terms of texture, organic carbon carbon content and structural developments. The results also show that although Jippujam soils are floodplain soils, there is some limitations in terms of soil aggregation and structural developments, however, this may be compensated by high nutrient recharge typical of floodplain soils. The results show that Sangere soils are much better aggregated with a reasonable content of organic carbon compared to the other locations studied. It is expected that the benefits like improved water holing capacity, resistance to erosion, and microbial diversity, which are derived from such attributes as cited in literature will be better manifested in this soil [15]. Further cultivation of this soil must ensure that management strategies be put in place for sustainability and improvement on existing conditions. There are several strategies in literature (reduced/zero tillage, full residue retention, organic amendments etc.), but not all can be employed. Location and soil specific strategies must be identified for these soils, and this provides opportunities for further research in these soils.

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Table 1: Coordinates of sampling points (decimal degrees)

	Girei		**Sangere**		**Jippujam**	
S/N	**East**	**North**	**East**	**North**	**East**	**North**
1	9.352994	12.530151	9.280793	12.354161	9.123748	12.466855
2	9.352824	12.529564	9.281494	12.353392	9.125127	12.468365
3	9.352372	12.530076	9.279314	12.350469	9.1205755	12.496897
4	9.352468	12.530381	9.279273	12.350399	9.216578	12.467732
5	9.35233	12.531129	9.278716	12.346621	9.215746	12.465406
6	9.355142	12.529065	9.278865	12.347063	9.21485	12.46410
7	9.35557	12.528057	9.282623	12.352069	9.221752	12.463776
8	9.355452	12.527847	9.282335	12.350298	9.21919	12.464504
9	9.356006	12.527479	9.281331	12.34934	9.220042	12.464184
10	9.356142	12.527366	9.28382	12.347951	9.221709	12.464043

Table 2: Descriptive statistics on soil parameters of the study sites

	GIREI						**SANGERE**						**JIPPUJAM**					
Parameter	***pH***	***EC***	***O.C***	***Sand***	***Silt***	***Clay***	***pH***	***EC***	***O.C***	***Sand***	***Silt***	***Clay***	***pH***	***EC***	***O.C***	***Sand***	***Silt***	***Clay***
Mean	6.07	0.61	0.98	82.00	8.70	9.30	6.04	0.62	1.43	67.40	15.60	17.00	6.10	0.54	1.36	58.30	19.04	22.66
Standard Error	0.11	0.04	0.03	1.82	0.55	1.49	0.17	0.03	0.08	1.57	0.99	1.38	0.04	0.03	0.08	3.06	2.32	1.63
Median	6.20	0.62	1.02	84.40	9.60	6.00	5.95	0.62	1.26	66.40	14.60	18.00	6.10	0.51	1.25	59.40	15.00	21.80
Mode	6.20	-	1.06	86.40	9.60	6.00	5.30	0.70	1.11	72.40	13.60	18.00	6.20	0.40	1.03	70.40	10.00	17.60
StdDev.	0.48	0.17	0.14	8.12	2.47	6.66	0.74	0.15	0.38	7.00	4.45	6.17	0.18	0.15	0.36	13.70	10.36	7.30
Sample Var.	0.23	0.03	0.02	65.94	6.09	44.33	0.55	0.02	0.14	49.05	19.79	38.11	0.03	0.02	0.13	187.57	107.31	53.33
Minimum	5.00	0.39	0.68	64.40	3.60	2.00	5.20	0.35	1.01	56.40	9.60	8.00	5.80	0.37	0.70	36.40	8.00	8.00
Maximum	6.90	0.94	1.22	92.40	13.60	24.00	7.80	0.85	2.35	80.40	25.60	28.00	6.50	0.83	1.98	78.40	39.60	34.00
Count	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Conf.L. (95%)	0.22	0.08	0.06	3.80	1.16	3.12	0.35	0.07	0.18	3.28	2.08	2.89	0.09	0.07	0.17	6.41	4.85	3.42

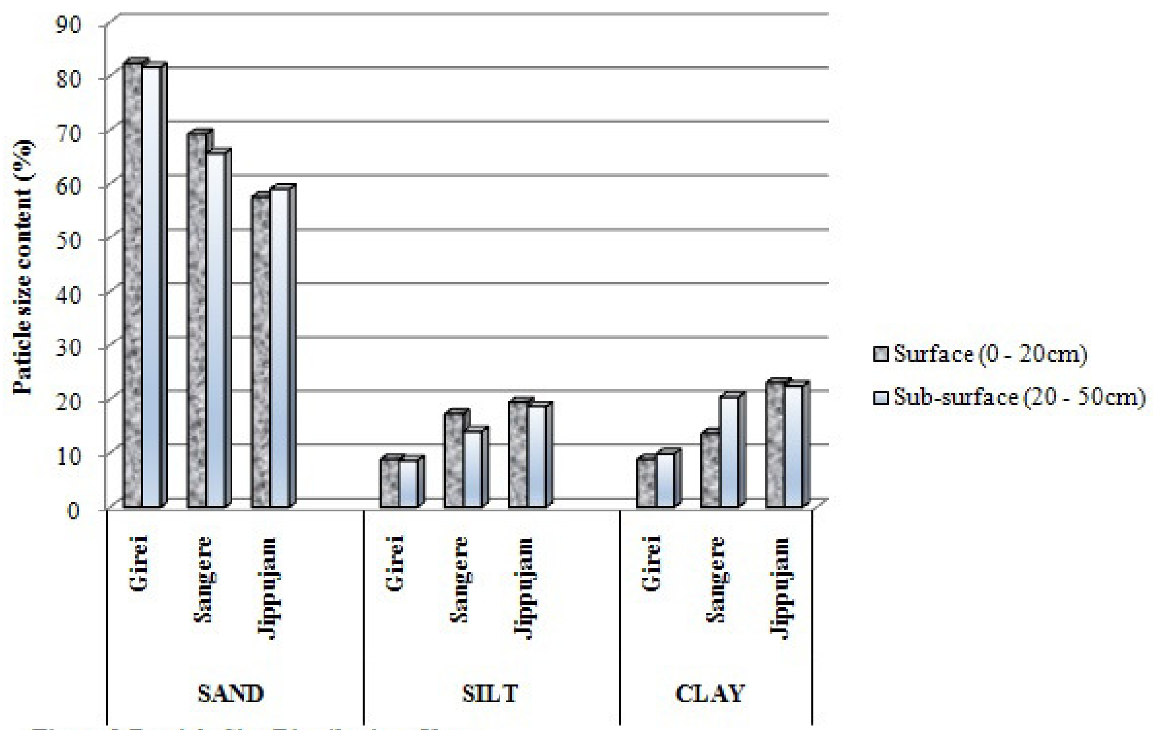

Figure 1 Particle Size Distribution Chart

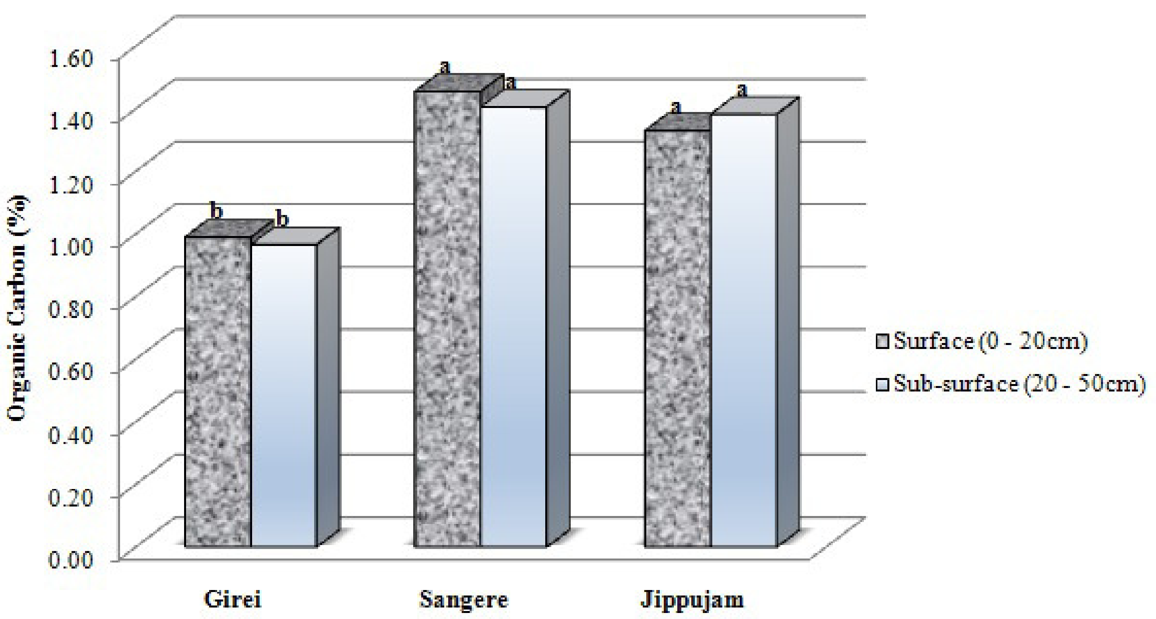

Figure 2 Soil Organic Carbon

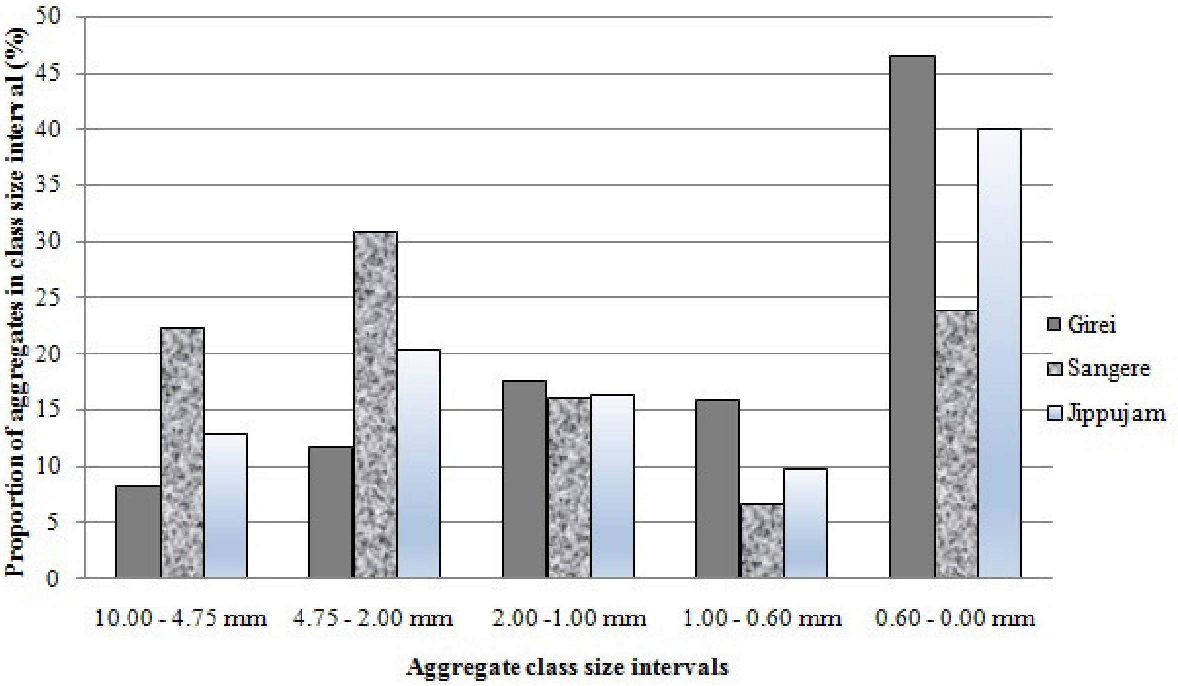

Figure 3 Aggregate Size Distribution in Surface Horizons (0-20cm depth)

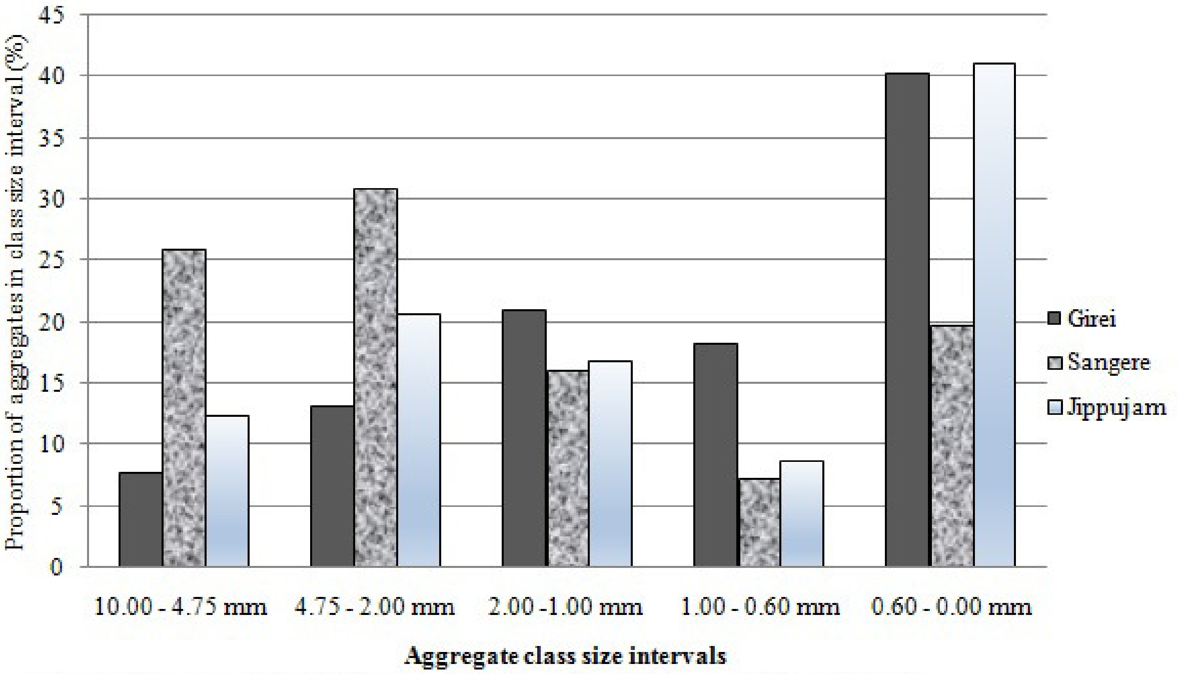

Figure 4 Aggregate Size Distribution in Sub-surface Horizons (20-50cm depth)

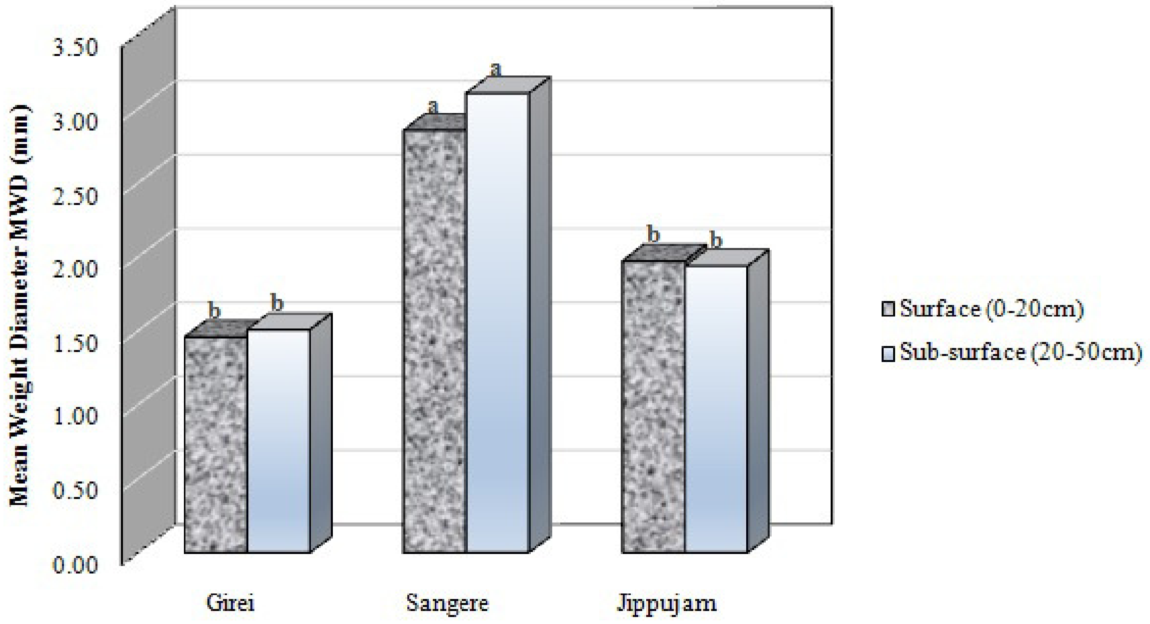

Figure 5 Dry Soil Aggergate Stability Index (MWD)