STRUCTURAL STABILITY RESPONSE TO TILLAGE AND DEPTH TREATMENTS OF A SANDY ALFISOL IN SOUTHWESTERN NIGERIA

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Abstract
The stability of a soil is a function of its structure and this influences physical and chemical properties of the soil based on the level of disruption either by tillage or erosion. The effect of three tillage systems Zero Tillage (ZT), Disc Ploughing(DP) and Disc Harrowing(DH) on the stability of soil aggregates at depths 0-10 and 10-20 cm were studied on a sandy soil in Abeokuta. Parameters investigated were bulk density, particle size distribution,geometric mean diameter, mean weight diameter, coefficient of vulnerability and stability index.Bulk density ranged from 1.35 to1.58 gcm^{-3}. Porosity was highest on zero tilled plots with values of 48 and 49 % at 0-10 cm and 10-20 cm depth respectively. Gravimetric moisture content and porosity were influenced by tillage type and depth of sampling (P values 0.002 and 0.001 respectively) Disc harrow had the highest geometric mean diameter (1.25 mm) at the 0-10 cm depth. Values of stability index at 10-20 cm depth for zero tillage, disc plough and disc harrow were 0.52, 0.30 and 0.36 respectively. Highest coefficient of vulnerability was exhibited by disc plough plots with value of 1.24 while zero tillage had the lowest value of 0.83. Mean weight diameter (wet sieved), stability index and coefficient of vulnerability were not influenced by tillage type and depth of sampling. Results indicated that stability parameters were not affected by tillage and depth but disc ploughing exhibited the best stability index, making it a good tillage practice for the study area.

Keywords: Tillage practices, Depth, Stability index, Mean weight diameter, Geometric mean diameter, coefficient of vulnerability

Introduction
Tillage is a kind of soil management method that involves theagricultural preparation of the soil by mechanical agitation of various types, such as digging, stirring, and overturning. Hence, tillage operations usually disturb soil structurethereby affecting its aggregation. The degree of this disturbance influences the soil aggregate size and stability which will subsequently have effects on soil productive quality. Soil aggregates and their stability have a strong influence on physical properties such as infiltration, aeration, soil strength and erosion (Topp et al., 1996). In crop production, land for farming is prepared to give adequate support for the intended crop to be cultivated through tillage operations which are always targeted at having the best soil aggregation achieved. While tillage operation can improve the soil quality, it can also be a way of degrading soil structural quality. Therefore, there is the need to investigate the role of some tillage practices on the soil structural stability as a means of evaluating the impact of tillage systems on soil sustainability. Though, studies have evaluated and compared the effects of

tillage operations on soil aggregate stability but as reported by Mbagwu, 2003, the factors that influence aggregate stability of soils depend on the soil environment, the type and dominance of the stabilizing substances and land use. Physical disintegration as a result of tillage practices can ultimately lead to the decrease in aggregate stability thereby affecting crop production and soil structural framework Six et al., (2000)The objective of this work is to evaluate structural response of different tillage operations with respect to depth on a sandy soil and investigate the best tillage practice that will give optimum aggregate stability.

Materials and Methods

Experimental Site Description: The site for this project was situated in Federal University of Agriculture Abeokuta (Latitude 7^{o} 14' North and Longitude 3^{o} 25' East), Alabata, Abeokuta, Ogun State, Nigeria.

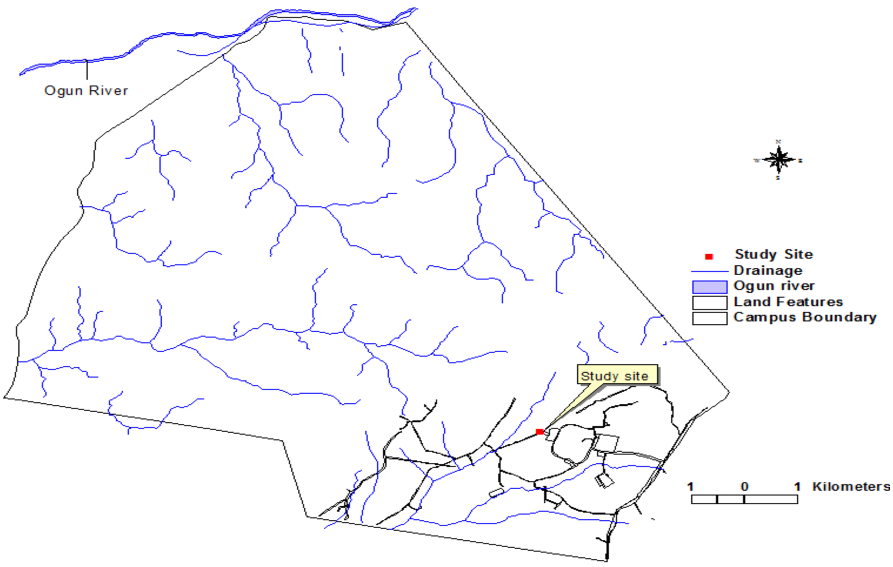

Plate 1: Location of study site

The annual average rainfall is 1200mm. The common cropping practices in this area are disc ploughing, disc harrowing, ridging and zero tillage. Visual observation of the location shows prevalence of gravel on the top surfaces of the land. The site has a gentle slope of about 3%. The land was initially established by manually clearing the land using the simple cutlass. Clearing was done to remove shrubs and other small trees that may hinder the introduction of the tractor for the tillage operations. The land was demarcated into nine (9) plots and the intended tillage operation (treatment) was carried out on each. The tillage operations were distributed on the plots using a Randomized Complete Block Design (RCBD) which involved three replicates of three tillage operations.

Each plot has a dimension of 10m by 8m, with 3m alley between plots and from the boundary which acted as a buffer (Figure 1). The buffer allows for tractor passage and turning during the tillage operations. For the disc ploughed plots, a three disc plough coupled to the tractor was used for the operation while plots involving disc harrowing involved the use of the disc harrow with 20 discs (Figure 2).

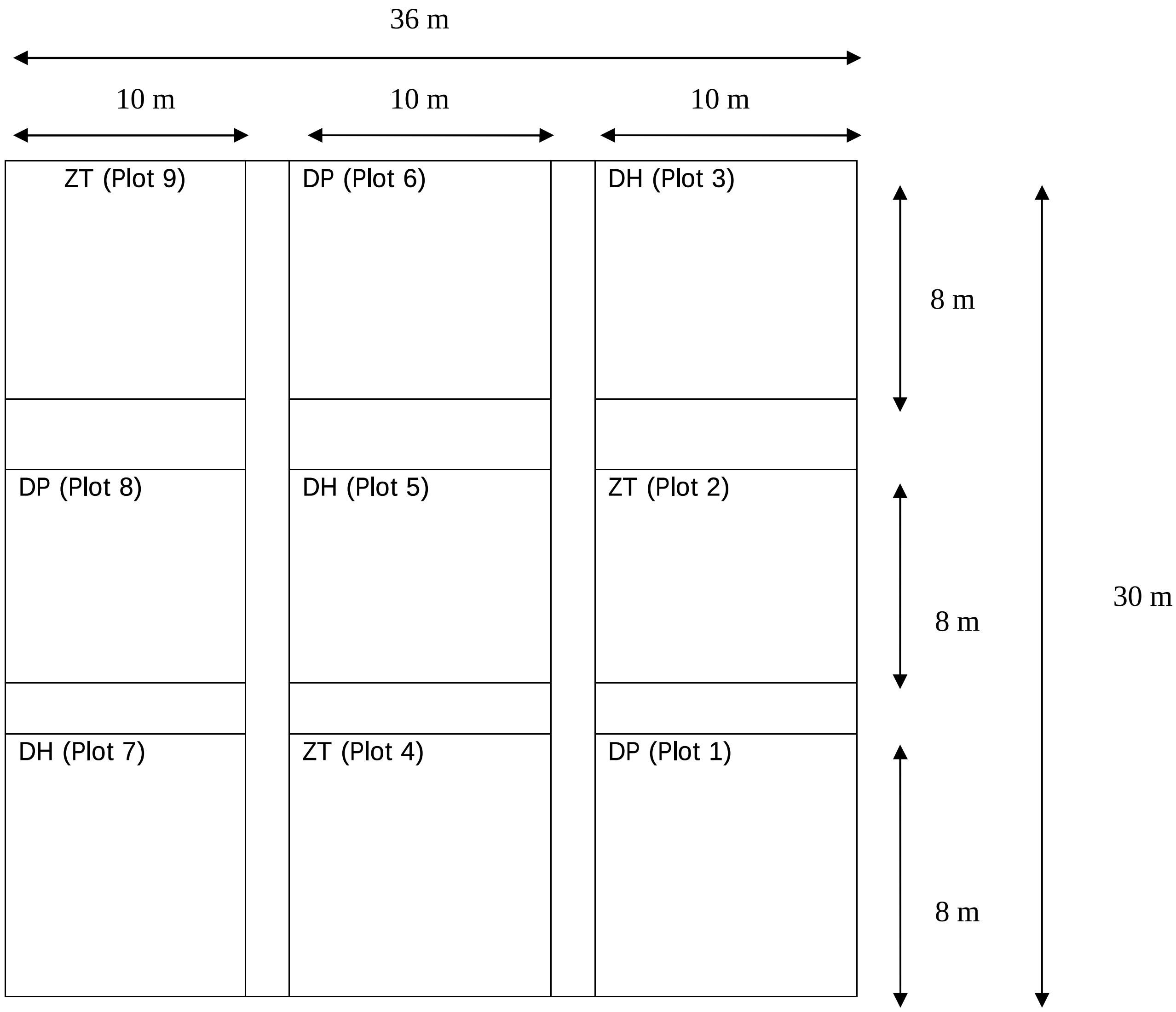

Figure 1: Plot layout in metres

Key: ZT- Zero Tillage

DP- Disc Ploughing

DH- Disc harrowing

Figure 2: Tillage operations in progress

Soil Sampling

Soil samples (Undisturbed) were collected at two depths (0–10cm and 10–20cm) using a core sampler of dimension 8cm height and 6cm diameter. Sample collection for wet sieving analysis in determining aggregate stability were done using spade. This was used to gently and carefully cut and lift the soil samples into containers while ensuring minimum soil disturbance.The following selected soil physical properties were investigated; bulk density, particle size analysis, aggregate stability, mean weight diameter, geometry mean diameter, stability index, and vulnerability index. Soil samples were presieved using 8 mm sieve and soil retained on the 8 mm sieve were separated by wet sieving. Soil samples were separated based on five classes i.e. 0.25-0.5, 0.5-1.0, 1.0-2.38, 2.38-5.66 and 5.66-7.93 mm. Soil samples retained on each sieve was removed and over dried at 105^{o}C for 24 h.

Investigated parameters

Bulk Density: Bulk density samples were taken from each plot at depths of 0-10 and 10-20 cm using cylindrical cores (Blake and Hartge, 1986) 7 cm diameter x 10 cm height. Each of the samples were transferred into a moisture can, weighed and oven dried at 105^{o}C to constant weight. Thereafter the samples were reweighed to determine the mass of dry soil. This was determined to access the degree of compaction as a result of the tillage practices carried out. Mathematically, bulk density can be calculated using:

$$Bd = \frac{Wdry}{Vol} \quad (1)$$

Where:

Bd = dry bulk density (g cm^{-3})

Wdry = weight of the dried soil sample (g)

Vol = total volume of the soil core sampler (cm^{3}) = $\pi r^2 h$.

Where r is radius of soil core and h is the height (cm)

Particle Size Distribution: Particle Size Distribution was determined by Hydrometer method of Gee and Or (2002), to determine the textural class of the soil in study area.

Aggregate Stability Index (SI): This is an indication of soil resistance to disintegration by water erosion and rain drop impact. It was estimated from the result of water stable aggregates (Nichols and Toro, 2011) thus:

$$SI = \frac{\left[\sum_{i=1}^{n} (I) \times (Pai) \times ((WSAi) \times 100)\right]}{n} \quad (3)$$

Where

SI = stability index;

n = the number of the aggregate size classes;

I = *n* and decreases by an increment of 1 from the largest to the smallest aggregate sizes class;

Pa*i* = proportion of aggregate weight for each size class *i*;

WSAi = water stable aggregates for each size class *i*.

Geometric Mean Diameter, GMD

This was determined from the relation: Kemper and Rosenau (1986):

$$GMD = Exp\left[\sum_{i=1}^{n} (Ri \ln Di)\right] \quad (4)$$

Where

i = the aggregate classes

n = the total size classes.

Ri = the ratio of aggregate mass from class *i* related to the total

Di = the mean diameter for class *i*.

Mean Weight Diameter, MWD

This was calculated using the equation below from the relation:Kemper and Rosenau (1986)

$$MWD = \sum_{i=1}^{n} (RiDi) \quad (5)$$

Where

i = the aggregate classes

n = the total size classes.

Ri = the ratio of aggregate mass from class *i* related to the total

Di = the mean diameter for class *i* (mm)

Coefficient of Vulnerability:

Coefficient of vulnerability gives an indication of how many times the size of aggregates decreased due to breakdown mechanism (Valla et al. 2000). It was calculated as follows

$$Kv = \frac{x}{MWD} \quad (6)$$

where:

Kv is the coefficient of vulnerability,

x is the mean weight diameter of aggregates before the disintegration

MWD is the mean weight diameter of aggregates after their disintegration (mm).

Analysis of Experimental Result

Experimental results were processed statistically by two-way analysis of variance. The LSD procedure was performed to compare means of investigated parameters.Statistical Analysis was carried out with MINITAB 16.0 statistical package.

Results and Discussion

Mean values of soil physical properties at depths of 0-10 and 10-20 cm with respect to the tillage methods showed that the soil was generally sandy in nature with sand content as high as 86% (Table 1). Bulk density ranged from 1.35 g cm^{-3} to 1.58 g cm^{-3}. Highest bulk density was found on disc ploughed plots while zero tillage had the lowest bulk density and in all the tillage treatments, bulk density reduced with soil depth despite the fact that sand content reduced with depth. This can be attributed to the clay content increasing within the soil profile depth signifying the role of clay particles in increasing bulk density. Generally the high bulk density observed in all the tillage methods adopted can be attributed to the sand content. Gravimetric moisture content ranged from 4.07 to 9.74% with disc ploughed plots having the highest moisture content of 9.54 and 9.74%. Results revealed that tillage type had significant effect on gravimetric moisture content (P value: 0.002) but the effect of depth was not significant. Similar effect was observed with respect to void ratio where the effect of tillage method was significant but void ratio was not influenced by depth. In all the tillage treatments, zero tillage exhibited the highest void ratio of about 0.98 which is expected due to the sandy nature and low bulk density. In terms of porosity, both tillage and depth had significant effect. Percentage Carbon increased with depth in all the tillage methods with disc plough and disc harrow having the highest level at the 10-20 cm depth but there tillage did not show any significant effect of percentage carbon.

Geometric mean diameter (GMD) was high at both depths on disc harrowed plots with values as high as 1.25 mm but both the tillage method and depth of sampling did not have any significant effect on the geometric mean diameter (Table 2). This could be as a result of the sandy nature of the soil. The mean weight diameter of aggregates during wet sieving showed that at depth of 0-10 cm, values ranged from 1.25 to 1.42 mm while at depth of 10 to 20 cm, values ranged from1.08 to 1.68 mm. Highest mean weight diameter was at the 20 cm depth under zero tillage though tillage method and depth did not have any significant effect on the mean weight diameter. Stability index which revealed the stability of aggregates was higher at the 10-20 cm depth compared to the 0-10 cm depth though tillage and depth had no significant effect on it(P values of 0.366 and 0.469 respectively). Highest value of stability index was observed on zero tillage plots at the 10-20 cm depth. Disc harrowed plots at both depth had the highest geometric mean diameter revealing the effect of the tillage equipment on the soil and the level of pulverization attained. The coefficient of vulnerability showed that disc ploughed plots exhibited high rate of vulnerability than zero tillage and disc harrowed plots which means that the higher the coefficient of vulnerability, the lower the stability. Disc ploughed plots were less stable than disc harrowed and zero tillage plots. At the 0-10 cm depth, zero tillage exhibited better stability than other conventional tillage methods but at the 10-20 cm depth, disc ploughed plots had the highest coefficient of vulnerability (Kv) revealing its low stability though disc harrowed plots showed better stability at the 10-20 cm depth compared to the 0-10 cm depth.

Table 1: Mean values of soil physical properties at different depths in relation to tillage practices

Tillage Method	Depth (cm)	Particle size Distribution			Bulk density g/cm3	Gravimetric Moisture Content (%)	Void Ratio	Percent Carbon	Porosity (%)
		Sand %	Clay%	Silt%					
Zero Tillage	0-10	86.03	11.06	2.8	1.38	4.07	0.97	1.20	48.00
	10- 20	86.40	11.07	2.47	1.35	4.28	0.98	1.60	49.33
Disc Plough	0-10	86.13	10.83	3.03	1.58	9.54	0.76	1.40	43.00
	10- 20	86.33	10.93	2.70	1.47	9.74	0.82	2.90	44.67
Disc Harrow	0-10	86.03	10.93	0.8	1.51	8.15	0.76	1.20	43.33
	10- 20	85.63	12.06	2.2	1.46	7.96	0.84	2.90	45.00
LSD P<0.05									
Tillage		0.443	0.493	0.318	0.059	0.002	0.029	0.425	0.001
Depth		0.831	0.369	0.710	0.119	0.634	0.138	0.097	0.005

Table 2: Mean values of aggregate stability indicators in relation to tillage and depth

Tillage Treatment	Depth (cm)	GMD (mm)	MWDa (mm)	MWDw (mm)	Stability Index	Coeff of vulnerability (Kv)
Zero Tillage	0-10	0.93	1.08	1.32	0.353	0.83
Disc Plough		1.12	1.46	1.25	0.310	1.17
Disc Harrow		1.25	1.58	1.42	0.363	1.11
Zero Tillage	10-20	1.02	1.70	1.68	0.520	1.00
Disc Plough		0.99	1.33	1.08	0.300	1.24
Disc Harrow		1.04	1.24	1.41	0.360	0.88
LSD P<0.05						
Tillage		0.455	0.998	0.379	0.366	0.326
Depth		0.451	0.880	0.739	0.469	0.980

Key: GMD = Geometric Mean Diameter, MWDa = Mean Weight Diameter (Air-dried), MWDw = Mean Weight Diameter (Wet-sieved), Coefficient of vulnerability = Kv

Conclusions

Soil physical properties including gravimetric moisture content were not influenced by any of the tillage methods adopted. The aggregates were more stable at the 10 – 20 cm depth on conservation tillage system (zero tillage) than on the conventional tillage system further establishing the fact that aggregate stability is greater in no-till than under conventional tillage system.The results obtained revealed that the tillage method did not have any significant effect on most aggregate stability indices but the effect of moisture content, void ratio and porosity were significant strongly corroborating the fact that water and presence of pores play a major role in soil structural stability. Disc ploughing displayed better stability than other tillage treatments and is therefore recommended as the best tillage method for sandy soils.

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