EFFECT OF TILLAGE DEPTH ON SOME SOIL PHYSICAL PROPERTIES IN GIDAN KWANO

Aliyu, M[1]., Mohammed, I. S[1]., Agyoh, T. T[1]. and Abdullahi, L[2]

[1]*Department of Agricultural & Bio-resources Enginnering, Federal University of Technology Minna, Niger State, Nigeria.*
[2]*National Cereals Research Institute Badeggi*
E-mail: aliyu.mohd@futminna.edu.ng

ABSTRACT

Soil tillage management influences soil, as a result of altering physical, chemical and biological properties statement not clear. This study was conducted to evaluate the effect of tillage depth on some soil physical properties in Gidan Kwano of the Federal University of Technology, Minna using the school farm. Twelve (12) soil samples were analyzed to check the effect on the physical properties at varied tillage depths; 0-10 cm, 10-20 cm and 20-30 cm. These physical properties include soil moisture content, bulk density, porosity, soil volume disturbed, soil temperature and soil particle distribution. The soil particle size analysis reveals that the soil textural class majorly falls on loamy sand with 80.8-85.1 % sand, 5.56-10.85 % silt and 7.40-12.9 % clay. Results showed significant ($p<0.05$) difference in soil physical properties due to the imposed variation in tillage depth. Soil temperature was only significant at tillage depth of 0-10cm, while no significant difference was observed for No-Tillage (NT) and tillage depth range from 10 to 30 cm. It was observed that bulk density increased with corresponding depth, tillage depth 20-30 cm recorded the highest value for bulk density. Also moisture content showed significant difference as the highest moisture content value was recorded at 20-30 cm tillage depth. It was discovered that soil volume disturbed increased with tillage depth. Soil porosity was observed to show little significant difference ($p\leq0.05$) against variation in tillage depth.

KEYWORDS: *Tillage depth, soil physical properties, moisture content, soil, no tillage.*

INTRODUCTION

Tillage is the manipulation of the soil in order to provide conditions necessary for crop growth. In general, the objectives of tillage include; providing a good soil tilt which will be suitable for the operation of subsequent machinery and growth of the crop, to prepare land for irrigation and drainage operation and also to mix fertilizers, crop residue and other soil amendments into the soil (Onwualu *et al*., 2006).

Tillage is used to manipulate the soil to create conducive environment (soil loosening) for crop growth. In the process, the soil physical properties can be impacted either positively or negatively depending on the management technique. Soil tillage may be defined as the mechanical manipulation of the soil aimed at improving soil conditions for crop production. It represents the most costly single item in the budget of a farmer. Tillage provides good weed control with low herbicide cost; allows the control of disease and insect pests by destroying them through burying of crop residue. Three things are involved in soil tillage which includes: the power source, the soil and the implements (Olatunji, 2007). Tillage implements or tools vary in terms of both width and depth of ploughing and in terms of the intensity in soil overturn administered by the implement (plough, harrow, etc.). Furthermore, interactions between natural factors (e.g., soil-type, geology, topography, and climate and weather patterns) and crop selection in part, determine the intensity, depth, frequency, and timing of tillage, which highlights the need for a mechanistic understanding of tillage effects on soil physical properties. Even incidental effects of tillage, such as wheel traffic, can lead to complicated and stochastic soil response. Some soil physical properties especially the hydraulic properties significantly vary even in a short time period, such as during crop cycle, especially immediately after tillage. Similarly, other researchers (Strudley *et al*., 2008; Alletto and Coquet, 2009) related the dynamics of temporal and spatial variability in soil physical properties and processes to tillage management practices. Tillage is used to manipulate the soil to create a conductive environment (soil loosening) for crop growth. In the process, the soil physical properties can be impacted either positively or negatively depending on the management technique.

However, tillage may have negative impacts on soil and crop production, when excessive or inappropriate. Among the disadvantages are land degradation, compaction of soil below the depth of tillage, increased susceptibility to water and wind erosion, accelerated decomposition of soil organic matter, high energy cost of tillage operations, and labour and temporal obligations (Mitchel *et al.*, 2007). The impact of tillage depends on the combination of tillage operations and their timing which is the tillage system, to provide specific functions in given situations. The ways in which these operations are implemented affect the physical and chemical properties of the soil, which in turn affect plant growth and crop yield potential. Therefore, the first step in making sustainable production management decisions is to understand the practices associated with each tillage system (Aina, 2011). Soil bulk density, penetration resistance (PR), and water movement in the soil, all indices of soil compactness and porosity, depend on depth and method of tillage (Hamza and Anderson 2002, 2003, 2005). Therefore, assessing the effect of tillage depth and method on these soil physical properties may explain variability in crop growth, crop development, yield, and quality (Hamza and Anderson, 2002, 2003, 2005). Generally speaking, all tillage methods reduced soil bulk density and penetration resistance to the depth of tillage (Erbach *et al.*, 1992). It is needful to state that soil tillage is among the important factors affecting soil physical properties. Tillage method affects the sustainable use of soil resources through its influence on soil properties (Schwartz *et al.*, 2010). The proper use of tillage can improve soil related constrains, while improper tillage may cause a range of undesirable processes, e.g. destruction of soil structure, accelerated erosion, depletion of organic matter and fertility, and disruption in cycles of water, organic carbon and plant nutrient (Aina, 2011). Use of excessive and unnecessary tillage operations is often harmful to soil. Therefore, currently there is a significance interest and emphasis on the shift to the conservation and no-tillage methods for the purpose of controlling erosion process (Iqbal *et al.*, 2005).

It therefore becomes needful to test the commonly practiced tillage depths in Nigeria by plough implement in order to ascertain the efficacy of each in relation to what is desirable.

The Objectives of this study are;

- To carryout ploughing operation at different tillage depth.
- To determine the soil physical properties after ploughing operation.

MATERIALS AND METHODS

Site Description

The study was carried out at the Federal University of Technology, Gidan Kwano Campus, Minna (latitude 9° 41 ' N and longitude 6° 31 ' E; 258.5 m above sea level), in the southern Guinea savanna zone of Nigeria. Climate of Minna is sub humid with mean annual rainfall of about 1284 mm and a distinct dry season of about 5 months duration occurring from November to March. The mean maximum temperature remains high throughout the year, about 33.5 oC particularly in March and June (Ojanuga, 2006). The town has a mean annual precipitation of 1300mm taken from an exceptionally long record of 50 years. The highest mean monthly temperature is in September with almost 300mm. the raining season starts on average between the 11th and 20th April, and last between 190 and 200 days. Temperature rarely falls below 22 °c .The peaks are 40°c (February-March) and (November-December). The experiment was conducted during the first peak of rainy season.

Equipment Description

A 70 hp (50.2 kW) 275 Massey Ferguson tractor was used to pull the implement during the field operations. Standard disk plough (SDP) was used for the experiment, the plough consist of three (3) plane concave discs with a spacing of 680 mm.

Experimental Design

The single-factor experiment was laid out in a randomized complete block design (RCBD) with three (3) treatments and three (3) replicates and a control experiment in each block. Three blocks were used with area coverage of 150 m² per block. Three tillage depths were compared. The description of the tillage treatment in RCBD is presented in Table 3.1. The size of each block was 15.0m long and 10.0m wide, also each block was composed of four (4) plots with 1m spacing so that each plot in a block . A buffer zone of 1.0m spacing was provided between blocks. The field experiment was done on the 8th June, 2016.

Measurements

Four (4) soil samples were taken from each block with the aid of locally made Soil Auger commonly used for obtaining soil samples near the surface and for boring depths where samples may be obtained. Total of twelve (12) soil samples were taken on the 8th June, 2016 after the field operation was conducted. The distance apart from one sampling point to another was approximately 3 m at each location.

Soil Moisture Content

For each sampling occasion, total of twelve (12) soil samples were taken randomly four (4) samples from each block at 10 cm depth increment to 30 cm as designated. A no-tillage plot was reserved in each block. Soil samples were weighed, oven-dried at 105°c for 24 hours, and weighed again to determine the gravimetric moisture content.

Bulk Density

Soil samples from three replicates for each plots randomly collected, at 10cm depth increment to 30cm were taken to the laboratory to determine the soil bulk density. Soil samples were oven dried at 105ºc for 24 hours. Soil bulk density was calculated by using the following equation:

$$BD = \frac{W}{V} \qquad (1)$$

Where, BD = bulk density, (g/cm^3); W = weight of dried soil sample, (g); V= total volume of the soil sample, (cm^3), (Osman *et al.*, 2011).

Soil Porosity

Soil porosity was obtained from the relationship between bulk density and particle density. Usually, particle density is expressed in units of grams per cubic centimeter (g/cm^3). An average value of 2.65 g/cm^3 is assumed for soil sample (Ahaneku and Dada, 2013).

$$\text{Soil Porosity} = \left(1 - \frac{\text{Bulk density}}{\text{Paticle density}}\right) \qquad (2)$$

Soil Volume Disturbed

The total soil volume disturbed was calculated in cubic meters per hour by multiplying the effective field capacity with the depth of cut as below. It was assumed that the implement disturbed the soil up to its recorded depth and no undisturbed patch of land was left (Osman *et al.*, 2011).

$$V = 10000CD \qquad (3)$$

Where, V= Soil Volume disturbed, m^3/h; C= Field capacity, ha/h; D= Depth of cut, m.

Soil Temperature

Soil temperature is simply the measurement of the warmth in the soil. Soil temperature samples were measured with the use of soil thermometer by putting the silver sensor of the thermometer 2-2.5cm into each soil sample.

Analysis of Soil Particle Distribution (using hydrometer method)

Fifty (50) grams of soil sample was weighed of 2mm sieve; 100ml of distilled water was added to the sample in a bottle of and 5% sodium hexametaphosphate solution (Calgon $(NaPO3)6$, which served as dispensing agent. The mixer was placed in a shaker and shacked content was transferred quantitatively without losing any particle into the sedimentation cylinder, up to the liter marked with distilled water. The soil suspension was stirred with glass rod for 2mins. The hydrometer was inserted and reading taken at 40 seconds, also the temperature was measured by use of thermometer. Sample was placed on a surface undisturbed for 2 hours at which the hydrometer and thermometer were inserted respectively to take readings.

The 40 seconds reading was taken to measure the percentage of silt and clay in suspension. A blank sample was prepared without soil and the readings were also obtained. For every 1 °c above 20 °c, 0.36 was added to the hydrometer reading and for every 1°c below 20 °c, 0.36 was subtracted from the hydrometer reading (Anderson and Ingram, 1993)

$$\% Silt + clay = \frac{(S_1 - B_1) + ((ST_1 - 20^oc) \times 0.36)}{50} \times \frac{100}{1} \quad (4)$$

$$\% Clay = \frac{(S_1 - B_2) + ((ST_2 - 20°c) \times 0.36)}{50} \times \frac{100}{1} \quad (5)$$

$$\% Sand = 100 - \% silt + Clay \quad (6)$$

$$\% Silt = \% Silt + Clay - \% Clay \quad (7)$$

Where,
S_1= Sample Hydrometer reading at 40 sec; ST_1= Sample Thermometer reading at 40 sec;
S_2= Sample Hydrometer reading at 2 hrs; ST_2= Sample Thermometer reading at 2 hrs;
B_1= Blank Hydrometer reading at 40 sec; BT_1= Blank Thermometer reading at 40 sec;
B_2= Blank Hydrometer reading at 2 hrs; BT_2= Blank Thermometer reading at 2 hrs.

Tillage Depth

Tillage depth was achieved by releasing the hydraulic lever at various level to allow the disc plough penetrate the soil. Immediately following the tillage operations, tillage depth was measured on each plot to suit the stated depth. A steel rule was inserted into the tilled soil until a characteristic hard pan was encountered. The tillage depth was measured from the corresponding reading on the steel rule.

Data Analysis

Analysis of variance (ANOVA) in statistical package for social sciences (SPSS) version 20 was used to evaluate the significance of each treatment on all parameter under this study in a randomized complete block design with three replications. Mean between treatments were compared with Duncan's multiple range test. The statistical inference was made at 0.05 (5 %) level of significance.

RESULTS AND DISCUSSION

Effect of Tillage Depth on Soil Temperature

Soil temperature was significantly ($p<0.05$) affected by the tillage depth as shown in Table 3.1. Tillage depth at 0-10cm yielded higher value of soil temperature for the period of the study when compared with other tillage depth as the range of soil temperature (30.8-31.0°c). At NT there was no significant difference in soil temperature as observed from Table 1. This may be attributed to short term of the period during which tillage operation was established in this study. There was no general trend in soil temperature difference with respect to tillage depth, as fluctuation in temperature value was noticed. This fact is supported by the study of Nofziger (2005) that soil temperature fluctuates annually and daily affected mainly by variations in air temperature and solar radiation. The annual variation of daily average soil temperature can be estimated using a sinusoidal function. (Hillel, 1982; Marshall and Holmes, 1988; Wu and Nofziger, 1999). Factors also likely to affect the surface soil temperature are radiation from the sun, slope of the land, water content, vegetation cover and albedo. Other factors that may be responsible for uniform subsurface soil temperature are heat flux from surface, moisture content, bulk density and heat capacity of soil.

Table 1 Average Temperature at Different Tillage Depth

	Soil Temperature (°c)		
Tillage depth (cm)	Block 1	Block 2	Block 3
0-10	$30.80^a \pm 0.100$	$31.00^a \pm 0.100$	$30.9^b \pm 0.000$
10-20	$28.50^{ab} \pm 0.200$	$28.30^a \pm 0.000$	$28.20^a \pm 0.100$
20-30	$27.60^a \pm 0.200$	$27.80^a \pm 0.000$	$28.00^b \pm 0.800$
NT	$28.40^a \pm 0.100$	$28.30^a \pm 0.000$	$28.20^a \pm 0.100$

NT-No Tillage. Values are means of three replicates in all Treatment. Results presented are mean values of each determination ± standard error mean (SEM). Values on the same row for each parameter with different superscript are significantly different (P≤ 0.05) while those with the same superscript are not significantly different (P≥ 0.05).

Effect of Tillage Depth on Soil Bulk Density

Bulk density was significantly (p<0.05) affected by tillage depth as shown in Table 2. Bulk density reflects the soil condition disturbed. Table 4.2 shows slight increase in mean values of bulk density of the soils along rows of different tillage depth under consideration. This is consistent with similar studies (Osman *et al.*, 2011; Doa, 1996). All the recorded bulk density values were between 0.910 to 1.123 g/cm³, which is the range described by Chi *et al.* (1993) for usual agricultural soils. Highest bulk density was noticed at tillage depth (20-30 cm), and that is probably referred to the variation in the structural conditions of the soil as described by Chen *et al.* (1998). It was also noticed from the Table 4.2 that closely followed with higher value of bulk density was no till. Some studies have found that bulk density increased under no-till in relation to conventional tillage (Disc plough) as reported (Terbrugge and During, 1999) or reduced tillage (Mc Vay *et al.*, 2006). Bulk density may generally increase with depth but did not follow any consistent trend with time among tillage depth (Table 2). Tillage depth may be responsible for the significant difference on soil bulk density at depth 0-10 cm, 10-20cm and 20-30 cm (Table 3.2).

Table 2 Average Bulk Density at Different Tillage Depth

Tillage Depth (cm)	Bulk Density (g/cm³)		
	Block 1	Block 2	Block 3
0-10	$0.953^{a}\pm0.029$	$1.049^{b}\pm0.067$	$0.944^{a}\pm0.042$
10-20	$0.910^{a}\pm0.073$	$0.916^{a}\pm0.084$	$1.123^{b}\pm0.140$
20-30	$1.034^{a}\pm0.0277$	$0.953^{b}\pm0.980$	$1.032^{a}\pm0.0257$
NT	$0.988^{a}\pm0.021$	$0.994^{a}\pm0.973$	$1.045^{b}\pm0.036$

NT- No Tillage. Values are means of three replicates in all Treatment. Results presented are mean values of each determination ± standard error mean (SEM). Values on the same row for each parameter with different superscript are significantly different (P≤ 0.05) while those with the same superscript are not significantly different (P≥ 0.05).

Effect of Tillage Depth on Soil Moisture Content

Different tillage depth significantly affected soil moisture content during the study. The highest soil moisture content (15.68 %) was obtained for tillage depth 20-30cm and the lowest (9.02%) for NT as shown in Table 3.3. Result show that NT obtained the lowest soil moisture content compared to other tillage depth. The low value of moisture content associated with NT is due to the decreased pore space, increased shear strength and stable aggregates (Mitchell *et al.*, 2007) associated with conservation tillage (NT). Another reason attributed to low moisture content with NT soil is the level of compaction known with conserved soils (Garnet *et al.*, 1984; Ried, 1978; Cambell *et al.*, 1974; Raper *et al.*, 1994). The general trend of variation amongst the tillage depths with regards to moisture content shows 20-30cm>0-10cm>10-20cm>NT respectively.

Effect of Tillage Depth on Soil Porosity

Soil porosity and organic matter content play a critical role in the biological productivity and hydrology of agricultural soils. The effect of different tillage depths on soil porosity is presented in Table 3.4. However, the significant is quite slim if not non-significant. Soil porosity across tillage depth are closely related as Pagliai and Vignozzi (2002) state that soil porosity characteristics are closely related to soil physical behavior, root penetration and water movement. The Table 3 also shows a thin line difference across tillage depth. Highest soil porosity was recorded at 0-10cm tillage depth for the period of the study as compared to other tillage depth; this is consistent with the report of Ahaneku and Dada (2013). This may be attributed to less pulverization of the soil provided by later tillage depths. Porosity can be said to decrease with increase in soil depth due to the natural increase in packing density with depth. Overall, in both 0-10cm and 10-20cm tillage depth produced the highest total porosity, while the NT treatment gave the lowest porosity, this result is in agreement with that recorded by Aikins and Afuakwa (2012) which state that overall, in both the 0-10 cm and 10-20 cm soil layers, the disc ploughing followed by disc harrowing treatment produced the highest total porosity while the No Tillage treatment gave lowest total porosity.

Table 3: Average Moisture Content at different Tillage Depth

Tillage Depth (cm)	Moisture Content (%)		
	Block 1	Block 2	Block 3
0-10	9.96^{a}±1.423	11.66^{b}±0.277	12.53^{c}±1.147
10-20	11.52^{b}±0.213	10.53^{a}±0.776	11.87^{c}±0.563
20-30	12.07^{b}±0.320	15.68^{c}±3.29	9.42^{a}±2.97
NT	9.02^{a}±0.820	10.03^{b}±0.46	10.47^{c}±0.630

NT- No Tillage. Values are means of three replicates in all Treatment. Results presented are mean values of each determination ± standard error mean (SEM). Values on the same row for each parameter with different superscript are significantly different ($P< 0.05$) while those with the same superscript are not significantly different ($P> 0.05$).

Table 4: Average Porosity at Different Tillage Depth

Tillage Depth (cm)	Soil Porosity		
	Block 1	Block 2	Block 3
0-10	0.640^{b}±0.011	0.604^{ab}±0.015	0.644^{c}±0.0147
10-20	0.657^{b}±0.028	0.654^{b}±0.089	0.576^{a}±0.053
20-30	0.606^{a}±0.013	0.640^{b}±0.021	0.611^{a}±0.008
NT	0.627^{a}±0.007	0.625^{a}±0.006	0.606^{b}±0.013

NT- No Tillage. Values are means of three replicates in all Treatment. Results presented are mean values of each determination ± standard error mean (SEM). Values on the same row for each parameter with different superscript are significantly different ($P\leq 0.05$) while those with the same superscript are not significantly different ($P\geq 0.05$).

Effect of Tillage Depth on Particle Size Distribution

The result Loamy sand was the dominant textural class across various tillage depth (0-10, 10-20, and 20-30 cm); sand ranges from 80.80-85.10 %, silt ranges from 5.56-10.85 % while clay ranges from 7.40-12.90 %. These results are similar to the Loamy sand textural class having 82.63% sand, 9.14 % silt and 8.23 % clay as reported by Sadik (2014). The result also show that tillage depth 0-10cm and NT have similar textural class (sand loamy); with ranges of sand 74.80-77.58 %, Silt 10.19-12.14 % and clay 12.80-12.23 % respectively, which are similar in comparison with those reported by Afolabi *et al.* (2014) (76.50 % of sand, 10.20 % of silt and 13.30 % of clay). This also correspond to the study of Odoh and Adebayo (2011) having 71.77% of sand, 12.27% 0f silt and 15.97 % of clay.

Effect of Tillage Depth on Soil Volume Disturbed

The soil volume disturbed was influenced by bulk density and soil water content at tillage (Cholaky *et al.*, 2010). Fig. 1 shows the result of the average soil volume disturbed at 0-10cm, 10-20cm and 20-30cm tillage depth respectively. The highest soil volume disturbed as seen in Fig. 1 was at 20-30 cm depth, while the lowest at 0-10cm tillage depth. Soil volume disturbed increases with increase in tillage depth, thus establishing a direct proportionality. There is a significant difference on soil volume disturbed with respect to tillage depth. This result is reverse to the study by Osman et al. (2011,) that recorded soil volume disturbed decreases with increase in tilt angle of the of the disk plough, thus an indirect proportionality.

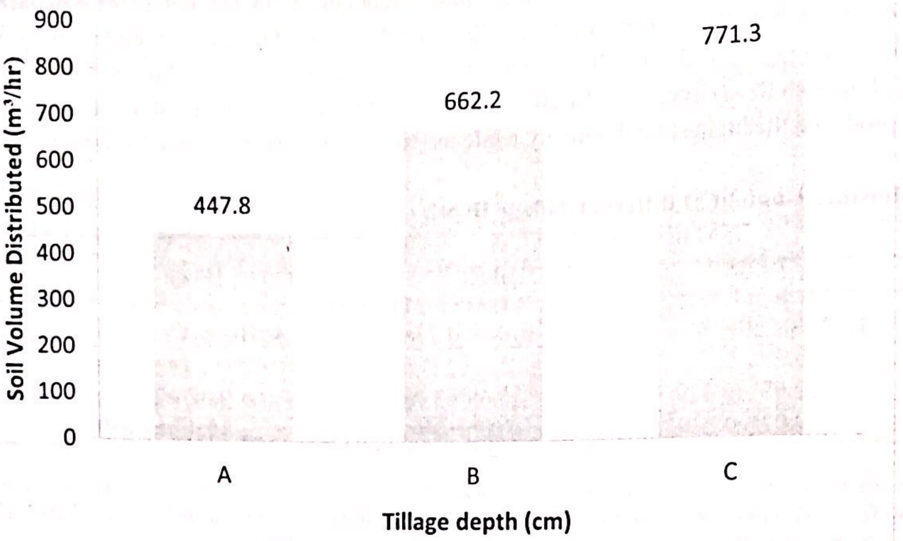

Fig. 3.1 Average Soil Volume Disturbed at Different Tillage Depth.

For Fig. 1

A- Tillage Depth at 0-10cm; B-Tillage Depth at 10-20cm; C-Tillage Depth at 20-30cm

4.0 CONCLUSION

Extracts from this study established a data base that can aid the predictions of the effect of conservation tillage depths on the soil physical properties. Results from the study indicate that:

- Soil temperature was only significant at tillage depth of 0-10 cm, while no significant difference was observed for NT and tillage depths 10-30 cm.
- Bulk density increases with tillage depth, highest bulk density was observed at the deepest tillage depth recorded (20-30cm).
- Decreased pore space account for low moisture content which was observed in NT. However, 20-30cm tillage depth exhibited highest moisture content. It therefore depicts that if high soil moisture content is required for crop cultivation, then deep tillage operation should be employed.
- Soil moisture content, particle size distribution and bulk density are more reliable indices for assessing soil tilth than soil temperature and soil porosity under different tillage depth.
- The study reveals that with increase in tillage depth during operation soil volume disturbed increased uniformly.

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