Effect of Tillage and Wood Ash on the Physical Parameters of an Ultisol

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Abstract: Physical properties are group of soil parameters that have profound influence on the different physical, chemical and biological processes that goes on in soil. Thus, a field research was undertaken to evaluate the effect of three tillage methods (mound, ridge, flat) and four rates of wood ash (0t/ha, 2t/ha, 4t/ha, 6t/ha) on the physical parameters of an ultisol in Abakaliki southeast, Nigeria. The findings from the study showed that rates of wood ash (WA) had no significant (P<0.05) effect on the parameters for second and third year cropping periods except for hydraulic conductivity (HC) results of second year planting period. Bulk density (BD) decreased as total porosity (TP) increased for the three years period under study and moisture content (MC) and HC decreased as the planting period increased. The tillage methods (TM) had significant (P<0.05) effects on the physical parameters although the result of MC, HC showed non-significant in second and third year planting periods. The recorded values indicated that the soil physical parameters varied among the tillage methods, mound method show less value in BD, HC and an increased value in TP. The interaction effect of tillage methods and rates of wood ash on the tested parameters were significant (P<0.05) except for BD in first year, MC, HC in second year and MC in third year planting period. The values obtained for the parameters decreased as the year of planting period increased. Tillage methods and wood ash interaction at the rates of 4t/ha and 6t/ha were relatively alike in values obtained. The physical properties of the soil should be kept optimal as they influence many processes in soil.

Keywords: Tillage, Wood ash, Soil physical properties.

Introduction

Proper land management is a major influence in agricultural sustainability, because sustainable crop production in tropical soils like Nigeria requires efficient and effective soil management practices in order to ensure crop yield in a rain fed agriculture. Tillage and wood ash are soil management practices that have been found to influence crop production activities in various forms. Management practices such as continuous tillage and removal or burning residues in situ have been observed to increase bulk density while such practices as addition of organic amendment decreased soil bulk density. The non-judicious tillage operations by the farmers can also result in various soil problems. Changes in soil physical properties due to tillage and in particular no-tillage was found to depend on several factors that include differences in soil properties, weather conditions, history of soil management, intensity and tillage methods [1]. The work of Osunbitan et al., [2] examined the tillage effects on bulk density, hydraulic conductivity and strength of a loam sand soil. They found out that the bulk density and penetration resistance of surface soil decreased with increase in the intensity of soil loosening by tillage operation.

The following authors; Chartterjere and Lal [3], Chivenge et al., [4] and Lal [5] reiterated that soil tillage is an important agricultural activity because of its impact on soil properties. However, the work of Struddley et al., [6] showed that the impact of different tillage methods on soil physical properties,
showed no constant trend. Soil tillage is one of the very important factors that affect soil physical properties and yield [7]. Although the effect of no tillage have been found to improve the soil physical characteristics [6,8] Temesgen, [9], emphasised that only appropriate and improved tillage system could improve the soil hydraulic characteristic of crustung tropical soils. While Lal [5] and Aboudare et al., [10] observed that tillage impacts are generally more pronounced in marginal soil and harsh environment than in inherently fertile soils of high resilience, cool favourable macro and micro-climates. Other research findings by Adamu and Ezeaku [11] showed that no-tillage performed less creditably in both the forest and savannah zones of Nigeria. Nigerian farmers mostly subsistent ones of which are of higher population use traditional tillage impacts called hoe.

The tool could have potentials of creating different impacts on soil physical parameters over time. Generally, a good tillage system should provide good soil tilt, improved soil water infiltration and retention, minimum soil erosion, encourage activities of soil organisms, recycle soil organic matter, etc. The effectiveness, however, depends on the ecological zones, soil types, crop response to tillage methods and economic viability of the tillage methods [12,13]. Therefore, soil tillage methods have a significant effect on sustainable soil management and are still subject of investigation.

On the other, application of organic waste to the soil has been reported to influence soil properties. Mbah et al., [14] observed that land application of burnt, un-burnt and mixtures of rice mill waste improved soil physical properties and enhanced maize yield. While Nweke and Nsoanya [15] observed remarkable improvement in soil physical parameters following organic waste application. Shaver et al., [16] found out that as crop residue accumulation increased, soil bulk density decreased, thereby increasing soil porosity and the potential for water infiltration. Nnabude and Mbagwu [17,18] reported significant reduction in bulk density and increment in total porosity of soil amended with rice mill waste relative to control, as well as increase water transmission, root penetration, hence cumulative feeding area of the crops that translate to better yield. Improvement in soil moisture content, total porosity, temperature and reduction in soil bulk density due to incorporation of waste were also reported by Mbah and Mbagwu [19], Okonkwo et al., [20], Adeleye [21] and Nweke and Nsoanya [22]. The reduction in soil BD and increase in moisture content brought about by waste application causes a reduction in cohesion and soil strength. For successful intensive crop production, soils should be managed to reduce compaction as much as possible. The essence of the present study was to evaluate the effect of three tillage methods (mound, ridge, flat) and four rates of wood ash (0t/ha, 2t/ha, 4t/ha, 6t/ha) on the physical properties of an ultisol.

**Materials and Methods**

**Location of Experiment**

This study was carried out in three different cropping seasons at Teaching and Research Farm of Faculty of Agriculture and National Resources Management (FARM), Ebonyi State University, Abakaliki: The area of the study is located within latitude 06°19’ N and Longitude 08°06’ of the southeast in the derived savannah agro-ecological zone of Nigeria. The rainfall distribution is bimodal with wet season from April to July and peak in June and September to November. It has an average annual rainfall range of 1700 – 1800mm. The temperature of the area ranges from 27°C – 31°C. The relative humidity of the study area is between 60 – 80% and the soil is ultisol and classified as Typic Haplustult by FDALR (1985). The vegetation of the area is dominated by Andropogon gayamus, Panicum maximum, Pennisetum purpureum, shrubs and some other weed species.

**Land Preparation and Treatment Application**

A land area measuring 41m x 15m (0.0615ha) was mapped out and used for the study. The experimental site was cleared of the natural vegetation using cutlass and the debris removed. Tillage operation was done manually using hoe. The tillage treatments are mound (Md), Ridge (Rd) and Flat (Ft). Wood ash of different levels was spread uniformly on the soil surface and buried in
their respective plots immediately after cultivation. The details of treatments used are as follows:

1. Md0 - Mound without wood ash (Md0)
2. Rd0 - Ridge without wood ash (Rd0)
3. Ft0 - Flat without wood ash (Ft0)
4. Md + 2 t/ha of wood ash (Md2)
5. Md + 4 t/ha of wood ash (Md4)
6. Md + 6t/ha of wood ash (Md6)
7. Rd + 2t/ha of wood ash (Rd2)
8. Rd + 4t/ha of wood ash (Rd4)
9. Rd + 6t/ha of wood ash (Rd6)
10. Ft + 2t/ha of wood ash (Ft2)
11. Ft + 4t/ha of wood ash (Ft4)
12. Ft + 6t/ha of wood ash (Ft6)

Two castor seeds per hole were planted at a spacing of 0.9m between rows and 0.45m within rows at a depth of 8cm. There was basal application of NPK fertilizer to all plots two weeks after plant. The seedlings were thinned down to one plant per stand two weeks after germination. Weeding was done manually with hoe at 3-week intervals till harvest. Harvesting was done when the capsules containing the seed turn brown. The harvested spikes was dried in the sun 2-3 days and then threshed to release the seeds. The same procedure was repeated in the second and third year of the experiment but without application of wood ash in the third year to test the residual effect.

Experimental Design

The total land area used for the study was 41m x 15m (0.0615ha). The experiment was laid out as split plot in a randomized complete block design (RCBD), with 12 treatments replicated 3 times to give a total of 36 plots each measuring 3m x 4m (12m²). A plot was separated by 0.5m alley and each replicate was 1m apart. Four (4) rates of wood ash viz., control (0t/ha); wood ash (WA) at the rate of 2t/ha equivalent to 2.4kg/plot, WA at 4t/ha equivalent to 4.8kg/plot and WA at 6t/ha equivalent to 7.2kg/plot were used for the study. Each treatment was replicated 3 times along with the three tillage methods (Mound, Ridge and Flat) used for the study.

Soil Sample Collection

Auger soil samples were randomly taken from ten (10) observational points in the experimental area at the depth of 0 – 20cm prior to planting. Similarly undisturbed core soil samples (ten) were randomly taken prior to the experiment. The Auger soil samples were mixed thoroughly to form a composite soil sample and used for pre-planting soil analysis of which the result is shown in Table I. Also the wood ash treatment used was analyzed for determination of its nutrient values, quantity and chemical composition. The result is presented in Table 2. At the end of each cropping season that is after crop harvest, undisturbed core samples were collected from 36 observational points that is from each plot and used for the determination of the physical properties of the soil.

Laboratory Methods

Physical Properties

The following soil physical properties were determined.

**Bulk Density:** Core soil samples were collected from each plot at the end of each cropping season and used to determine the bulk density as described by Blake and Hartage [23].

**Total Porosity:** Total porosity is calculated using the formula:

\[ TP = 100 \left(1 - \frac{Db}{Dp}\right) \]  

Where TP = Total porosity
Db = Bulk density
Dp = Particle density

The determination was according to the method of Danielsen and Sutherland [24] using the relationship between bulk density and particle density [23] as was stipulated above.

**Saturated Hydraulic Conductivity:** The saturated hydraulic conductivity was determined by the constant head soil core method of Reynolds [25]. It was calculated using Darcy’s equation for vertical flow of liquid.

\[ K_{sat} = \frac{Q \times L}{At \times DH} \]  

Ksat = Saturated hydraulic conductivity
Q=Amount of water being collected constantly.
\[ A = \text{Area of the core containing soil sample} \]

\[ L = \text{Length of the core containing core sample} \]

\[ T = \text{Time interval collection} \]

\[ DH = \text{Constant water level height being maintained.} \]

**Moisture Content:** It was calculated using the equation below:

\[
OM = \frac{Mt - Ms}{Ms} = \frac{MW}{Ms} \quad \text{equation 3}
\]

Where

- \( OM \) = Gravimetric Moisture Content
- \( Mt \) = Mass of Moist Soil
- \( Ms \) = Oven dry Mass of Soil

**Particle Size distribution:** The determination was done following the method described by Bouyocous [26].

**Results**

**Physical Contents of the Study site Before Treatment Application**

The initial soil properties presented in Table 1 show that the tested physical properties of the soil were of medium values and the textural class is of sandy loam, while Table 2 shows that the ash contains lower levels of organic carbon (OC) and total nitrogen (TN).

<table>
<thead>
<tr>
<th>Test Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>56.20%</td>
</tr>
<tr>
<td>Clay</td>
<td>7.00%</td>
</tr>
<tr>
<td>Silt</td>
<td>36.80%</td>
</tr>
<tr>
<td>Textural class</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>Bulk density (BD)</td>
<td>1.45 gcm(^{-3})</td>
</tr>
<tr>
<td>Total porosity (TP)</td>
<td>46.67%</td>
</tr>
<tr>
<td>Hydraulic conductivity (HC)</td>
<td>26.90 cmhr(^{-1})</td>
</tr>
<tr>
<td>Moisture Content</td>
<td>18.72%</td>
</tr>
</tbody>
</table>

**Effect of Tillage and Wood ash on the Physical Parameters of the Soil**

**Effect of Tillage and Wood ash on Soil Bulk Density (gcm\(^{-3}\))**

The bulk density (BD) result presented in Table 3 vary among the tillage methods and showed significant (\( P < 0.05 \)) effect in 2\(^{nd}\) year and 3\(^{rd}\) year planting period. Among the tillage methods (TM), Mound (Md) showed less value in BD compared to the Ridge (RD) and Flat (Ft) and the order of decrease were Md < Rd < Ft. In comparing the values of BD of the 3 years under study in all the 3 tillage methods, the 2nd year planting period showed a decrease in value compared to 1\(^{st}\) and 3\(^{rd}\) year planting season. While the 3\(^{rd}\) year (residual year) showed the highest BD value in the three (3) tillage methods (Md, Rd, Ft) studied.

The wood ash application showed non-statistical significant (\( P < 0.05 \)) difference among the treatment rates but vary in the value obtained among the rates. The order of variation in value of BD obtained among the rates in 1\(^{st}\) year planting period in mound were; Md\(_4\) > Md\(_0\) > Md\(_2\) > Md\(_6\), for the 2nd year planting Md\(_6\) > Md\(_2\) > Md\(_0\) > Md\(_4\) and the residual year (3rd year) showed Md\(_6\) > Md\(_0\) > Md\(_4\) > Md\(_2\). The result of the 3 years planting showed that the least value of BD was observed in 2\(^{nd}\) year planting period with the Md\(_4\).
The result in RIdge showed that the value of BD decreased as the rate of WA application increased in 1st and 2nd year result, though the value increased at Rd. While the residual year (3rd year) result showed an increase in value as the rate of WA application decreased in the order; Rd < RId < RId < Rd. The least value of BD among the 3 years study was observed in Rd in the 2nd year planting period. The result of WA in Flat method showed inconsistence in the order of variation of BD values. The 1st year planting showed an order of Ft > Ft > Ft, while 2nd year result showed an order of Ft > Ft > Ft > Ft. The 3rd year which is the residual year, however, showed an increase in the value of BD as the rate of WA application decreased to Ft, though with attendant increase in Ft.

Table 4: Effect of Tillage and Wood ash on Soil Total Porosity (%)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1st Year</th>
<th>2nd Year</th>
<th>3rd Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Md</td>
<td>51.333</td>
<td>52.667</td>
<td>44.333</td>
</tr>
<tr>
<td>Md</td>
<td>52.000</td>
<td>52.667</td>
<td>47.333</td>
</tr>
<tr>
<td>Md</td>
<td>51.000</td>
<td>55.667</td>
<td>46.333</td>
</tr>
<tr>
<td>Md</td>
<td>53.000</td>
<td>51.667</td>
<td>41.000</td>
</tr>
<tr>
<td>Mean</td>
<td>51.833</td>
<td>53.167</td>
<td>44.750</td>
</tr>
<tr>
<td>Rd</td>
<td>48.000</td>
<td>49.667</td>
<td>39.000</td>
</tr>
<tr>
<td>Rd</td>
<td>49.000</td>
<td>50.667</td>
<td>39.333</td>
</tr>
<tr>
<td>Rd</td>
<td>50.667</td>
<td>52.000</td>
<td>41.333</td>
</tr>
<tr>
<td>Rd</td>
<td>49.667</td>
<td>49.333</td>
<td>50.000</td>
</tr>
<tr>
<td>Mean</td>
<td>49.333</td>
<td>50.417</td>
<td>42.417</td>
</tr>
<tr>
<td>Ft</td>
<td>46.667</td>
<td>47.667</td>
<td>41.667</td>
</tr>
<tr>
<td>Ft</td>
<td>49.333</td>
<td>50.667</td>
<td>57.667</td>
</tr>
<tr>
<td>Ft</td>
<td>47.000</td>
<td>48.000</td>
<td>38.667</td>
</tr>
<tr>
<td>Ft</td>
<td>47.333</td>
<td>43.000</td>
<td>42.000</td>
</tr>
<tr>
<td>Mean</td>
<td>47.583</td>
<td>47.333</td>
<td>40.000</td>
</tr>
</tbody>
</table>

LSD0.05

Tillage method (TM) 0.06
3.52 NS
Wood ash (WA) 0.38
NS NS
TM x WA 0.91
7.38 11.59

Md = Mound without wood ash (WA); Md = Mound + 2t/ha WA; Md = Mound + 4t/ha WA; Md = Mound + 6t/ha WA; Rd = Ridge without WA; Rd = Ridge + 2t/ha WA; Rd = Ridge + 4t/ha WA; Rd = Ridge + 6t/ha WA; Ft = Flat without WA; Ft = Flat + 2t/ha WA; Ft = Flat + 4t/ha WA; Ft = Flat + 6t/ha WA

Effect of tillage and Wood ash on Soil Total Porosity (%)

The tillage methods (TM) had significant effect on the soil total porosity (TP) as was recorded in Table 4, though the result showed non-significant (P < 0.05) effect in the residual year. Mound show an increased value in TP when compared to the results obtained from Ridge and Flat methods. TP variation in Mound for the years under study showed that 2nd year > 1st year > 3rd year (residual year), this scenario was equally the same for the Ridge method. While contrary result was obtained from Flat method were the TP result showed that 1st year > 2nd year > 3rd year planting. The percentage decrease in TP result of residual year relative to the 2nd year result for the tillage methods were 15.82 (Md), 15.86 (Rd) and 15.49% (Ft) and this showed an order of Rd > Md > Ft.

The result of the TP in Table 4 showed that rates of wood ash had no significant effect on the TP for the 2nd and 3rd year planting.
period. The TP increased as was observed in the 2nd year planting, but the 3rd year showed a decrease in TP results. There was inconsistence in the order of decrease or increase in the values of TP obtained from rates of WA with their tillage methods and the years of study. For example, rates of WA in mound in the 1st planting period showed an order of Md<sub>6</sub> > Md<sub>2</sub> > Md<sub>0</sub> > Md<sub>4</sub>. The 2nd year planting showed that Md<sub>4</sub> gave the highest TP value, while Md<sub>2</sub> and Md<sub>0</sub> yield the same value of TP. The 3rd or residual year result showed an order of increase; Md<sub>2</sub> > Md<sub>3</sub> > Md<sub>0</sub> > Md<sub>4</sub>. The rates of WA in Ridge showed that lowest value of TP in the 1st planting year was observed in Rd<sub>0</sub> (48.00%) and the highest value was observed in Rd<sub>4</sub> (50.667%). The percentage decrease in TP value relative to Rd<sub>0</sub> was 5.26%. The 2nd year planting result indicated that Rd<sub>4</sub> was still highest in value compared to the other rates of WA and the results are ranked Rd<sub>4</sub> > Rd<sub>2</sub> > Rd<sub>0</sub> > Rd<sub>6</sub>. The 3rd year result showed a decrease in value of TP in all the rates of WA when compared to the values of TP obtained in the 1st and 2nd year planting, with the highest value of 50% TP obtained from Rd<sub>6</sub>. The result of the 1st year planting with regard to rates of WA in Flat, showed Ft<sub>2</sub> to have the highest TP value. The orders of result are Ft<sub>2</sub> > Ft<sub>6</sub> > Ft<sub>4</sub> > Ft<sub>0</sub>. For the 2nd year result, the Ft<sub>6</sub> gave the lowest value of TP and the percentage decrease in value of TP at Ft<sub>6</sub> relative to Ft<sub>2</sub> that gave highest TP value was 15.13%. The 3rd year result showed an order of Ft<sub>6</sub> > Ft<sub>0</sub> > Ft<sub>4</sub> > Ft<sub>2</sub>. Among all the rates and 3 years’ of study Ft<sub>2</sub> of residual year gave the least value of TP. The effect of tillage methods and rates of wood ash on TP were significant (P < 0.05). The values of the parameter increased as the year of planting increased to 2nd year, but decreased in the residual year. Higher values of TP were observed in WA amended soils than the control plots and do not depend on the rates of increase in WA applied.

The tillage methods showed non-significant effect (P < 0.05) on soil moisture content (MC) for the three (3) years’ study as was recorded in Table 5. The result of the Mound showed that the values of MC decreased as the years of planting increased. The same scenario applies to the results obtained from Ridge and Flat methods. The lowest value of MC among the 3 tillage methods was observed in the Ridge from the 3rd year result. The 1st year planting result showed a variation of Flat > Mound > Ridge; this result was equally true for the 2nd year planting result. The 3rd year (residual), however, showed a contrary result of Mound > Flat > Ridge. The 1st and 2nd year result generated from the 3 tillage methods were

### Table 5: Effect of Tillage and Wood ash on Soil Moisture Content (%)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1&lt;sup&gt;st&lt;/sup&gt; Year</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt; Year</th>
<th>3&lt;sup&gt;rd&lt;/sup&gt; Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Md&lt;sub&gt;6&lt;/sub&gt;</td>
<td>18.990</td>
<td>17.977</td>
<td>16.000</td>
</tr>
<tr>
<td>Md&lt;sub&gt;4&lt;/sub&gt;</td>
<td>20.673</td>
<td>19.369</td>
<td>18.000</td>
</tr>
<tr>
<td>Md&lt;sub&gt;2&lt;/sub&gt;</td>
<td>23.277</td>
<td>22.257</td>
<td>17.000</td>
</tr>
<tr>
<td>Md&lt;sub&gt;0&lt;/sub&gt;</td>
<td>20.113</td>
<td>19.277</td>
<td>18.000</td>
</tr>
<tr>
<td>Mean</td>
<td>20.688</td>
<td>19.718</td>
<td>17.250</td>
</tr>
<tr>
<td>Rd&lt;sub&gt;6&lt;/sub&gt;</td>
<td>18.850</td>
<td>17.830</td>
<td>15.333</td>
</tr>
<tr>
<td>Rd&lt;sub&gt;4&lt;/sub&gt;</td>
<td>20.057</td>
<td>19.003</td>
<td>15.333</td>
</tr>
<tr>
<td>Rd&lt;sub&gt;2&lt;/sub&gt;</td>
<td>21.987</td>
<td>20.937</td>
<td>14.333</td>
</tr>
<tr>
<td>Rd&lt;sub&gt;0&lt;/sub&gt;</td>
<td>20.527</td>
<td>19.575</td>
<td>15.083</td>
</tr>
<tr>
<td>Mean</td>
<td>20.618</td>
<td>19.575</td>
<td>15.083</td>
</tr>
<tr>
<td>Ft&lt;sub&gt;6&lt;/sub&gt;</td>
<td>19.867</td>
<td>18.813</td>
<td>16.333</td>
</tr>
<tr>
<td>Ft&lt;sub&gt;4&lt;/sub&gt;</td>
<td>22.503</td>
<td>21.453</td>
<td>15.333</td>
</tr>
<tr>
<td>Ft&lt;sub&gt;2&lt;/sub&gt;</td>
<td>20.883</td>
<td>19.843</td>
<td>14.667</td>
</tr>
<tr>
<td>Ft&lt;sub&gt;0&lt;/sub&gt;</td>
<td>20.630</td>
<td>19.590</td>
<td>15.667</td>
</tr>
<tr>
<td>Mean</td>
<td>20.971</td>
<td>19.925</td>
<td>15.590</td>
</tr>
</tbody>
</table>

LSD<sub>0.05</sub>

Tillage method (TM) | NS
---|---
Wood ash (WA) | 0.12
TM x WA | 0.91

Md<sub>6</sub> = Mound without wood ash (WA); Md<sub>4</sub> = Mound + 2t/ha WA; Md<sub>2</sub> = Mound + 4t/ha WA; Md<sub>0</sub> = Mound + 6t/ha WA; Rd<sub>6</sub> = Ridge without WA; Rd<sub>4</sub> = Ridge + 2t/ha WA; Rd<sub>2</sub> = Ridge + 4t/ha WA; Rd<sub>0</sub> = Ridge + 6t/ha WA; Ft<sub>6</sub> = Flat without WA; Ft<sub>4</sub> = Flat + 2t/ha WA; Ft<sub>2</sub> = Flat + 4t/ha WA; Ft<sub>0</sub> = Flat + 6t/ha WA

Effect of Tillage and Wood ash on Soil Moisture Content (%)

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generally alike, but higher in value than the 3rd year results of the 3 tillage methods.

The rates of wood ash effect on MC in Table 5 except for 1st year planting indicated non-significant difference among the rates. Its effect on Mound method in 1st year planting showed that the value of MC increased as the rates of WA application increased, though the value decreased at Md6. This result was equally true for the 2nd year planting result. The result of the 1st and 2nd year showed that the highest value of MC was observed in Md4 among all the rates of WA applied. The 3rd year results showed an inconsistency in the order of decrease in the values of MC obtained. Even it was observed that Md2 and Md6 gave the same value of MC. Among the 3 years under study it was found out that the 3rd year gave least values in all rates of WA compared to the 1st and 2nd year results of the rates of WA. The 1st year result of WA application on Ridge showed an order of Rd4 > Rd6 > Rd2 > Rd0 and this was also true for 2nd year planting result. This signifies that the highest value of MC in 1st and 2nd year planting was observed in Rd4. The nature of results variations obtained in the 1st and 2nd year planting from the rates of WA on Ridge and Mound are quite the same. The 3rd year planting showed that Rd0, Rd2 and Rd4 gave the same value of MC, with Rd6 given the least value of MC. The rates of WA application on Flat showed a contrary result from Mound and Ridge in the sense that Ft2 gave the highest value of MC among the rates of WA in both 1st and 2nd year planting.

The 1st year result showed variation of Ft2 > Ft4 > Ft6 > Ft0 and the percentage decrease in MC value relative to Ft0 with regard to Ft2 value was 11.71%. The same scenario of result was observed in 2nd year planting, however, the percentage decrease in value of MC relative to Ft0 in the 2nd year was 12.3%. The 3rd year result showed a decrease in value compared to 1st and 2nd year result, but contrary in result variation in the sense that highest value of MC was observed in Ft0, and the least value obtained in Ft4. The variation showed Ft0 > Ft4 > Ft2 > Ft4.

The tillage and wood ash effect had no significant effect on MC for the years under study except for the 1st year planting season. The moisture content values decreased as the years of planting period increased. Based on the recorded values, the control plots were poor in this parameter when compared to the WA amended plots.

### Table 6: Effect of Tillage and Wood ash on Soil Hydraulic Conductivity (cm/hr⁻¹)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1st Year</th>
<th>2nd Year</th>
<th>3rd Year</th>
</tr>
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<td>Md0</td>
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<tr>
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<tr>
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<td>8.333</td>
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<tr>
<td>Mean</td>
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LSD0.05

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<table>
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Md0 = Mound without wood ash (WA); Md2 = Mound + 2t/ha WA; Md4 = Mound + 4t/ha WA; Md6 = Mound + 6t/ha WA; Rd0 = Ridge without WA; Rd2 = Ridge + 2t/ha WA; Rd4 = Ridge + 4t/ha WA; Rd6 = Ridge + 6t/ha WA; Ft0 = Flat without WA; Ft2 = Flat + 2t/ha WA; Ft4 = Flat + 4t/ha WA; Ft6 = Flat + 6t/ha WA
Effect of Tillage and Wood ash on Soil Hydraulic Conductivity (cm h⁻¹)

The 1st year planting result of soil hydraulic conductivity (HC) in Table 6 indicated significant difference among the tillage methods (TM). However, the effect of TM in 2nd and 3rd year planting was not effective. The values of HC obtained from each TM, showed that the values decreased as the planting years increased. The 3rd year planting recorded the least value of MC in each of the TM, while the least value of HC among TM was observed in Mound. The result of HC in Mound is of the order 1st year > 2nd year > 3rd year. The result is equally true for Ridge and Flat. In comparison of the TM and years under study, the 1st year result showed that the highest value of HC (21.764 cm h⁻¹) was obtained from Flat and the order of variation was Flat > Ridge > Mound. The 2nd year showed that the least value of HC was observed in Mound in order of Mound < Ridge < Flat and the percentage increase in Flat relative to the Mound was 73.074%. The 3rd year planting presents a contrary result as it showed that Ridge gave the highest value of HC, that is Ridge > Flat > Mound and the percentage decrease in value of HC in Mound relative to the Ridge value was 29.803%.

The rates of WA application showed a statistical significant (P<0.05) difference among the rates of WA in 1st and 2nd year planting period. This effect was however, not effective in the residual year period. The rates of WA on Mound in the 1st year planting showed that the value of HC increased as the rates of WA increased though the value decreased in Md6. The highest value of HC among the rates of WA was obtained from Md1. The 2nd year planting showed an order of Md4 > Md2 > Md6 > Md0 and the percentage decrease in value of HC in Md0 relative to Md4 was 75.81%. This percentage difference is very much on the higher side, which simply testifies the limited ability of the Md0 to transmit water and all that dissolve there in. The 3rd year result showed that the HC decreased in Md6, but increased as the rate of WA applied increased. The result of the 1st year planting showed that the value of HC was highest in Rd6 followed by the Rd2 while the least value was obtained from Rd0.

The result scenario in 2nd year planting was a replicate of 1st year result in nature but not in value in the sense that the order was Rd6 > Rd2 > Rd4 > Rd0. The percentage decrease in value of HC in Rd6 relative to Rd6 was 71.98%. The residual year results showed lower values in all the rates compared to the values of 1st and 2nd year results. The lowest value of HC in the residual year was obtained in Rd2 while Rd4 gave the highest HC among all the rates. The rates of WA in Flat showed that higher values were observed among the rates in comparison to the results of the rates of WA in Mound and Ridge. The 1st and 2nd year planting results showed that the value of HC increased as the rates of WA applied increased. The result variations for the two years planting season was Ft6 > Ft4 > Ft2 > Ft0.

The findings from the 1st and 2nd year planting result indicated that the highest value of HC was observed in Ft6 and the least value in Ft0. The residual year result showed inconsistence in the order of results among the rates of WA, which signifies that the values of HC obtained are independent of the amount of wood ash applied. This may be due to non-application of wood ash in the 3rd year (residual). The result variation showed Ft4 > Ft0 > Ft2 > Ft6.

The effect of tillage methods and rates of wood ash on the tested parameter was significant and the soil analysis of the experimental site before the initiation of the study indicates that the soil of the area is of the sandy loam textural class. The textural class was found not to have changed throughout the period of the experiment, showing that neither rate of wood ash nor tillage methods has effect on the particle size distribution of the studied soil. The values of physical parameters such

Discussion

Properties of the Soil and ash at Beginning of the Study

The soil analysis of the experimental site before the initiation of the study indicates that the soil of the area is of the sandy loam textural class. The textural class was found not to have changed throughout the period of the experiment, showing that neither rate of wood ash nor tillage methods has effect on the particle size distribution of the studied soil. The values of physical parameters such
as bulk density (BD), total porosity (TP), hydraulic conductivity (HC) and moisture content (MC) were 1.45 gcm$^{-3}$, 45.67%, 26.90 cmhr$^{-1}$ and 18.72% respectively. The selected physical properties analysed in relation to the work are indices for measuring soil productivity in relation to crop production. The content of total nitrogen, OC, OM of ash were found to be very small and hence classified and rated as been low in these nutrients. Tillage improved soil productivity with time especially when tillage is combined with soil amendments [27]. Thus it is expected that the soil and test crop will benefit from wood ash application in the long term. Since manure is known to influence soil parameters positively.

**Soil Physical Parameters**

It was observed that after three years of cropping Mound tillage had lower bulk density (BD), hydraulic conductivity (HC) and increased total porosity (TP) compared with Ridge and Flat. Flat tillage gave higher bulk density, HC and lower TP. While there moisture content (MC) values were relatively alike. This implies that tillage over the years compact the soil there by reducing porosity. Higher BD reduces water infiltration and lower HC will limit water transmission and all that dissolve therein, hence impairing nutrient recycling and up take by plants. Omou and Ojeniyi [28] observed that minimal tillage like manually cleared followed by bed making with hoe ensure relatively porous soil and lower moisture content compared with non-minimal tilled soils.

Irrespective of the tillage method the 3rd year result show higher BD that is in the range of 1.478gcm$^{-3}$ - 1.592gcm$^{-3}$ compared to the 1st and 2nd years results. These only suggest soil too compact for rapid root growth and good crop yield. The 3rd year result therefore agrees with the findings of Stoscopf [29] who emphasised that soil bulk densities of 1.46-1.66gcm$^{-3}$ are too compacted for rapid root growth and high crop yield. The compaction can arose from cultivating at same piece of land and depth for 3 years and reduction in the use wood ash which was not applied at 3rd year. Soils which are continuously or intensively cultivated are more susceptible to compaction; declines in the air and water content of the soil by altering the pore spaces in the soil and may reach high bulk densities over time. According to the work of Bescansa *et al.*, [30] if cultivated soils compact over time it is likely that micro-pores constitute the majority of the total porosity and water is therefore held at lower matrix potentials, making it less available to plants. When the soil is lacking air and water it becomes inhabitable for soil microbes which make the soil a living entity and invariable non-mineralization of plant nutrients for plant uptake. This is as a result of the effect of tillage methods on the soil physical properties. The greater the compaction, the more adverse effects it will have on root development and crop yield. Tillage reduces soil bulk density by breaking the aggregates into smaller particles and increase aeration. It enhances rapid root elongation with depth and induces a high root density in the sub soil of which will increase yield.

The observed reduction in BD and increased TP of Mound method (MM) compared to Ridge method (RM) and Flat method (FM) might be due to deep tillage usually observed in Mound in the study area relative to the other methods, with increase in MC; there will be reduction in cohesion and soil strength. Motuvali *et al.*, [31] found out that deep tillage breaks up high density soil layer, improve water infiltration and movement in the soil, enhances root growth and increases crop production. All tillage methods reduced soil BD and penetration resistance and together with water movement to the soil. No wonder the closeness in the values of the tillage methods on the parameters.

All indices of soil compactness and porosity depend on depth and method of tillage [32-34]. The soil MC of the tillage methods for the 3 years’ of the study were found to be statistically similar and decreased in value as the year of planting increased irrespective of the tillage method. Although the values of MC of the tillage methods are relatively unlike the result order show Mound < Ridge < Flat. According to the works of Fabrizzi *et al.*, [1] and Bescansa *et al.*, [30], no-till soils usually maintain a higher moisture content than soils which are ploughed. This probable might be reason why the values of MC in

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Flat is relatively higher compared to the value of Ridge and Mound as very minimal tillage was observed in Flat compared to Ridge and Mound. Soil response to tillage is however likely to depend on the long term basis. As studies by Lamurlanes et al., [35] observed no significant difference between soil tillage methods studied. The studies conducted by Aboudrare et al., [10] and Hemmat and Taki, [36] however indicated that the effects of soil tillage methods increased moisture content and were statistically significant. Irrespective of the TM the 3rd year result of HC is very small compared to the 1st and 2nd year results. This suggests lower water transmission due to high compact of the soil in the 3rd year planting, for the 3 years of planting the HC value showed Mound < Ridge < Flat. Osunbitan et al., [2] found that the surface soil had a higher HC under no-tillage compared with conventional tillage methods.

Due to its relationship with the porosity, bulk density is a useful measure for assessing tillage effects on the structural characteristics of the soil and the consequent effects on the soil water and aeration, hydraulic conductivity, infiltration rate, water retention, characteristics and soil strength. Many authors have examined influence of different tillage systems on the soil physical properties. Kovac and Zak [37] found that changes in soil physical properties were induced by different tillage methods, but the changes were small and insignificant. Some authors pointed out that the tillage practices affected the soil physical properties, especially when similar tillage systems have been practiced for a long period [38, 39]. This might be the reason for the closeness of the values of the parameters obtained from Ridge and Mound compared with Flat as both Ridge and Mound has being in practice much in the studied area.

The result observed may as well be associated with the climatic environment of the study area as Buschiazzo et al., [40], found out that the influence of tillage system on the soil physical properties was greater in the humid climate area and loamy soil than in the arid climate and sandy soils. Also Chang and Lindwall [41] indicated that soil property changes due to tillage are related to several things and those things include soil type, tillage equipment, tillage depth, soil conditions such as moisture at the time of tillage and climate conditions. Therefore, since soil physical properties represent a group of properties having substantial impact on the different physical, chemical and biological processes in soil, they need and should be kept optimal according to Lal, [42]. Irrespective of the TM, wood ash (WA) application reduced soil BD, increased porosity, MC and HC. The tested parameters changed progressively with the level of ash applied. Thus the WA improved soil physical conditions. For the 3 years of the study the plot that received 4tha\(^{-1}\) (Md\(_{o}\), Rd\(_{o}\), Ft\(_{o}\)) and 6tha\(^{-1}\) (Md\(_{o}\), Rd\(_{o}\), Ft\(_{o}\)) rate of WA showed lower values of BD and higher values of TP, MC and HC compared to the other rates. Although some minor differences can be observed in their values when compared to the other rates and in years of planting. The WA application on Flat method show relatively higher values in BD and less value in TP compared to its application on Mound and Ridge. The plots not amended with WA (Mdo, Rdo and Fto) have higher BD and less TP compared to the plots amended with WA.

The MC and HC values irrespective of the tillage method the WA was applied decreased as the planting period increased. The MC value of all the rates of WA irrespective of the tillage method was observed to be relatively alike, but WA on Mound showed less value in HC of the rates of WA in most cases compared to WA rates on Ridge and Flat values. Based on the recorded values the control plots were poor in these two parameters when compared to the WA amended plots. The observed variations in the soil physical parameters could have arisen from the interactions of many factors such as organic matter contents of the soil, the impact of rain drop on the soil surface that might lead to the structural collapse of the aggregates. Lower BD values were observed in WA amended soil relative to the control plots and decreased with an increase in the rates of WA applied indicating that WA application could loosen compacted soil. The result further demonstrated the potential of WA in sustaining physical structures of the soil. The ability of organic wastes in sustaining the physical structures of the agricultural soils have been reported by Nwite et al., [43]
and Mbah and Nneji [44]. The lower bulk density values observed in the second planting season could be due to increased organic matter (OM) content in the soil as a result of repeated application of the WA. Hence, WA application contributed more to BD reduction. Higher soil OM helps to reduce the compaction of the soil according to Anikwe and Nwobodo [45]. The result of this study demonstrated that amendment of soil with WA is beneficial as it reduces the soil BD, which will increase plant feeding area, root proliferation and adequate aeration. The 3rd year planting result showed increases in BD irrespective of the TM the WA was applied of which ranged from 1.400gcm\(^{-3}\) - 1.657gcm\(^{-3}\). The increases were beyond the limiting values for root penetration and proliferation, because higher BD as reported by Anikwe et al., [46] will decrease soil pore values and water available to crops. Among the recorded result, the 6tha\(^{-1}\) (Mds, Rd\(_2\) and Ft\(_2\)) rate showed a remarkable residual impact on the BD.

Porosity affects water movement and gas exchange in soils. Therefore, the increase in TP of the amended soils relative to the control soils are good omen as it tend to portray that the amended soils will contain the required water and oxygen that are important for soil organisms to survive and eventually help to liberate plant nutrients. Improvement in soil TP following organic waste application have been observed by Asadu et al., [47] and Nnabude and Mbagwu [17,18]. The observed high TP values may have contributed to the higher hydraulic conductivity values observed on the WA amended soils. Nwite et al., [43] and Mbah et al., [48] reported increased hydraulic conductivity in organic waste amended soils relative to the control, while other reported high values of hydraulic conductivity on sandy loam soil amended with organic waste. Ezekaku and Anikwe [49] attributed such high hydraulic conductivity result to bioactivity leading to creation of channel of flow of water. Increasing the rates of WA application led to increase in hydraulic conductivity with the 6tha\(^{-1}\) rate recording the highest value of HC in 1st and 2nd year planting seasons. The increases may be attributed to higher pores in plots amended with higher quantity of WA. Higher HC means better water transmission in the soil column and therefore, the amount of water storage. This in effect will have an impact on the fertility status of the soil, while lower HC values in the control plot might mean increased reduction in physiological activity of the test crop. The MC of the amended plots were observed to be higher than the control plots and increased as the rates of WA increased. Although the increases were not orderly as the 2tha\(^{-1}\) (Mds, Rd\(_2\) and Ft\(_2\)) rates were found to be higher in MC in 1st and 3rd year planting. The higher MC values observed in plots amended with WA might be due to the changes in the specific surface area of the soil as a result of the WA application. Also, the observed lower values in MC of the study could be attributed to low and variations in rainfall observed throughout the period of the study. Improvement in soil MC due to organic waste application in soil were reported by Mbah [50].

The TM and WA interaction effect showed that the values decreased as the year of planting increased though except for the values of BD that increased in the 3rd year planting period. The result equally showed that TM and WA at the rate of 4tha\(^{-1}\) and 6tha\(^{-1}\) are relatively alike and higher in values than the other rates in the TM it was applied. Although the 3rd year result showed 6tha\(^{-1}\) to have recorded higher values in most of the parameters tested, hence showing strong residual effect on the tested soil physical properties. Tillage practices and soil amendments using organic wastes are known to lead to improvements in soil conditions [51-55]

**Conclusion**

The present study is of the evidence that tillage methods and wood ash have substantial impacts on the physical properties of soil. The result of the tested parameters were found to vary with the tillage methods, mound method show less values in BD, HC and an increased value of TP relative to their values in Ridge and Flat. The rates of wood ash decreased the BD and increased the TP for the 3years’ of the study, while MC and HC decreased as the planting period increased. The interaction effect of tillage methods and rates of wood ash on the
tested parameters were significant. The values decreased as the cropping years increased. Soil physical parameters are important soil parameters and therefore need to be in the best possible results in order to effect positive and useful changes in soil environment.

References


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