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Response of selected physical properties of Fluvisols to tillage implements and frequencies at Haramaya, Eastern Ethiopia

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Abstract

The study was conducted to evaluate the effects of tillage implements and frequencies on selected physical properties of Fluvisols at Haramaya University, Eastern Ethiopia, during the 2013 cropping season. Soil bulk and particle density, total porosity, texture, and soil water retention were analyzed immediately (within 72 hours) and one month after tillage for samples collected from 0-20 and 20-40 cm depths. The experiment was laid out in a split-plot design with treatment combinations consisting of three levels of tillage frequencies (0, 2 and 4) and two tillage implements, oxen-drawn traditional *Maresha* and disc plows, with three replications. Results indicated that the mean bulk density values were significantly different ($P \leq 0.05$) at plow layers (0-20 cm). It ranged from 1.68 g cm^{-3} for disc plows at two passes to 1.72 g cm^{-3} for zero tillage and disc plows at four passes one month after tillage at a depth of 21-40 cm. Tillage with a disc plow at increased frequencies decreased total porosity, while oxen-drawn *Maresha* increased total porosity. Insignificant differences ($P \leq 0.05$) in mean values of particle size distribution were observed except for percent clay content immediately after tillage with disc plows at two passes, which showed significant highest mean value (26.30%). Tillage by traditional *Maresha* resulted in more water holding capacity at increased tillage frequencies. Tillage practice using disc plows at two passes significantly affected the bulk density, total porosity, and soil water retention characteristics. In conclusion, tillage implements and frequencies have shown a negative effect on the physical properties of Fluvisols by disrupting the structure of the soil at surface and subsurface depths, resulting in varying levels of impact on soil bulk density, total porosity, and soil water retention characteristics. Therefore, it is recommended to use the tillage implements at reduced frequencies for less disruption of soil properties while performing soil tilth for agricultural production.

Keywords: Tillage, *Maresha,* Disc plow, Implements, Haramaya.

Introduction

Tillage is the physically manipulating and managing soil for the purposes of managing previous crop leftover, preparing a seedbed for planting, controlling competing plants, and incorporating fertilizers and other crop production inputs. It entails of breaking the earth's compact surface to alter the soil's state to a particular depth and loosen the soil mass to allow crop roots to enter and spread into the soil (Wolkowski, 1996; Sahay, 2008). Tillage implements type and frequency alter the physical properties of soil, causing changes in biological activity, which in turn affects the soil's chemical properties and nutrients availability (Sundermeier et al., 2011; Iqbal et al., 2013). As a result, effective tillage is employed to create essential soil physical conditions for producing reasonably yields and maintaining acceptable soil quality (Kishor et al., 2013).

Tillage plays an important part in high and lucrative yields in modern agricultural production, where extensive mechanization has a beneficial financial impact, because it gives the soil a good growth environment for crops.

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However, it was discovered that it was negatively influencing soil conditions around the world by destroying soil structure, losing nutrients, and polluting the environment (Montgomery, 2007; Tayari and Jamshidi, 2011; Boloor et al., 2013). Soil compaction can be induced by a variety of tillage implements and the amount of passes used in ploughing, especially in intense tillage and heavy gear (Seladji et al., 2010). Approximately 80% of Africa's farmed land is prepared by hand using human power, 16% with animal draught power, and 4% with equipment power. Because Ethiopia is an agrarian country, tillage is a common concern (Chanyalew et al., 2010). According to Temesgen et al., (2009), smallholder farmers in Ethiopia use an ard plow called *Maresha* to implement traditional tillage practices. Land degradation (development of a plow pan) and inadequate rainwater utilization have resulted in reduced agricultural productivity due to traditional tillage practices that require repeated cultivations with the *Maresha* plow.

The *Maresha* (a primitive animal-drawn plow made of wood and steel) only penetrates the soil to a shallow depth (less than 20 cm). Tillage with tractor passes also causes undesirable changes in soil properties, which are strongly linked to changes in physical qualities of soil like porosity and bulk density, which further raises mechanical impedance, limiting oxygen, water, and nutrient availability (Lipiec and Stenieswski, 1995; Coelho et al., 2000). Multiple passes during conventional tillage can result in up to 70% of the field being trafficked, which has implications for soil compaction (Raper, 2005). Increased soil tillage frequency creates excessively localized pulverization, which causes structural damage (Souchere et al., 1998).

Because the usage of various tillage implements is increasing over time, it is vital to research the impacts of tillage implements and frequencies on selected soil physical attributes under Ethiopian conditions. Therefore, at Haramaya University in Eastern Ethiopia, a study was conducted to evaluate the impact of tillage implement and frequency of ploughing on selected physical attributes of Fluvisols.

Material and Methods

A description of the study area

The research was conducted during the 2013 cropping season at Haramaya University research field which is located in eastern Ethiopia at Haramaya, which is 508 km east of the capital city, Addis Ababa. The experimental site is geographically located between latitudes of 9° 24' 54.45''N and 9° 24' 55.83''N, and between longitudes of 42° 01'56.49''E and 42° 02' 02.23''E. The average altitude is about 2021 meters above sea level, with an annual rainfall of 909.1 mm from January to August of 2013. The mean annual (2004-2013) rainfall of the area is about 810.7 mm with the short rainy season, locally called *Bega* (March to April), and the long rainy season, also called *Kiremt* (June to October) (Simane et al., 1998). The annual mean minimum and maximum temperatures are 11.4 and 24.7 °C, respectively, with monthly values ranging between 4.6 and 14.4, and 23.1 and 25.7 °C (Figure 1). The soil type of the study site is characterized as a Fluvisols (Tamire, 1973) that is sandy clay loam in texture. Due to continuous nutrient depletion resulting from intense soil erosion, cereal mono-cropping and complete removal of crop residues, the soil becomes infertile. It contains low organic matter content (1.5-2.0 %) (Zewdie, 1994).

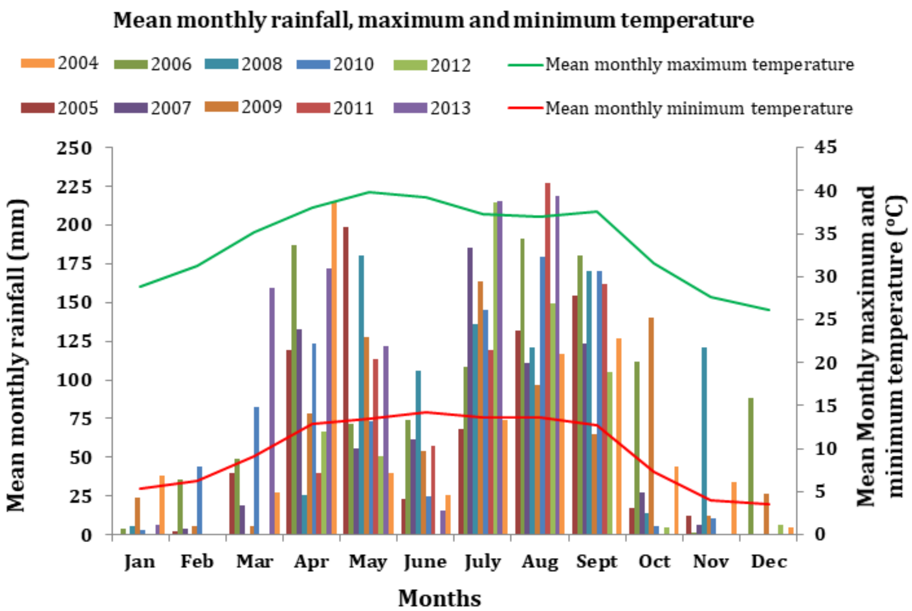

Figure 1. Mean (2004-2013) annual rainfall, maximum and minimum temperatures of Haramaya as recorded at the Haramaya Meteorological Station.

Experimental treatments and design

Two types of tillage implements, including traditional *Maresha* and the disc plow, served as main plot factors, with three tillage frequencies (zero, two, and four) serving as subplot factors and the treatments combinations were used as experimental treatments (Table 1). A split-plot design with three replications was used to lay out the treatment combinations. The disc plow was pulled by Landini 8860 Model tractor with a 62 horse power (hp), while the local *Maresha* was drawn by pair of oxen, for total of five treatment combinations. Without tillage, the zero tillage (ZT) was utilized as a control without tillage practice. Each plot area in a block was 15 m x 6 m in size. Treatments with multiple tillage frequencies were operated every 14 days. The soil samples were collected the plow layer (0-20 cm) and the subsurface layer (21-40 cm) for certain parameters. Tillage depth was achieved with the disc plow implement using a depth control wheel and with the *Maresha* implement by adjusting the *Maresha's* tying unit and controlling the plow during the plow.

Table 1. Treatments

Treatments code	Description
ZT	Zero tillage, no till
ODM2	Oxen drawn *Maresha* at two times plough
ODM4	Oxen drawn *Maresha* at four times plough
DP2	Disc plow at two passes
DP4	Disc plow at four passes

Soil sampling

To assess the status of selected soil properties, samples were collected randomly using a zigzag pattern from the entire experimental field. Accordingly, six disturbed sub-samples were used to make one composite sample. Similarly, three core samples each from the surface (0-20 cm) and subsurface (21-40 cm) layers were collected. The disturbed samples were collected using an auger, while the undisturbed samples were collected using core samplers. The samples were collected immediately (within 72 hours after plowing) and one month after the plowing operations (set up specifically to evaluate the effects of ploughing on soil physical parameters over time due to the modifications caused by climatic and environmental factors, especially the natural succession of wetting and drying cycles of the soil with subsequent progressive compaction) of the respective treatments. There is evidence that there are significant interactions between tillage and time for all properties, indicating that the tillage effect changes with time (Hu et al., 2018). Three randomly selected subsamples from tilled surface were collected from the entire plot. The air-dried soil samples were then ground and allowed to pass through a 2 mm size and analyzed at the Haramaya University soil physics and chemistry laboratories.

Methods of soil analysis

Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos, 1936). The textural class was determined using textural triangular procedures as laid out in the USDA system (Shirazi and Boersma, 1984; Gerakis and Baer, 1999). Bulk density was determined using the core method (Blake and Hartge, 1986a) and particle density was measured by the Pycnometer method (Blake and Hartge, 1986b), Total porosity (TP) was calculated from soil bulk (ρb) and particle (ρp) densities using equation (1) (Hall et al., 1977).

$$TP = (1 - \frac{\rho b}{\rho p}) * 100 \qquad \text{Equation (1)}$$

The water contents were tested at seven matric potentials, namely 0, -3, -5, -7, -10, -33.3, and -1500 KPa, to establish a typical water retention curve. A sand suction table was used to evaluate the water content at matric potentials of (0, -3, -5, -7, and -10 KPa) (Stakman et al., 1969). Gravimetrically, the water contents corresponding to these matric potentials were determined. The bulk density was used to transform the gravimetric water content determined at each matric potential into volumetric water content as shown in equation (2).

$$\theta = w \times \frac{\rho b}{\rho_w} \qquad \text{Equation (2)}$$

Where θ is the volumetric water content (v/v); *w* is the gravimetric water content (w/w); ρb is bulk density (g cm^{-3}), and ρw is the density of water (≅ 1 g cm^{-3}).

Available water capacity (*AWC*) (mm m^{-1}) was computed using equation (3) (Barthakur and Baruah, 1998):

$$AWC = 1000\,(\theta_{FC} - \theta_{PWP}) \qquad \text{Equation (3)}$$

Statistical data analysis

The selected soil physical properties measured were subjected to analysis of variance appropriate to the experimental design (Gomez and Gomez, 1984) using statistical analysis system institute package (SAS, 2008). Multiple comparisons of treatment mean values were made by the least significant difference (LSD) test method. In all analyses, a probability of error of P ≤ 0.05) was considered significant.

Results and Discussion

Soil analysis

Soil analysis result before the experiment (Table 2) indicated that soil has higher proportions of sand (57 %) with textural class of sandy clay loam. The soil pH was 7.62 which is rated as moderately alkaline (Mamo, 1991) with a soil organic carbon content of 0.78% which is rated as low (Debele, 1980).

Table 2. Selected physicochemical characteristics of the experimental soil before the experiment

Parameters	Soil depth	Values
Textural class	0-20 cm	Sandy clay loam
Sand (%)	0-20 cm	57.00
Silt (%)	0-20 cm	21.00
Clay (%)	0-20 cm	22.00
pH (H_2O)	0-20 cm	7.62
Organic carbon (%)	0-20 cm	0.78
Particle density (g cm^{-3})	0-20 cm	2.49
Bulk density (g cm^{-3})	0-20 cm	1.56
	21-40 cm	1.64
Total porosity (%)	0-20 cm	37.00
	21-40 cm	34.00
Water content(% w/w)	0-20 cm	5.12
	21-40 cm	4.66

Particle size distribution

Tillage implements and frequencies significantly affected percent clay content (P ≤ 0.05) immediately after tillage, but not one month after tillage (Table 3). The highest and the lowest mean percent clay contents were 26.3% and 17.67% for disc plow at two passes and oxen-drawn *Maresha* plow immediately after twice tillage, respectively. In the same way, the mean values of 24.33 % and 20.00 % disc plow at two passes (DP2) and oxen-drawn *Maresha* plow twice (ODM2), respectively were recorded one month after tillage. The results obtained were in line with the finding of Canarache (1991) who reported that tillage could increase the proportion of clay content in soil. This could be due to tillage equipment moving finer soil particles around within the soil profile (Hajabbasi, 2005).

Tillage implements and frequencies did not bring about significant variations (P ≤ 0.05) in silt and sand content immediately after and one month after tillage operations. But, the sand content showed a slight reduction in mean values for the oxen-drawn *Maresha* plough with increased tillage frequencies. These slight differences in the mean values were probably due to changes in mean percent clay (Table 3).

The differences in soil textural classes after the tillage experiment were not apparently seen as compared to soil test results before the experiment. The result was in line with the work of Sauwa et al., (2013), indicating that tillage treatments had no significant effect on the particle size distribution of the soil at the plow layer. The textural classes of the plow layers of all plots were sandy clay loam one month after tillage. However, immediately after tillage, soils under zero tillage and ODM2 were sandy loam in texture. Therefore, the textural classes of the soil were not changed under this experiment except for the slight increments in percent clay content. These results were in line with the work of Hajabbasi (2005) and USAID (2008), indicating that the differences might be due to the mixing of soil layers by repeated soil turning and sorting as a result of tillage implements and frequencies. It also suggests that the soil tillage by DP2 showed a relatively higher proportion of clay (Table 3).

Table 3. Mean particle size distribution variations immediately and one month after tillage

Treatment	Particle size distribution (%) immediately after tillage			STC	Particle size distribution (%) one month after tillage			STC
	Sand	Silt	Clay		Sand	Silt	Clay	
ZT	62.67	18.00	19.33[bc]	SL	62.00	14.67	23.33	SCL
ODM2	66.00	16.33	17.67[c]	SL	64.67	15.33	20.00	SCL
ODM4	59.67	15.33	25.00[ab]	SCL	63.33	16.00	20.67	SCL
DP2	61.67	12.00	26.30[a]	SCL	58.33	17.33	24.33	SCL
DP4	63.30	15.33	20.33[abc]	SCL	61.67	15.33	23.00	SCL
SE (±)	1.31	1.07	1.13		0.92	0.45	0.68	
LSD (0.05)	NS	NS	6.02		NS	NS	NS	
CV (%)	5.66	19.34	14.71		5.07	10.18	10.89	

Note: Means for specific soil parameters followed by the same letter (s) within a column are not significantly different at P 0.05; SE = standard error, LSD = least significant difference, STC = Soil textural class, SL = Sandy loam, SCL = sandy clay loam, NS = Non significantly different, CV = Coefficient of variation, % = Percentage

Bulk density

The tillage implements and frequencies resulted in significant differences ($P \leq 0.05$) in bulk density values at the plow layer (0-20 cm) both immediately and one month after tillage (Table 4), but the differences were not significant for the depth below the plow layer (21-40 cm). According to Ji et al. (2013), shallow tillage (up to 20 cm depth) is referred to as the plow layer, whereas tillage beyond this depth is considered deep tillage. Thus, the impact of tillage implements and frequencies on soil bulk density values was found to be significant at those specified depths of tillage. The mean bulk density values for the traditional *Maresha* implement and that of zero tillage were relatively higher than those for the tractor pulled implements. These differences might be due to the shallow tillage capacity of the oxen-drawn *Maresha* plow that probably resulted in less soil disturbance. The highest bulk density observed in the control treatment is probably due to the undisturbed soil, which is in line with the work of Monneveux et al. (2006), which indicated that zero tillage is associated with increased soil bulk density.

The results also showed that the tractor powered disc plow at two passes decreased the mean bulk density values, unlike the other tillage treatments, and this reduction might be due to heavy soil pulverization with the lesser frequency of tillage. Oxen-drawn *Maresha* at increased frequencies of tillage slightly decreased the mean bulk density of the soil. The increase in mean bulk density values under the disc plow at four passes of tillage might be attributed to the compaction caused by the effects of axle load and tire traffic, leading to shear and vertical soil stresses, as has been evidenced by the research reports of Abu-Hamdeh (2004) and Sarker et al. (2011).

The lowest mean bulk density value of 1.59 g cm-3 was reported for disc plow at two passes one month after tillage, whereas the tilled layer had the greatest mean value of 1.72 g cm-3 for ZT and DP4. The sand content of the soil was not significantly influenced by tillage equipment and frequencies immediately after and one month after tillage (Tables 3 and 4). The irregular decline in mean sand content values for *Maresha* plow tools immediately and one month after plowing was also recorded, indicating that there were generally proportional increments and decrements in sand and bulk density.

However, with increased frequency tillage under disc plow implement, a steady drop in mean sand and bulk density values were found both immediately and one month following tillage. The findings also revealed that sand content had a direct effect on soil bulk density under various tillage implements and frequencies, which is consistent with the findings of Aşkın and Özdemir (2003) and Tanveera et al. (2016), who found that sand content was the most effective soil fraction in influencing soil bulk density.

At the depth of 21-40 cm, the highest mean value of 1.72 g cm^{-3} was observed for ZT and DP4, which is against the finding of Qin et al. (2006) and Sornpoon and Jayasuriya (2013), who reported that bulk density was significantly higher in the zero tillage than in the tilled conditions. However, disc plow at two passes resulted in the lowest mean values of 1.68 g cm^{-3} among the other treatments. Even though the mean values of bulk density were significantly different, all mean values showed that the soils had a bulk density greater than 1.60 g cm^{-3}. It might be related to prone to compaction (Greenland and Lal, 1979; USDA, 2008; Mada et al., 2013). The mean bulk density values for the tilled layers of all the tillage implements and frequencies were lower for plots immediately after tillage as compared to one month after tillage. The mean bulk density values at the depth of 21-40 cm for most treatments showed an increment in mean values one month after tillage, which is in line with the finding of Nath (2014). The probable reason for this might be the soil condition created by tillage implements and frequencies where recently tilled soils tend to have lower bulk density compared to conditions before tillage. In line with this finding, different researchers (Nuhu and Tashiwa, 2006; Agbede et al., 2009; Ramzan et al., 2012; Ramzan et al., 2014), revealed that the number of passes of a tractor and traditional plow during tillage creates hardpan by compacting and pressing the agricultural land, which leads to the increased bulk density that finally brings decreased total porosity. Furthermore, Ahmad et al. (2009) reported that plowing with the same implement at the same depth for a long period affected soil physical properties such as bulk density and total porosity.

Table 4. Mean bulk and particle densities, and total porosities immediately and one month after tillage practice

Treatment	Immediately after tillage						One month after tillage			
	BD (g cm-3)		PD (g cm-3)	TP (%)			BD (g cm-3)		TP (%)	
	0-20cm	21-40 cm	0-20 cm	0-20 cm	21-40 cm		0-20 cm	21-40 cm	0-20 cm	21-40 cm
ZT	1.67[a]	1.70	2.58	37.11[b]	35.85		1.68[a]	1.72	36.60[b]	35.09
ODM2	1.65[a]	1.69	2.51	37.86[b]	36.23		1.64[a]	1.70	37.99[b]	35.72
ODM4	1.64[a]	1.67	2.55	38.24[b]	37.11		1.68[a]	1.71	36.60[b]	35.34
DP2	1.55[b]	1.67	2.62	41.51[a]	37.11		1.59[b]	1.68	40.00[a]	36.60
DP4	1.63[a]	1.70	2.58	38.37[b]	35.72		1.67[a]	1.72	36.98[b]	35.22
SE (±)	0.11	0.11	0.03	0.44	0.42		0.01	0.01	0.28	0.21
LSD(0.05)	0.043	NS	NS	1.62	NS		0.039	NS	1.48	NS
CV (%)	1.40	1.90	4.78	2.24	3.33		1.26	0.96	2.09	1.74

Note: Means within a column for specific soil parameters followed by the same letter(s) are not significantly different from each other at P ≤ 0.05; SE= Standard Error, LSD = Least Significant Difference, BD= Bulk Density, PD = Particle Density, TP = Total Porosity, NS = Non Significantly Different, CV = Coefficient of Variation, % = Percentage

Particle density

The tillage implements and frequencies did not bring about significant differences in mean particle density. The lowest and the highest mean values of 2.51 g cm^{-3} and 2.62 g cm^{-3} were recorded for ODM2 and DP2, respectively (Table 4). The mean values were below the average particle density values for mineral soils (2.67 g cm^{-3}). The results showed that the effects of tillage implements and frequencies were non-significant on soil particle density and this might be explained by the fact that particle density is the same as the specific gravity of the soil's mineral materials, excluding the pore spaces. This result is in agreement with those reported by Brady and Weil (2008) that revealed the particle densities of most mineral soils vary between the narrow limits of 2.0–2.75g cm^{-3}. Several studies have shown that particle density of soils do not vary unless there are highly significant differences in soil organic carbon contents (Rühlmann et al., 2006; Martínez et al., 2008).

Total porosity

Following the pattern of bulk and particle densities, the total porosity significantly varied among the treatments for plow layers both immediately and one month after tillage (Table 4). Immediately after tillage, disc plow at two passes and zero tillage resulted in the highest and lowest mean values of total porosity of 41.51 % and 37.10 %, respectively, for the plow layer. At a depth of 21-40 cm, all treatments showed non-significant differences in mean total porosity both immediately after and one month after tillage. The total porosity under tillage with traditional oxen-drawn *Maresha* implements increased with increased frequencies of tillage. Unlikely, the tractor powered tillage implements decreased the total porosity with an increased number of passes through the plow layer. This decrease in mean values of total porosity under motorized implements could be due to the general increase in mean values of bulk density as a result of the repeated heavy wheel traffic causing compaction on the soil which was in line with the findings of Jamshidi et al. (2013) and Miriti et al. (2013).

The lowest mean total porosity value for zero tillage at the plow layer could be attributed to minimal or no soil disturbance, allowing the present soil bulk density to be maintained. According to Foth (1990), the disc plow's highest mean total porosity value at two passes could be attributable to the lowest mean bulk density of the soil during disc plow tillage at two passes, which is likely produced by the disc plow's mechanical disturbance. In addition, Anken et al. (2004) found that disc plow tillage resulted in higher overall porosity than zero tillage.

The mean total porosity values for all treatments revealed a slight decrease for all treatments one month following tillage. At the plow layer, the disc plow with two passes resulted in the highest mean total porosity value of 40.00 percent. At a depth of 21–40 cm, the mean total porosity values were lower than in the plow layers. The drop in mean total porosity values at a depth of 21–40 cm could be attributable to compaction caused by the weight of underlying soil layers and severe machinery loads during multiple passes, which likely raised the mean bulk density of the soil. The results showed that tillage implements and frequencies had a substantial impact on total porosity mean values. The highest mean values of total porosity were found at the plow layer as well as at a depth of 21–40 cm when tillage was done with a disc plow in two passes. This could be because disc plow plowing at two passes creates more porous soil. The soils were more porous just after tillage than they were a month later. The lowest mean total porosity values in zero-tilled soil could be owing to higher soil compaction caused by hard pan, which could lower the number of pores in the soil. This was in contrast to the findings of Tangyuan et al. (2009), who found that zero-tillage soil had higher overall porosity than tilled soil.

Soil water retention characteristics

Soil water content at field capacity (FC) and permanent wilting point (PWP), as well as available water content (AWC), were significantly affected by tillage implements and frequencies immediately after and one month after tillage (Table 5). Tillage by traditional oxen-drawn *Maresha* resulted in more water holding capacity at increased tillage frequencies, while tillage with tractor powered implements at an increased number of passes decreased the water content held by the soil (Figures 1 and 2). The soil water retention characteristic curve also showed that tillage implements and frequencies significantly affected the soil water retention characteristics at each suction. Four frequencies of oxen-drawn *Maresha* tillage resulted in finer soil particles, which increased soil pore space and water retention.

Table 5. Mean variations in soil water contents at field capacity, permanent wilting points and available water

	Immediately after tillage				One month after tillage			
	FC (v/v)	PWP (v/v)	AWC (mm m^{-1})	IR (cm hr^{-1})	FC (v/v)	PWP (v/v)	AWC (mm m^{-1})	IR (cm hr^{-1})
ZT	0.174^{a}	0.073^{c}	101.920^{a}	7.470^{d}	0.076^{b}	0.049^{bc}	26.915^{b}	20.570^{a}
ODM2	0.183^{a}	0.151^{a}	32.550^{b}	15.130^{bc}	0.062^{b}	0.044^{c}	18.197^{b}	7.700^{d}
ODM4	0.208^{a}	0.114^{b}	94.070^{a}	19.530^{ab}	0.123^{a}	0.070^{a}	52.847^{a}	17.200^{b}
DP2	0.178^{a}	0.104^{b}	74.660^{a}	22.700^{a}	0.137^{a}	0.064^{ab}	72.787^{a}	12.500^{c}
DP4	0.126^{b}	0.107^{b}	18.470^{b}	10.270^{cd}	0.065^{b}	0.042^{c}	22.485^{b}	2.930^{e}
SE (±)	0.008	0.007	0.009	1.699	0.009	0.004	0.006	1.713
LSD(0.05)	0.037	0.031	30.006	5.93	0.021	0.018	20.161	3.458
CV (%)	11.35	15.01	24.77	20.98	12.08	17.69	27.71	15.25

Note: Means within a column for specific soil parameters followed by the same letter(s) are not significantly different from each other at $P \leq 0.05$; SE= Standard Error, LSD = Least Significant Difference, CV = Coefficient of Variation, FC = Field capacity, PWP = Permanent Wilting Point, AWC = Available Water Content, IR = Basic Infiltration Rate

The decrease in available water content of the soil tilled by disc plow at four passes, on the other hand, could be owing to an increase in mean bulk density as a result of increased compaction. Furthermore, repeated disc runs on a soil can cause a decrease in mean total porosity values, which can squeeze bigger pores into smaller ones. This result matched the findings of Abu-Hamdeh (2004), who found that the kind of tillage implements and frequency had an effect on the soil water retention characteristics curve and water holding capacity of the soil.

Immediately after tillage, the highest and lowest mean values of water content at field capacity for ODM4 and DP4 were 0.208 cm^3 and 0.126 cm^3, respectively. Tillage with a disc plow in four passes lowered the water content at field capacity substantially. For DP2 and ODM2, the highest and lowest mean water content at field capacity one month after tillage were 0.137 cm^3 and 0.062 cm^3, respectively. This could be attributed to the disc plow's soil loosening impact, which reduced soil bulk density, resulting in larger pores and the ability to hold more water at lower frequencies. Gbadamosi (2013) found that two passes of conventional tillage with a disc plow increased soil water content and lowered soil bulk density. Moreover, Reynolds et al. (2009) revealed that at the plow layer, the water content at a field capacity of greater than 0.14 cm^3 was required in sandy clay loam soils to meet the plant water requirements. However, the more traditional threshold level of soil water content greater than 0.10 cm^3 was typically recommended for agricultural soils in order to reduce the incidence of yield-reducing aeration deficits in the root zone. Accordingly, the results of all treatments immediately after tillage showed good water content for crop growth. But, one month after tillage, only the disc plow at two passes and the oxen-drawn Maresha at four frequencies brought significantly different water content at field capacity, which was ideal for crop growth.

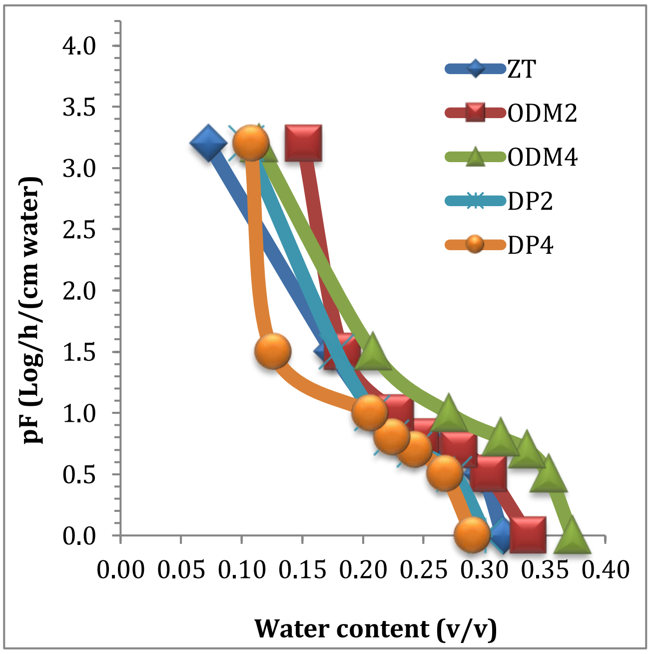

Figure 2. Effects of tillage implements and frequencies on soil water retention characteristics curve immediately after tillage

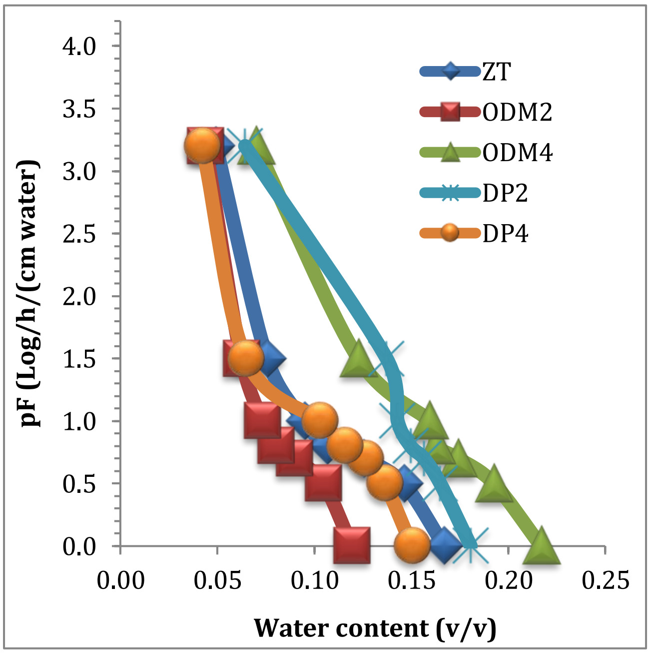

Figure 3. Effects of tillage implements and frequencies on soil water retention characteristics curve one month after tillage

At the permanent wilting point, there was a considerable change in mean water content values. The water content at the permanent wilting point was substantially higher in oxen-drawn *Maresha* at frequency of four, which could be linked to the relatively higher clay content (Table 3) one month after tillage. Because the water content at permanent wilting points pertains to the soil's ability to retain and provide water to plant roots, treatments with higher water content at permanent wilting points are likely to provide and replenish more plant-available water to plant roots.

Available water content (AWC) was significantly different immediately after and one month after tillage. Tillage by ODM4 resulted in the highest available water contents of 94.07 mm m^{-1} at field capacity (Figures 1 and 2). One month after tillage, the highest available water content was 72.80 mm m^{-1} for DP2. The treatment of ODM2 revealed the lowest mean values of 18.197 mm m^{-1} which could be associated with more compaction due to the relatively highest bulk density and low total porosity (Table 4), which resulted in variations of water content at field capacity and permanent wilting points.

In general, the variations in AWC among the treatments were due to the variations in water contents at field capacity and permanent wilting capacity which was in line with the findings of Hodnett and Tomasella (2002). These could, in turn, might be due to differences in bulk densities, sand and clay contents resulting in differences in water held by the soil (Table 3, 4, and 5). The effect of the tillage implements and frequencies on soil water characteristics curve also indicated that tillage under frequent plough by oxen-drawn *Maresha* hold more water at field capacity immediately after tillage, but disc plow at two passes hold more water at field capacity one month after tillage (Figure 2 and 3).

Despite the fact that the mean values of available water contents were significantly different, all treatments had available water contents lower than the average value for ideal crop growth in sandy clay loam soil, as indicated by Saxton and Rawls (2006). According to Reynolds et al. (2009), available water content of ≥ 0.20 cm^3 cm^{-3} was regarded optimum for root growth and functioning, while 0.15 ≤ AWC < 0.20 cm^3 cm^{-3} was good, 0.10 ≤ AWC < 0.15 cm^3 cm^{-3} was limited, and AWC < 0.10 cm^3 cm^{-3} was poor. The results showed that all treatments had inadequate available water contents, with the exception of zero tillage, which had restricted available water contents immediately after tillage. However, one month after tillage, all treatments had mean water content values that could be categorized as limited.

Conclusion

The results of the study indicated that disc plow tillage at two passes affected most of the examined soil physical parameters considerably (P ≤ 0.05) immediately and one month after tillage. All of the treatments' bulk density values for the plow layer were lower immediately after tillage, and the mean values below the tilled layer for most treatments exhibited an increase one month after tillage. Due to substantial soil pulverization at lower frequencies, disc plows with a frequency of two dramatically reduced bulk density and total porosity.

The variation in particle density was non-significant. With the exception of percent clay contents (highest mean value of 26.30%) immediately after plowing by disc plows at two passes, insignificant changes in mean values of particle size distribution were observed. Apart from the minor increases in percent clay content one month following tillage, the soil's textural class remained sandy clay loam. However, soils under zero tillage and oxen drawn *Maresha* at two passes were sandy loam in texture immediately after cultivation. Water contents at field capacity and permanent wilting point was significantly different due to the variations in bulk density and percent clay content, resulting in considerable variances in available water content. At increasing tillage frequency, traditional *Maresha* tillage resulted in more water retention capacity. Among the treatments, soil under zero tillage followed by four oxen-drawn *Maresha's* revealed greater available water content immediately after tillage, but one month later, a two-pass disc plow shown much higher available water content, which could be attributed to the soil's increased clay content, which may hold more water. Furthermore, plowing with a disc plow in two passes had a significant impact on bulk density, total porosity, and soil water retention characteristics.

In conclusion, tillage instruments and frequencies have a negative impact on the physical properties of Fluvisols by altering the soil structure at surface and subsurface depths, resulting in various degrees of impact on soil bulk density, total porosity, and water retention capacity. Therefore, for less disruption of soil properties while performing soil tilth for agricultural production, it is recommended to use tillage implements at lower frequency.

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