On farm evaluation and demonstration of animal drawn moldboard and Gavin plows in the Gumara-Maksegnit watershed

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Abstract: In most small holder farmers in Ethiopian highlands, farmers still use the wooden plow (Maresha).The present trial was conducted in 2011-2012 at Gumara Maksegint water shade, to evaluate the effect of four different tillage methods on teff and wheat yield and soil physical properties. The experiment was performed by using a randomized complete block design with four treatments and three replications. The experiment was carried out on two soil types, a sandy Nitosol prevailing in the hilly upper areas and clayey Vertisol prevailing the valleys. Land preparation by tillage was done with either a Moldboard plow, Gavin plow, or traditional plow, and was compared against ano-tillage treatment. Animal draft force, soil bulk density, penetration resistance, moisture content, and water infiltration, as well as crop yields were recorded. No statistical differencesin terms of yields were found among treatments for both soil types. On the lighter Nitosol tillage implement had significant effect on moisture content, the highest moisture content was on plots tilled with the Gavin plow and the lowest was obtained on no-till treatment. No such clear trend could be observed for soil bulk density. On the Vertisol the effect of tillage implement on moisture content and bulk density was not significant. No-till resulted in lower cumulative infiltrations as compared to Gavin and moldboard plowing, but no significant difference on yield is recorded. Therefore no- tillage can be used as an alternative tillage practice. On reduction of farm power, no-till is promising tillage practice for farmers who don't have draft animal. However, the long-term impact of this practice on soil strength should be further studied.

Keywords: no-tillage, moldboard plow

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1 Introduction

Tillage is the preparation of soil for plant emergence, plant development and unimpeded root growth (Lichet and Kaisi, 2005).In many agricultural systems tillage practices are critical components of soil management (Musaddeghi et al., 2009).

Inappropriate tillage practices could inhibit crop growth and yield, and lead to soil erosion. The selection of an appropriate tillage practice for production of crops is very important for optimum growth and yield. Agood soil management program practices prevent the soil from water and wind erosion, provide a good weed-free seedbed for planting (Wright et al., 2008).

Agriculture is a means of livelihood for about 85% of the Ethiopian population. The main sources of power to carry out agricultural operations are human and animal power. Traditional tillage method with the *maresha* plow requires repeated plowing with any two consecutive tillage operation carried out perpendicularly to each other. This requires longer time for seedbed preparation, and consumes high animal and human energy, while delayed

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planting shortens the length of the growing period available for the crop (Rowland, 1993).

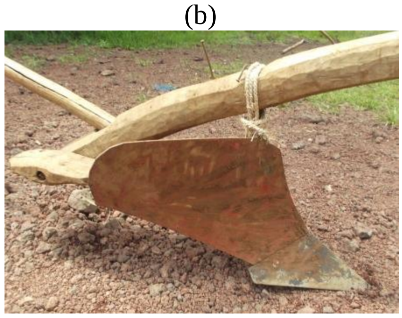
The *ard* or *maresha* plow is the main animal drawn cultivation implement currently use in Ethiopia. This plow consists of a sharply pointed metal shear and metal hook *(wogel*) made by local blacksmiths. The rest of the components of the plow are a wooden yoke, a long beam and two flat wooden parts (*diggers*) made by the farmers themselves. Theplow ha*s* certain advantages. Apart from the metal point and the hook it is entirely homemade. It is light, usually about 14 kg and (not exceeding 25 kg), and thus can easily be carried to and from fields and is simple and convenient to work with(Goe, 1987). The power requirement can be adjusted by the depth control and does not normally exceed the power developed by a pair of local *Zebu oxen*. Time required for land preparation is 90-150 h/ha depending on the soil type. After being broadcast seeds are unevenly covered by a final pass with the *maresha* and often germination is poor. To overcome this problem farmers generally use high seed rates (Astatke et al.,1983).

Some attempts were made in the past to improve and develop suitable tillage implement. The Agricultural Implement Research and Improvement Center (AIRIC) of Ethiopia developed a moldboard plow (width 26 cm,depth 12 cm)which can be attached to traditional plow beam, handle, *deger* and *merget*, with that of the moldboard plough bottom. This reduces the weight of the moldboard plough from about 26 kg to 15 kg (the *maresha* weighs 14 kg). In some cases the original steel moldboard plow weighs up to 35 kg. The reduction in weight has avoided the problem of soil compaction and hard pan formation (Meless, 1999), and has increased attractiveness to farmers who prefer a light plow.

The Gavin Armstrong plow was introduced in Ethiopia by Germany technical cooperation (GTZ). It is a primary tillage implement, which can perform deep-plowing, harrowing and seed covering. The implement was developed by combining the traditional *maresha* plow parts such as its wooden beam, handle, and double *diggers*, with a common Gavin plow. The plowing depth is about 15 cm, which is sufficient to cut the plowing pan created by plowing at shallower depth with the *maresha*. In addition, with the help of the attached knife it can plow even deeper into the soil, thus potentially improving deep-soil water infiltration and thus reducing runoff.

(a)

(b)



(c)

Figure1 Tillage implements selected for the experiment: (a) *Maresha* (b) *Gavin plow* (c) Moldboard plow

No-tillage is defined as a system of planting (seeding) crops into untilled soil by opening a narrow slot, trench or band only of sufficient width and depth to obtain proper seed coverage. No-tillage often relies on applying post-emergence broad-band herbicides, such as *glyphosate*.

Some studies shown that, on-farm and on-station experiments in different parts of Ethiopia have revealed promising results with no and minimum tillage systems with wheat (Triticumaestivum), maize (Zea mays), and sorghum (Sorgumbicolour (L.) Moench) (Asefa et al., 2004; Global S., 2001; Astatke et al., 2000).However, there is a paucity of information regarding the effect of tillage in *teff*.

Studies comparing no-tillage with conventional tillage systems have given different results for soil bulk density. In most of them, soil bulk density was greater in no-tillage in the five to ten centimeter soil depth (Osunbitan et al., 2005). In others, no differences in bulk density were found between tillage systems (Logsdon et al., 1999).

Study made by (Chan et al., 1989) indicated that untilled soils had greater hydraulic conductivity than tilled soils. Other authors have not found differences in infiltration rates between tilled and untilled soils (Ankeny et al., 1990), or have found lower infiltration rates in untilled soils (Heard et al., 1988).Economically no-tillage is superior over conventional method of sowing because more net returns were recorded on no- tillage farms than that of conventional wheat farms in addition to its edge of eco-friendly practice (Nagarajan et al. 2002). Therefore, this study was undertaken with the following specific objectives:

To evaluate the technical performance of the moldboard and Gavin plows against the traditional plow. To evaluate the impact of no-tillage as against the conventional methods; To evaluate the effect of the improved plows on soil infiltration and crop productivity; To undertake a farmers' evaluation on the system compatibility of the new implements.

2. Materials and methods

The field experiment was carried out for two years, 2011-2012, at *Gonder Zuria Woreda*, in the *Gumara-Maksegnit* watershed. The main rainy season in the study area lasts from June to August. It was conducted on farmer's field with two common soil types, a sandy Nitosol prevailing in the hilly upper areas and clay Vertisol prevailing the valleys. Due to double cropping practice in the area, farmers have cultivated the field immediately after the first year experiment harvest. As a result, the next experiment was conducted on the other field but adjacent field.

Table1 Location of the experimental site

Year	Vertisol	Nitosol
2011	Longitude $34^0 87'$E	Longitude $34^0 60'$E
	Latitude $13^0 74'$ N	Latitude $13^0 35'$ N
	Altitude 2101 m	Altitude 2013 m
2012	Longitude $37^0 34'$E	Longitude $37^0 36'$E
	Latitude $12^0 25'$ N	Latitude $12^0 26'$ N
	Altitude 2109 m	Altitude 2059m

2.1 Experimental Design and Tillage System

The experiment was set up as a randomized complete block design with four treatments and three replications. The treatments were *Maresha*, Gavinplow; Moldboard and No-tillage, in conjunction with two crops (wheat and teff) which were randomly assigned to the plots. The plot size for each treatment was 40 m x10m.

On Vertisol wheat variety *Taye* was planted at seed rate of 150 kg/ha and fertilizer was applied to the trial site uniformly at the rate of 100 kg/ha of Diammonium phosphate (DAP) and 125 kg/ha Urea. On Nitosol *teff* variety *Quncho* was planted at seed rate of 25 kg/ha and fertilizer Diammonium phosphate (DAP) 100kg/ha and 137 kg/ha Urea was applied.

After plowing the plots on Nitosol was compacted by trampling of cattle, to mimic traditional method, sowing *teff*, the seed and fertilizer were broadcasted by hand, and on Vertisol sowing wheat, seed and fertilizer were broadcasted by hand and covered using Broad Bed Maker (BBM). Herbicide (glyphosate) was used to control weeds in no- tillage treatments ten days prior to sowing. No- tillage farming involves planting and fertilizer in a narrow slot, opened by the Gavin plow.

Weed count data (per meter square) were collected prior to hand weeding. Four counts of 0.25 per m^2 each using quadrant were taken from each plot resulting in a total sample area of one square meter. At harvest, wheat and *teff* were harvested from an area 351 m^2 each plot for determination of yield.

2.2 Measurements

Measurements of draft force requirement were carried out using a digital dynamometer (RON 2000 Dynamometer Eilon Engineering Ltd) for all plows. The load cell was attached between the center of the yoke (*keniber)* and the end of the plow beam (*mofer*).Field performance tests were made on 40m long plots for all implements. Readings were taken every ten seconds and then averaged the mean.

The working height of both the yoke and the beam length were measured, and the force multiplied by cosα, where α is the angle the beam makes with the ground. Furrow Depth, width and cross-section area were measured during the test. Draft was divided by implement cross-section area to obtain unit draft (N/cm^2).

2.3 Soil physical properties

Soil penetration resistance as cone index, bulk density and gravimetric water content were measured at the site just immediately after land preparation and after crop harvesting. The penetration resistance of a soil was measured to a depth of 25 cm at 5 cm increments using hand pushed cone Penetrometer (Eijkelkomp). Cone having included angle of 60^0 with base area of 3.33 cm^2 and 1cm^2 were used after land preparation and harvesting respectively. The soil penetration resistance was recorded as a function of depth. Measurements were taken at five random locations in each plot and the average result was taken.

Soil moisture content on dry weight basis was determined randomly. The soil samples were taken from the test plots, at a depth of 0-10, 10-25, 25-40 cm. Soil samples were weighed and oven dried at 105 ℃for 24 hours and weighed again, and the soil moisture percent calculated. To measure soil bulk density (g/cm^3), undisturbed ring-core soil sample were randomly taken at a depth of 0-13, 13-26 and 26-39 cm from the test plot. The samples were dried in at 105 ℃for 24 hours and dry weight of soil sample was recorded. Soil samples collected from each plot were sent to *Gonder* soil laboratory for soil texture analysis.

2.4 Infiltration rate

Infiltration rate of the soil was measured in all treatments using double ring infiltro meter described by Michael (1978).The rate of fall of water was measured in the inner ring while a pool of water was maintained at approximately the same level in the outer ring to reduce the amount of lateral flow from the inner ring.

Table2 Frequency of tillage for different tillage treatment on vertisol

Treatment	Description	
	Vertisol	Light soil
Maresha	Two pass of *Maresh*a+BBM	Three pass of *Maresha+Maresha(Guligualo)*
Gavin plow	Two pass of *Gavin plow*+BBM	Three pass of *Gavin plow* +*Maresha(Guligualo)*
Moldboard plow	Two pass of moldboard+BBM	Two pass of Moldboard + *Maresha(Guligualo)*
No- tillage	Direct drill	Direct broadcast

Note: BBM- Broad bed maker

2.5 Data Collection and Analysis

Data collected were subjected to analysis of variance and means. The results with significant difference were separated using the Least Significant Difference (LSD) at 5% probability level Gomez and Gomez, (1984)

2.6 Calculating of Gross Margins

The profitability of moldboard plow and no-tillage system was assessed based on gross margins, calculated as the difference between the gross income and variable cost incurred. The value of the grain together with the value of straw constituted the gross income while the variable cost included fertilizer, herbicide seed, and land preparation, hand weeding, harvesting, and threshing cost. The gross margin was calculated for teff and wheat each on the area 1200m^2. The cost of straw and cost of a pair of oxen per day (including the handler) was estimated based on informal surveys. The market price for teff and wheat grain was obtained from grain traders.

3. Results and discussion

Table 3 Texture characteristics of the experimental soil under replication Vertisol and Nitosol

Soil type	Replication	2010/2011 Season			2011/2012 Season		
		Sand %	Clay %	Silt %	Sand %	Clay %	Silt %
Vertisol	R1	18.5	61.5	20	23.5	46	30.5
	R2	17	61.5	21.5	20.5	43	29
	R3	24.5	51.5	24	21	47	32
Nitosol	R1	22	45.5	32.5	21.5	42.5	36
	R2	25.5	42	33	23	36.5	40.5
	R3	24.5	51.5	24	25.5	38	36.5

3.1 Draft force

Analysis of draft force of all the implements during the tillage experiment showed significant difference in terms of working width (Table 4 and 5). Increasing working width means that fewer passes are needed to cover each hectare of land, thus as a constant speed increasing the working width also increases the rate of work. The highest cross-section area was recorded on moldboard plow. It is usually assumed that the higher the working width the better the hourly field capacity.

In the first year (2011) of the trial on both soil types the recorded draft forces were insignificant between treatments. As compared to the second year trial, the draft force was high for all treatments mainly due to low moisture in the soil. In the second year (2012) of the trial implement type had a significant effect on draft force. The highest draft force was recorded under moldboard plow at soil moisture of between11 % and 31 %in the Nitosol. Since first plowing was started at the beginning of the rainy season the range of moisture content was high. With 601N, or draft power of 0.3kN, at an average speed of 0.5 m/s, it was within the capability of a pair of oxen. Variation on draft values of different implements was attributed to the variation in implement geometry.

Hopfen, (1996), Goe and Mc Dowell, (1980) confirmed that the capability of a pair of typical Zebu oxen which is usually assumed to be in the range of 0.3to0.8kN.The speed of movement is in the range of 0.6 to1m/s, which is primarily depends on species and breed.

Table 4 Implement parameters affected by implement type on Vertisol

Crop year	Tillage implement	Draft force (N)	Working width (cm)	Working depth(cm)	Furrow cross-Section (cm^2)	Unite draft N/cm^2
2011	*Maresha*	705.4	17.1 b	9.8	137.4 b	6.1 ba
	Gavin plow	831.3	16.9 b	10	121.4 b	7.5 a
	Moldboard	719.8	22.6 a	9.5	181.7 a	4.3 b
	LSD (5%)	131 NS	1.7	1.3 NS	34.6	1.1
2012	*Maresha*	476.8 b	15.9 b	9.3 b	104.6 b	4.7
	Gavin plow	469.7 b	14.5 c	9.1 b	95.7 b	5.2
	Moldboard	582.6 a	19.3 a	10.2 a	136.7 a	4.4
	LSD(5%)	91.4	1	0.6	12.4	0.9 NS

Note: Means followed by different letter(s) within a column are significantly different.

NS= means are not significantly different

Table 5 Implement parameter as affected by implement type on Nitosol

Crop year	Tillage implement	Draft force (N)	Working width (cm)	Working depth(cm)	Furrow cross-Section (cm^2)	Unite draft N/cm^2
2011	Maresha	716.3 a	18.8 b	10.8 a	153.1	4.9 ba
	Gavin plow	739.8 a	18.5 b	10.6 a	142.6	5.4 a
	Moldboard	715.7 a	23.2 a	9.9 a	172.2	4.3 b
	LSD 5%	93.4 NS	1.2	1.4 NS	30.1	0.9
2012	Maresha	529.8 b	17.5 b	9.2 b	110 b	5.3 a
	Gavin plow	514.3 b	15.2 c	9 b	96.9 c	5.6 a
	Moldboard	601.7 a	18.8 a	10.1 a	127.6 a	4.9 a
	LSD 5%	67	1	0.6	11.8	1.1 NS

Note: Means followed by the same letter(s) within a column are not significantly different.

NS= means are not significantly different

3.2 Grain yield

Tillage treatments had no significant impact on the grain yield on both soil types (Table 6and 7).This study shows that no tillage seems to be an interesting option for farmers to plant wheat on Vertisol , as there is no yield difference between no tillage and conventional tillage.

Table6 Effect of different tillage treatment on crop yield of wheat

Treatment	Grain yield kg/ha	Straw kg/ha	Number of weeds per m^2
NT	1667 a	2134 a	120.5 a
MA	1541 a	1892 a	116.1 a
GV	1448 a	1853 a	140 a
MD	1657 a	2133 a	143 a
LSD(5%)	533.9	603	61
CV(%)	27	24.7	38

Note: NT-No tillage, MA-Maresha, GV- Gavin plough, MB- Moldboard plough

Means in the same column with different letters differ significantly at 0.05 probability levels.

Table7 Effect of different tillage treatment on crop yield of *teff*

Treatment	Grain yield kg/ha	Straw kg/ha	Number of weeds per m^2
NT	1505.8 a	4010.8 a	139 a
MA	1561.6 a	3645.7 ba	119.5 a
GV	1596.5 a	3382.3 b	150.2 a
MD	1656 a	3581.2 ba	142.5 a
LSD(5%)	225	509	58
CV(%)	11.7	11.4	34

Note: NT-No tillage, MA-*Maresha*, GV- *Gavin plough*, MB- Moldboard plough

Means in the same column with different letters differ significantly at 0.05 probability levels.

3.3 Soil moisture

Soil moisture content was determined after land preparation and crop harvesting. On Nitosol at the time of planting, tillage implement had significant effect on the moisture content, while the moisture content was high, with Gavin plow and the lowest moisture content obtained under no-tillage. The effect of depth on moisture content was inconsistent (Table 8). On Vertisol during planting tillage implement had no significant effect on moisture content. But effect of depth on moisture content shows significant effect on the top layer 0 to-13 cm. As the depth increase moisture content decreases (Table 9). During harvest on Nitosol, effect of tillage on soil moisture had significant effect, the highest moisture content 24.3% and 24.6 % was recorded on moldboard and Gavin plow. But effect of depth on moisture content was insignificant (Table 10). During harvesting effect of tillage implement and depth on moisture content shows insignificant effect (Table 11).

3.4 Soil bulk density

At the time of planting and harvesting on both soil types tillage implement had no significant effect on soil bulk density. Effect of depth on bulk density appeared in the top layer 0 to13 cm depth. As expected, given the rather low effect plowing depth of the tested implements, below 13 cm there were no detectable difference inbulk density, the lowest bulk density 0.63 g/cm^3 and the highest 1.23g/cm^3 was recorded. Kar et al. (1976) reported that a bulk density greater than 1.6 M/gm^3 for loam soil adversely affected the root growth.

3.5 Penetrationresistance

During planting on Nitosol and Vertisol tillage effects in relation to varying soil depth on penetration resistance were statistically significant among tillage implement. Penetration resistance increased with tillage depth under all tillage implements. The highest penetration resistance was recorded under no-tillage (1MPa), and the lowest penetration resistance detected on moldboard and *Gavin plow*.

In several studies comparing tilled and non-tilled soils, greater penetration resistance was found under no-tillage, especially in the upper 10 cm (Wander and Bollero, 1999; Ferreras et al.,2000).The highest penetration resistance after harvesting was detected on no-tillage treatment (Figure 2a, 2band 2c).

Table8 Effect of tillage and depth on Penetration resistance, bulk density and gravimetric water content on Nitosol during planting

Crop year	Treatment			BD (g/cm^3)	GWC (%)	PR (Mpa)
2011	No-till			1.18 a	32.5 b	1.00 a
	Maresha			1.21 a	37.2 a	0.77 b
	Gavin plow			1.16 a	36.5 a	0.80 b
	Moldboard plow			1.13 a	34.2 ba	0.69 b
	Depth 1	Depth 2	Depth 3			
	0-13	0-10	0-5	1.17 a	36.33 a	0.45 c
	13-26	10-25	5-10	1.16 a	35.8 ba	0.62 c
		25-40	10-15		33.25 b	0.85 b
			15-20			0.98 b
			20-25			1.18 a
	CV(%)			9.7	8.79	29.5
2012	No-till			0.925 a	28.08 b	0.55 a
	Maresha			0.950 a	30.87 ba	0.49 b
	Gavin plow			0.943 a	32.46 a	0.42 c
	Moldboard plow			0.946 a	31.2 ba	0.50 ba
	Depth 1&2	Depth 3				
	0-13	0-5		0.99 a	29.8 a	0.41 c
	13-26	5-10		0.90 b	30.8 a	0.46 bc
	26-39	10-15		0.92 b	31.2 a	0.50 ba
		15-20				0.52 a
		20-25				0.56 a
	CV (%)			5.66	12.3	14.9

Note: * Different letters in the columns indicate significant difference at 0.05 probability level
** BD is soil bulk density; GWC is gravimetric water content; and PR is soil penetration resistance
*** D1, D2 and D3 are soil depth for BD, GWC and PR

Table8 Effect of tillage and depth on Penetration resistance, bulk density and gravimetric water content on Nitosol during planting

Crop year	Treatment			BD (g/cm^3)	GWC (%)	PR (Mpa)
2011	No-till			1.18 a	32.5 b	1.00 a
	Maresha			1.21 a	37.2 a	0.77 b
	Gavin plow			1.16 a	36.5 a	0.80 b
	Moldboard plow			1.13 a	34.2 ba	0.69 b
	Depth 1	Depth 2	Depth 3			
	0-13	0-10	0-5	1.17 a	36.33 a	0.45 c
	13-26	10-25	5-10	1.16 a	35.8 ba	0.62 c
		25-40	10-15		33.25 b	0.85 b
			15-20			0.98 b
			20-25			1.18 a
	CV(%)			9.7	8.79	29.5
2012	No-till			0.925 a	28.08 b	0.55 a
	Maresha			0.950 a	30.87 ba	0.49 b
	Gavin plow			0.943 a	32.46 a	0.42 c
	Moldboard plow			0.946 a	31.2 ba	0.50 ba
	Depth 1&2	Depth 3				
	0-13	0-5		0.99 a	29.8 a	0.41 c
	13-26	5-10		0.90 b	30.8 a	0.46 bc
	26-39	10-15		0.92 b	31.2 a	0.50 ba
		15-20				0.52 a
		20-25				0.56 a
	CV (%)			5.66	12.3	14.9

Note: * Different letters in the columns indicate significant difference at 0.05 probability level

** BD is soil bulk density; GWC is gravimetric water content; and PR is soil penetration resistance

*** D1, D2 and D3 are soil depth for BD, GWC and PR

Table10 Effect of tillage and depth on BD, and GWC on Nitosol during harvesting

Crop year	*Treatment*		*BD (g/cm^3)*	*GWC (%)*
2011	No-till		1.22 a	21.01 b
	Maresha		1.26 a	22.06 ba
	Gavin plow		1.25 a	21.3 b
	Moldboard plow		1.21 a	24.3 a
	D 1	D 2		
	0-13	0-10	1.26 a	22.5 a
	13-26	10-25	1.21 a	21.3 a
		25-40		22.6 a
	CV(%)		*7.59*	13.8
2012	No-till		0.812 a	21.66 ba
	Maresha		0.816 a	18.02 b
	Gavin plow		0.807 a	24.61 a
	Moldboard plow		0.831 a	18.92 b
	D 1&2			
	0-13		0.88 a	18.9 a
	13-26		0.79 ba	21.16 a
	26-39		0.76 b	22.11 a
	CV(%)			

Note:*Different letters in the columns indicate significant difference at 0.05 probability level

** BD is soil bulk density; GWC is gravimetric water content; and PR is soil penetration resistance

*** D1, D2 are soil depth collected soil sample for BD &GWC

Table11 Effect of tillage and depth on BD, and GWC on Vertisol during harvesting

Crop year	*Treatment*		*BD (g/cm^3)*	*GWC (%)*
2011	No-till		1.18 a	28.9 a
	Maresha		1.23 a	28.4 a
	Gavin plow		1.19 a	28.1 a
	Moldboard plow		1.18 a	30.5 a
	D 1	D 2		
	0-13	0-10	1.2 a	21 c
	13-26	10-25	1.19 a	30.7 b
		25-40		35.5 a
	CV(%)		*8.13*	16.21
2012	No-till		0.745 a	32.15 a
	*Maresh*a		0.704 a	31.76 a
	Gavin plow		0.774 a	33.21 a
	Moldboard plow		0.776 a	30.26 a
	D 1&2			
	0-13		0.839 a	50.06 a
	13-26		0.739 b	32.8 a
	26-39		0.671 c	32.6 a
	CV(%)			

Note: *Different letters in the columns indicate significant difference at 0.05 probability level

** BD is soil bulk density; GWC is gravimetric water content; and PR is soil penetration resistance

*** D1, D2 are soil depth collected soil sample for BD &GWC

2.2.2 Apple identification approach

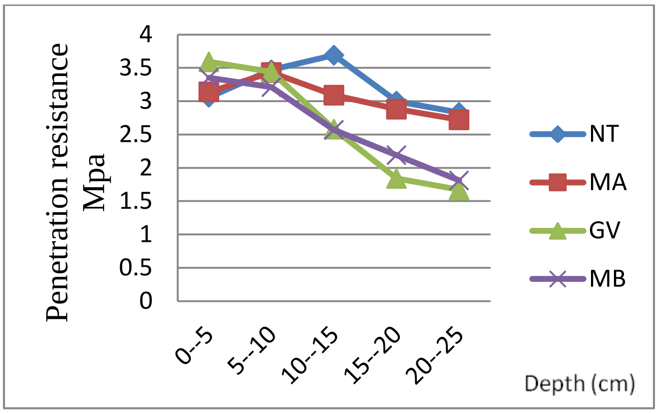


Figure2a Soil penetration resistance during harvest on Vertisol 2011year

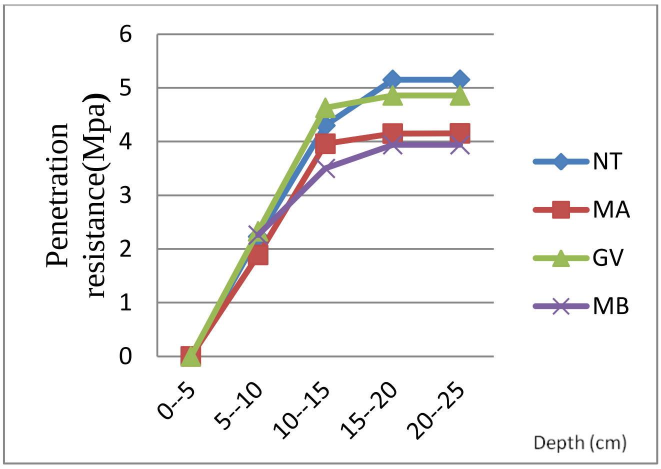


Figure2b Soil penetration resistance during harvest on Vertisol 2011/12

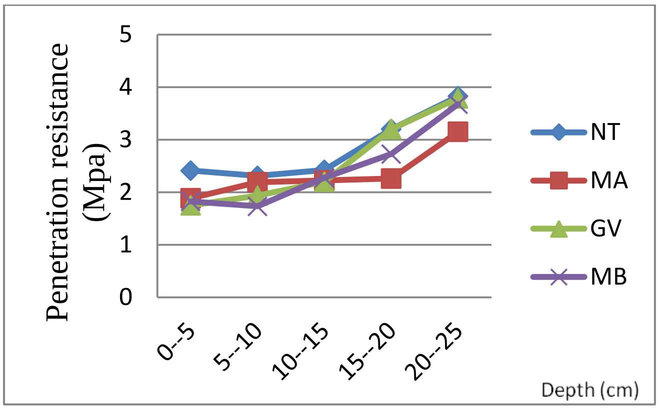


Figure2c Soil penetration resistance during harvest on light soil 2011/12

3.6 Infiltration

No-tillage had the lowest cumulative infiltration, whereas the Gavin and moldboard plow have the highest cumulative infiltration measured during harvesting crop (Figure3a 3b, and 3c).

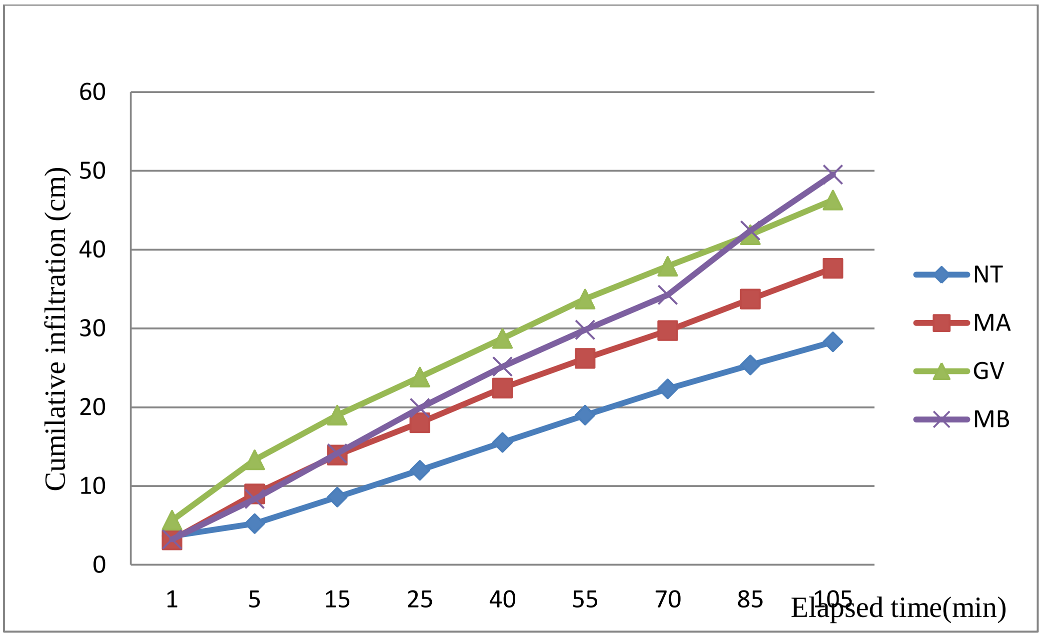


Figure3a Cumulative Infiltration on vertisol for 1st year (2011) experiment

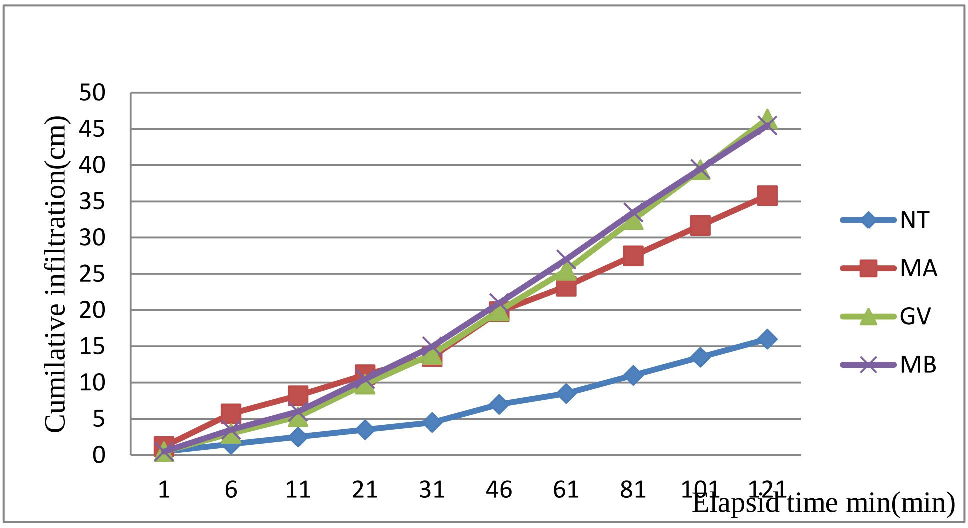


Figure 3b Cumulative Infiltration on Vertisolfor 2nd year (2012) experiment

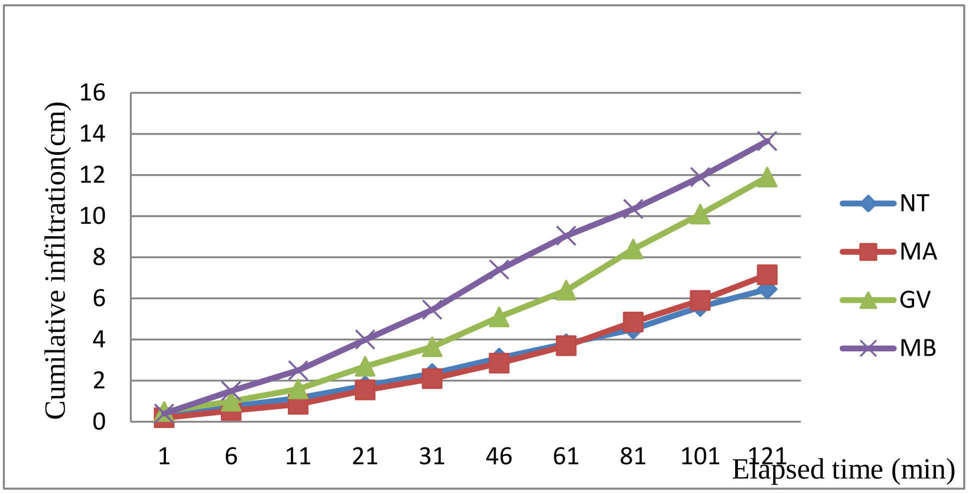


Figure3cCumulative Infiltration on Nitosolfor 2nd year (2012) experiment

Table 12 and 13 showed economic analysis indicated that on wheat production gross margins for no-tillage treatment were greater than for moldboard plow, but on *teff*production the gross margins of no- tillage is less than moldboard plow, so the performance of no-tillage was better on Vertisol than on Nitisol.

Farmers who do not have oxen often so late or pay 50% of their harvest to get their land plow resulting in lower yields. In this regard, no-tillage reduce work load at the pick season. Development of alternatives to conventional tillage may therefore reduce the cost of hiring oxen. No-tillage can be particularly very important for female-headed households.

Result obtained by Sasakawa Global(2002) for *te*ff in Ethiopia, showed that no-tillage combined with herbicides, fertilizer and mulching was more profitable than the traditional tillage and that the benefits of conservation agriculture increased over the years (Ito et al.,2007).

Table12 Consolidate budget for wheat treatment Moldboard plow and No- tillage

Activity	*Operation name*	*Moldboard plough*				*No-till*			
		time (hr)	Labor (birr)	A/power (birr)	Total (birr)	Time (hr)	Labor (birr)	A/power (birr)	Total (birr)
1	1st plowing	5	-	100	100	-	-	-	-
2	2nd plowing	4	-	100	100	-	-	-	-
3	Spraying herb.	-	-	-	-	1	15	-	15
4	Planting	8	-	100	100	8	90	100	190
5	1st weeding	10	210	-	210	10	120	-	210
6	2nd weeding	10	210	-	210	10	210	-	210
7	Harvesting	8	120	-	120	8	120	-	120
8	Threshing	10	150	-	150	10	150	-	150
Animal power & labor sub total		55	690	400	990	47	705	200	895
Material and services									
Activity	Materials	Qt	Cost/unit		Total	Qt	Cost/unit		Total
3	Roundup		-		-	0.25 l	314		78.5
4	Wheat seed	18 kg	8.03		144.54	18 kg	8		144.54
4	DAP	12 kg	15.14		181.68	12 kg	15.14		181.68
4	Urea	15 kg	12.42		186.30	15 kg	12.42		186.30
8	Fuel	1 lt	18		18	1 lt	18		18
Total material cost					530.52				609.02
1	Gross cost				1520.5				1504.02
2	Gross income wheat	181	9		1629	185	9		1665
	straw				100				100
3	Gross profit				208.48				260.98

Note: A/power =animal power, Gross profit is calculated for the plot area of 1200m^2

Table 13 Consolidate budget for *teff* treatment Moldboard plow and No- till

Activity	Operation name	Moldboard plough				No-till			
		time (hr)	Labor (birr)	A/powr (birr)	Total (birr)	Time (hr)	Labor (birr)	A/powr (birr)	Total (birr)
1	1st plowing	5	-	100	100	-	-	-	-
2	2 nd plowing	5	-	100	100	-	-	-	-
3	Spraying herbicide					1	15	-	15
4	Land clearing					6	150		150
5	Planting	8	60	160	160	1	3		3
6	First weeding	6	150	-	150	6	150	-	150
7	Spraying insecticide	1	15	-	15	1	15	-	15
7	Second weeding	6	150	-	150	6	150	-	150
8	Harvesting	10	150	-	150	10	150	-	150
9	Threshing	10	150	-	150	10	150	-	150
Animal power & labor sub total		51	675	460	975	41	783		783

Activity	Materials	Qt	Cost/unit	Total	Qt	Cost/unit	Total
Material and services							
3	Roundup				0.25 l	314	78.5
4	*teff* seed	3	14.08	42.24	3	14.08	42.24
4	DAP	12	15.14	181.68	12	15.14	181.68
4	Urea	16.4	12.42	204.18	16.44	812.42	204.18
7	Insecticide		110	36.66		110	36.66
9	Fuel	1 lt	18	18	1 lt	18	18
Total material cost				482.76			561.26
1	Gross cost			1457.76			1344.26
2	Gross income teff	179	14	2506	162	14	2268
	straw			120			120
3	Gross profit			1168.4			1043.74

4. Conclusion

The following conclusion can be drawn from this work: On conventional tillage implement, the highest moisture content was on plots tilled with *Gavin plow*; however work output is similar to the traditional plow. But moldboard plow cuts deeper and thus retained more water, it achieved greater working width and complete plowing in two pass thereby reduce tillage frequency by half compared to traditional *maresha*. Hence, farmers could get free time to do other activities and draft animal could get rest. Therefore, farmers in Ethiopia can improve tillage efficiency of the *maresha* ard plow by using improved moldboard plow. Gross margin analysis showed that wheat planting by no-till method is more profitable than the other treatment. On reduction of farm power, no-till is promising tillage practice for farmers who don't have draft animal. The technology can be particularly very important for female headed household in Ethiopia.

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