Participatory evaluation and demonstration of animal drawn compactor for Teff seedbed preparation

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Abstract: The research was conducted at north west of Ethiopia, Amhara Region, west Gojjam Zone, Burie Woreda and Bahirdar Zuria Woreda at two kebeles on two types of soils vertisol (heavy soil) and clay loam (light soil). Teff is the typical cereal production and staple food of Ethiopians. Teff needs six up to eight times of plowing and then during seeding time, the field needs trampling that makes the small size of Teff seed stick with the soil. Trampling is usually done by walking domestic animals (Cattle, Mules, Donkeys, Sheep and Goats) over the prepared teff field over more than six hours. It is demanded to substitute the trampling technique by other technologies, then the animal drawn compactor was produced in Bahirdar Agricultural Mechanization and Food Science research center and evaluated with Farmers. The result revealed that animal trampling and compactor have significant difference over the non trampling in terms of yield at Burie (T1&T2) sites, whereas at Bahirdar site there was no significant difference among all treatments (2010/2011). On the second year (2011/2012), the compactor had higher yield compared to animal trampled and non trampled; and the statistical analysis showed significant differences. In terms of economical benefit, animal trampled plot had more expenditure compared to non trampled plot, but the maximum profit is on animal trampled and compactor, than non trampled. During the demonstration and field day, the farmers commented the compactor is also useful for trampling finger millet field after seeding. According to observation and farmers comment and the result revealed that it is a must to compact the soil for Teff production at optimum moisture on vertisol and light clay soil. Hence, the evaluated technology should be demonstrated in Teff producing area where trampling is practiced and is better to collect other farmers' preference.

Keywords: animal trampling, compacting, Teff

Citation: Kidanemariam, G., G. Likeleh, A. Getahun, M. Liben, and A. Mulat. 2013. Participatory evaluation and demonstration of animal drawn compactor for Teff seedbed preparation. Agric Eng Int: CIGR Journal, 15(2): 112−121.

1 Introduction

Out of the estimated 19.6 million population of the Amhara region, 87.7% is rural population (BOA, 2007) and this population is dependent almost entirely on agriculture. Hence, it is undeniable fact that incredible effort has been pumped to enable this agrarian population produce for self-consumption and for marketing. However, agricultural survey results indicate lower agricultural productivity compared to self and world standards. It is obvious that productivity of agriculture is strongly related to the timely and efficient land preparation activities, among others. Most of the farmers in the region usually prepare their land either using human power or drafting animals.

Cereals are grown in almost all regions of Ethiopia with notable variation in the extent. The area coverage for Teff, Sorghum and Maize are 26.03%, 13.56% and 10.24% of the total cultivated land of the region respectively; whereas based on production of the crop, Teff, Maize and Sorghum are 21%, 19.33% and 15.58% of the total cereal production of the region respectively.

Received date: 2013-03-14 **Accepted date:** 2013-05-21
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In East Gojjam, Teff is the dominant crop that take in coverage 39.47% (170,168.53 ha) and in production 36.33 % (1,971.905 T) and in West Gojjam, similarly, Teff take in coverage 25.08 % (102,895.72 ha) and in yield 15.69% (896.714 T) (CSA. 2001). This shows that in west and east Gojjam zone, one of the dominant crops is Teff.

Teff is the typical cereal production and staple food of Ethiopian. Production of this crop requires more time and labor from field preparation (plowing, harrowing, seeding and weeding) and harvesting as well as post harvesting operation. Teff needs six up to eight times of plowing the land and then during seeding time, the field needs trampling that makes the small size of Teff seed stick with the soil. Trampling is usually done by walking all domestic animals (Cattle, Mules, Donkeys, Sheep and Goats) over the prepared Teff field for more than six hours.

The farmers couldn't utilize new technology, due to inadequate technological know-how in the region as well as in the country. The farmers experience seeding of Teff requires more animal power for trampling of the Teff field. An observation was made in farmers field to observe sever trampling during peak seeding time and the result shows that the power requirement for trampling quarter of a hectare of Teff needs 15 to 20 animals for 6 hours (personal communication with farmers).

Current studies reported shows that most farmers decrease their number of animals due to lack of animal feed and grazing land. This would be a serious challenge for trampling. Most of the farmers said that 'the crucial operation for producing of Teff' is trampling the field in order to compact the plowed field and prepare well seed bed in order to stick the small seed Teff. There are different challenges and constraints Teff production is currently facing, among which the trampling and weeding ranks first, especially in West Amhara region and also at Teff producing area of the country.

Amare T. et al. (2006) showed that there was no significant difference between trampled and not trampled field in terms of yield parameters; rather there is difference in runoff. The highest runoff (898.05 m^3 water ha^{-1}) and soil loss (3549 kg ha^{-1}) was registered from trampled treatment. In general according to Amare T. et al. (2006) trampling has no advantage except the demand of livestock and other inputs for the job, no reward or positive response was found from trampling; rather the loss of water and soil was very high.

In other word, trampling is exercised by farmers to promote germination and establishment, to make the seed bed firm, to prevent the soil surface from drying and free the seed bed from weeds (Seyfu, 1997). Compaction affected almost all yield and yield components of Teff significantly. Higher number of tillers per plant (2.64) from non compacted plots and higher stand cover (about 94%) from compacted plots were found. In addition, maximum biomass (4,210.617 kg ha^{-1}) and grain (1,221.98 kg ha^{-1}) yields were obtained from compacted plots due to enhanced soil to seed contact resulting in increased plant population Haftamu et al. (2009).

This research result agrees with the farmers' practice; however although farmers know trampling requires huge number of animal and labor, they are forced for trampling, because of its productivity advantage. The farmers are continuously requesting to have a technology which can assist the trampling, to continue producing the crops Teff which is vital for most people of the country.

Hence, this project aims at evaluating and demonstrating compactor drawn by animal at selected area and extends for others. Moreover, it aims at demonstrating these technologies to the farmers and collecting the comparative advantage or disadvantage of trampled over not trampled field in terms of yield and its economic benefit.

2 Material and methods

2.1 Designing and production

The design of compactor system was prepared according to the design procedure as given by Karel. N. et al. (1989).

The basic requirements of the compactor are:

- Size of the compactor should not be more than 1 meter width, it must be easy for turning and maneuvering of the implement
- The draft force required to pull the compactor

should not be more than 60 – 80 kgf and is considered to be pulled by Ethiopian oxen

❖ The weight of the compactor should not be more than 70 kg and should be easy for transportation

2.2 Conceptual design

To determine the draft force for the compactor the resistance of soil based on the type of soils should be known.

Resistance force or required force for compaction (Equation (1)) (Karel. N. et al. (1989)

$$p = q_0 \times \sqrt{h} \quad (1)$$

where, p-resistance force against the compactor, kPa; q_0-at the given soil density the resistance for compaction, Nm^{-3}; q_0 -for fresh ploughed land, 2 – 4 MN m^{-3}; q_0 -For unploughed land and grassy field, 10 – 25 MN m^{-3}; q_0 -for asphalted and concreted field, 100 – 200 MN m^{-3}; h-the depth of compacted soil, m.

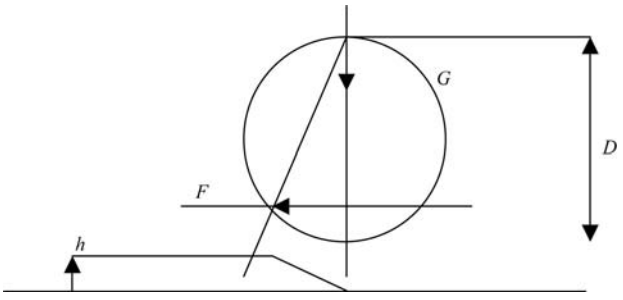
The density of soil estimated for common soil, Ds = 1170 – 1680 kg m^{-3}

So total weight of compactor that needs to compact the soil at h=20 mm was calculated assuming the soil q_o = 3 MN m^{-3}

P = 3 MN m^{-3}×0.02 m = 6000 N m^{-2}

The compactor size diameter was calculated based on the depth of soil intended to be compacted, and it was estimated to compact the soil at a depth of h = 10– 25 mm as given.

To determine the diameter of the cylinder used the following formulas as given Karel. N. et al. (1989)



Then, $D/h \geqslant 4^2+1$

D> (20-25) (17)=340-425, and 400 mm was chosen as the diameter of the compactor

The length of the compactor was determined based on traction capacity and draft force of the animals and easiness for maneuverability, is to be maximum of 80 kgf. Using the following formula as given (Equation (2)) by Karel. N. et al. (1989)

$$G = \frac{2}{3} q_0 \times B \times \sqrt{D} \times \sqrt[3]{h} \quad (2)$$

$$80 \text{ kgf} = \frac{2}{3} \frac{4 \text{ MN}}{\text{m}^3} \times B \times \sqrt{0.4 \text{ m}} \times \sqrt[3]{0.02 \text{ m}}$$

$$B = \frac{800}{\frac{2}{3} \frac{4 \text{ MN}}{\text{m}^3} \times B \times \sqrt{0.4 \text{ m}} \times \sqrt[3]{0.02 \text{ m}}}$$

$$B = \frac{800}{0.008 \text{ MN/m}}$$

B = 1 m

- Material selection was considered using available row material and environmentally friendly and easy produceability and maintainability
- Ergonomically suitability for operator handling and operating condition was considered (the height of the handle was determined by taking the average height of the farmers in the area & position of the handle to be easy for manipulation)
- The price was set at affordable level (2000 ETB (about 100 USD)

Table 1 Specification of the animal drawn compactor

SN	Parameters	Unit	Size
1	Overall size		
	Length	mm	1000
	Width	mm	1100
	Height working cylinder	mm	400
	Height up to handle	mm	800
2	Total Weight	kg	55
3	Working width	Meter	1.0

Figure 1 Bahirdar model animal drawn compactor

Table 1 Parts of compactor (Figure 1)

SN	Description	Material	size	Main purpose
1	Beam (mofer)	Wood	L = 3100 mm	To connect the compactor to the yoke
2	Drawbar	Sheet metal and Galvanized pipe	Lxw = 210 mm × 160 mm	To connect the compactor to the beam
3	Main frame	Angle iron	Lxw = 1000×900 mm	To hold the cylinder and shaft
4	Shaft	Solid shaft	Ø25×1200 mm	To hold the cylinder
5	Cylinder opening cover	Sheet metal	Lxw = 150 × 75 mm	To increase and decrease the load in the cylinder
6	Cylinder	Sheet metal	Lxw = 1260 × 1000 mm	It hold different amount of soil or sand and to compact the soil
7	Handle	Galvanized pipe	Ø3/4″×1100 mm	To guide the animal to compact in the right way

2.3 Establishment of FRG in different Woredas

- The second activities performed were establishing Farmers research group (FRG) in the two Woredas and discussing with Woreda Bureau of Agriculture Experts, Development Agents of selected Keble and then discussing with the Kebeles leader and selecting the innovative farmers considering the gender, geographic location, willingness and other criteria
- 1st FRG were established at Bahirdar Zuria Woreda, Woreb Kebele
- Number of FRG members: total 18 (15 Male and 3 Female)
- 2nd FRG were established at Burie Woreda, Wadra kebele
- Number of FRG members: total 18 (16 male and 2 female)

3 Testing of the implement

3.1 Treatments:

1) Animal drawn compactor
2) Animal trampling and
3) Non trampled

Figure 2 Animal drawn compactor and animal trampling

3.2 Testing sites

The sites are located at Amhara Region, west Gojjam Zone, Burie woreda, Wadra kebele and Bahirdar Ketema Woreda, Wreb kebele. The research activities were performed for two consecutive years (2010-2012 G.C) in the same Area, but in different FRG members and different type of soils.

Bahirdar zuria is located at 11º36′N latitude and 37º23′E Longitude with an altitude of 1,840 meter above sea level (Wikipedia), which has average maximum annual rainfall of 430 mm,with annual average maximum temperature minimum temperature of 36°C and 20ºC respectively (Woreda Bureau of Agriculture).

Burie is located at 10º42′N latitude and 37º4′E Longitude with an altitude of 2091 meter above sea level (Wikipedia), with maximum, minimum rain fall of 1,500 mm and 900 mm respectively; annual average maximum temperature minimum temperature of 27°C 19ºC respectively (Woreda Bureau of Agriculture).

Testing was conducted in first year (2010/2011) at three places, the first test (T1) at Bahirdar with the size of 20 m × 38.5 m for compactor and animal trampling and for non trampled 2.9 m × 38.5 m. The color of soil was red. The second test (T2) and third test (T3) at Burie woreda with the size of 22 m × 22 m for compactor and animal trampling and for non trampled 4 m × 22 m. The color of soil was red for (T2) and black for (T3).

Table 3 Soil test result by Bahirdar soil testing laboratory

SN	Site (location) Test number	Soil texture			
		sand/%	silt/%	clay/%	Class/%
1	Bahirdar zuria(T1)	24.36	32	43.64	clay
2	Burie (Tesfaw) (T2)	30.36	32	37.64	Clay loam
3	Burie (Desie)(T3)	28.36	38	33.64	Clay loam

In the second year (2011/2012) test was conducted at two places, the first test (T4) at Bahirdar Zuria woreda with the size of 22 m × 49 m for the compactor and animal trampling and for non trampled used only 5 m × 49 m. The color of the soil was red. The second test (T5) was at Burie woreda with the size of 20 m × 40 m

for the compactor and animal trampling and for non trampling used 4.2 m × 40 m. The color of the soil is dark brown (black).

3.3 Testing parameters

Table 4 Definition of some parameters and procedure of measurements

SN	Measured parameters	Descriptions
1	Soil moisture	Soil auger used for collecting sample of soil with the depth, and the length of the core sampler was taken three samples at different place and measure the weight of wet soil and dried by oven with 105 ^{o}c for 12 hours. The average of three sample before and after drying was calculated The soil moisture % \dry weight basis\ = $\frac{W1-W2\times100\%}{W2}$ where, $W1$ – weight of wet sample; $W2$ – weight of dry sample Soil moisture % \wet weight basis \ = 100% -- moisture content on dry weight basis
2	Bulk density	Was measured by inserting the cylinder with 20 cm depth before and after compacting and trampling, then calculating the weight in the volume in g cm^{-3}
3	Weight of the compactor	The weight of the compactor was determined by the farmers visual assessment (idea) by varying the weight of filling material (soil or sand) in the cylinder kg
4	Measured Drought force	The draft force was measured by digital dynamometer Model RON-2000 with capacity of 1tonne at the normal working speed and condition of the animal at different times, in kgf and we calculated the average value. 
5	No of pass per plot	Was counted during each working operation until the whole plot compacted and trampled
6	Working width	Working width of the compactor was measured by counting the number of pass in the plot and then the area of the plots was divided by the number of pass, in cm
7	Time of operation	was registered by stop watch when each operation start at starting and end at ending /min
8	Working speed	Speed by measuring the plots and having the pegs with the distance of 20 m apart and at the same pegs in other side parallel to the pegs and the time taken by the compactor to cover the 20m distance between the two lines was noted in 3 times with the help of a stopwatch. Arithmetic average of the readings was used to calculate the speed/ m/s
9	Theoretical field capacity /ha /h^{-1}	Was calculated by using the formula the working width of the compactor multiplied by speed of the animals $Tfe = 0.0036\times W\times S$ (ha h^{-1}) where, W - working width of the compactor, m; S - working speed, m s^{-1}
10	Actual capacity of the compactor & trampled/ha h^{-1}	Was calculated as area of the plot compacted by the compactor and trampled by animal dividing by total time spent for the plot and change in to hectare hour. (ha/h^{-1})
11	Field efficiency/%	Was calculated by dividing actual field capacity of the compactor by theoretical field capacity of the compactor $F_{efe}(\%) = \frac{Actual\ capacity}{Theortical\ capacity}\times100\%$
12	Cone index	Penetrometer reading was done by the help of cone penetrometer model-Eijkelkamp capacity -1000 N with direct reading. Each plot was divided diagonally and marks with 0.25 m^2 area at three places; pegs were made and measured before and after compacting and trampling, then compacted by the treatments and measuring at the same place (there may by limitation to measure exactly at the same place). Then dividing the reading by the area of the cone, in MPa. The depth was measured at 5 cm interval (5-30 cm)
13	Seed rate & fertilizer rate	Was determined based on the recommendation and the traditional broadcasting and the experience of the farmers, the seeds and fertilizers were weighed; and broadcast by experience farmers, then calculated in hectare.
14	Weed amount &type	Weed amount was registered at the first weeding time (which was assigned by Farmers) and registered on the 0.25 m^2 quadrant laying three times randomly at each plots and count the number and type of weeds.
15	Yield and yield components	The yield was calculate with the sample area 1 m^2 quadrant at randomly three place within the plot and threshed separately and calculated in kg ha^{-1}

3.4 Weight and main testing parameters of compactor

A hollow empty cylinder was fabricated to fill sand or soil in the field and the weight of the compactor can be varied according to the required compaction level with the type and moisture of the soil. During the test weight of the compactor was determined by the FRG (Farmers involved in the research) themselves. The weight of the compactor with sand for Andosols (light clay soil) in the first year at Bahirdar (T1) was 117 kg at Burie (T2) 141 kg and Vertisol (medium clay soil) at Burie (T3) 141 kg and in the second year for light clay soil at Bahirdar (T4) 152 kg and medium clay soil at Burie (T5)120 kg. The soil moisture was for T1 33.49%, T2 45.01%, T3 43.72%, T4 29.59% and T5 30.79%.

The testing crop was Teff Kuncho-CR-387 from Adet Agricultural Research Center, with the seeding rate of 20 kg/ha and the fertilizer application was as area recommendation.

3.5 Weed count

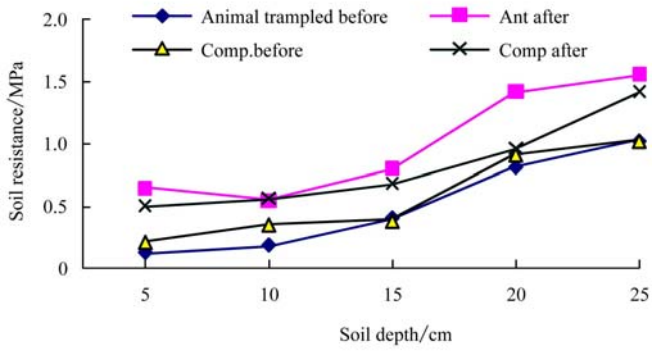
The effect of treatment on the weed infestation in the field can be clearly shown at the first weeding. So, the amount of weed infested in the plot were counted in one m^2 quadrant at three places, at the first weeding time for each treatment and man hour for weeding registered and calculated in hector (Figure 3). Plant height, panicle length and tillering potential were measured by randomly selecting 10 plants per plot.

Figure 3 Weed count in m^2

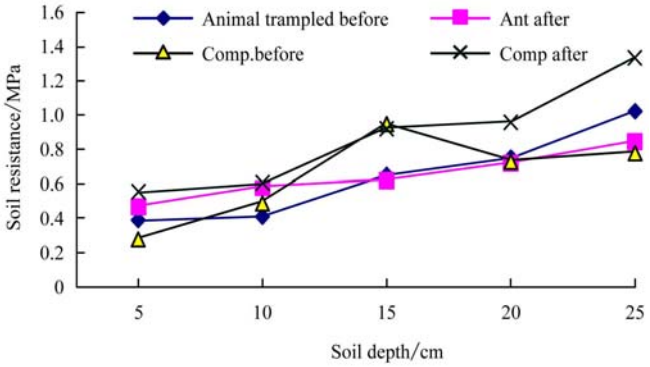
4 Result and discussion

4.1 Soil cone index First year (2010/2011)

The compactness and resistance of soil during seeding were registered and calculated in the rate of different soil depth from 5 cm up to 25 cm depth at Bahirdar zuria testing site showed there is difference value in different methods of compacting (Graph 1-2).

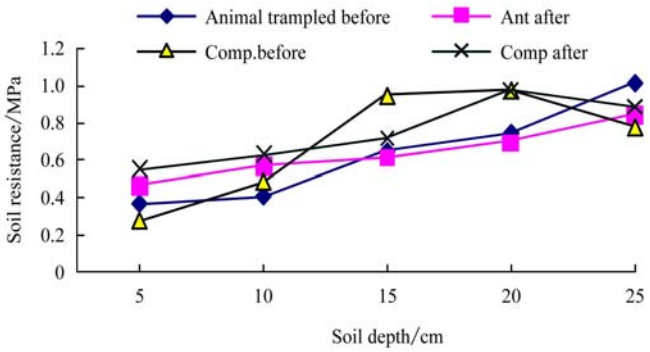


Graph 1 Relation of soil resistance in depth of penetration (T1)



Graph 2 Relation of soil resistance in depth of penetration (T2)

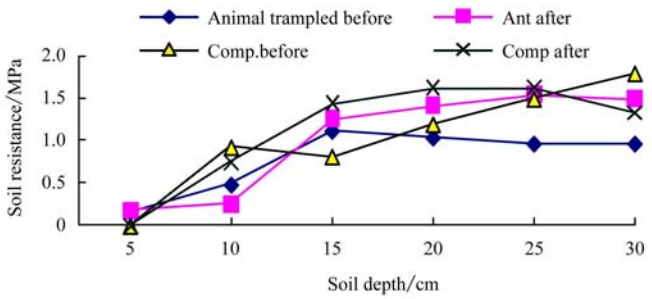
During seeding of Teff the compactness and resistance of soil were registered and calculated by the cone index with depth from 5 cm up to 25 cm at Burie testing site and showed there is difference value before and after on different methods of compacting (Graph 2-3).



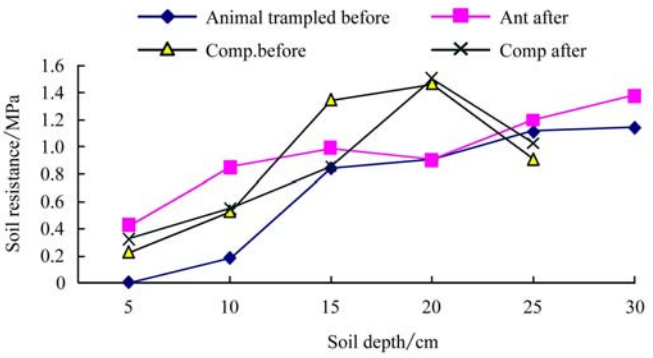
Graph 3 Relation of soil resistance in depth of penetration (T3)

4.2 Soil cone index Second year (2011/2012)

The measurements were performed before and after compacting by the compactor and trampling by the animals. The penetrometer reading shows, at the depth of up to 10 to 15 cm there is compacting difference in soil resistance within compactor and animal trampled as presented in Graph 1, Graph 2, Graph 3, Graph 4 and Graph 5. The weight of animal by their hoofs and the compactor with its weight exerted on the soil had enough pressure to push downward to be compacted. This shows the amount of change in bulk density of the soil by the compactor and animal trampled, especially at the depth of 5-10 cm where it is required to establish and firm the Teff root to the whole root length.



Graph 4 Relation of soil resistance in depth of penetration (T4)



Graph 5 Relation of soil resistance in depth of penetration (T5)

4.3 Main parameters

Working capacity of the animal drawn compactor ranged from 0.175 to 0.22 ha h^{-1}, whereas with 24 number of cattle and 11 cattle, an average capacity of 0.16 and 0.10ha h^{-1} was obtained respectively. The draft force requirement of the compactor with the above type of soil and moisture did not exceed 80 kgf which is under draft force on pair of animals Hopfen (1969). Number of weeds in the area at trampled and compacted field was lower than non trampled, which may be due to the uniformity and better population of Teff seed and it was influenced by computation of minerals for the emerging of weeds at the field. This practice agrees with Haftamu et al. (2009) who reported that the higher stand cover from the compacted plots is due to the good attachment of Teff seeds with the soil which might have resulted in efficient use of nutrients and moisture as well as improved germination.

Table 5 Main testing parameters during first year 2010/11

SN	Main parameters	Compactor				Animal trampled				Non trampled			
		BD	Burie		Aver.	BD	Burie		Aver.	BD	Burie		Aver.
		T1	T2	T3		T1	T2	T3		T1	T2	T3	
1	Soil moisture DB in %	33.49	45.01	43.72	40.74	33.49	45.01	43.72	40.74	33.49	45.01	43.72	40.74
2	Weight of compactor (Total weight with soil) /kg	117	141	141	133	-	-	-	-	-	-	-	-
3	Draft force average/N	48.50	62.25	65.50	58.75	-	-	-	-	-	-	-	-
4	Number of animal	2	2	2	2	11	30	29	24	-	-	-	-
5	Number of labor	2	2	2	2	2	4	4	4	1	1	1	1
6	Working capacity/ha h^{-1}	0.21	0.14	0.16	0.17	0.096	0.16	0.10	0.12	-	-	-	-
7	Bulk density/g cm^{-3}	1.78	1.56	1.38	1.57	1.63	1.41	1.35	1.46	-	-	-	-
8	Weed count at 1^{st} weeding/m^2	380	432	360	391	345	289	471	368	468	358	525	450
9	1^{st} Weeding labor hour, man h ha^{-1}	416.30	439:42	428:48	428.13	427.50	442:14	410:33	425.65	543.40	318	613:38	491.59

Table 6 Main testing parameters during second year 2011/12

SN	Main parameters	Compactor			Animal trampled			Non trampled		
		BD	Burie	average	BD	Burie	average	BD	Burie	Average
		T4	T5		T4	T5		T4	T5	
1	Soil moisture DB in %	29.59	30.79	30.19	29.59	30.79	30.19	29.59	30.79	30.19
2	Weight of compactor (Total weight with soil)/kg	152	120	136	-	-	-	-	-	-
3	Draft force average/N	58.60	74.30	66.45	-	-	-	-	-	-
4	Number of animal	2	2	2	12	10	11	-	-	-
5	Number of labor	2	2	2	3	3	3	1	1	1
6	Working capacity/ha h^{-1}	0.22	0.13	0.175	0.087	0.14	0.113	-	-	-
7	Bulk density/g cm^{-3}	1.46	1.41	1.44	1.34	1.62	1.48	1.28	1.13	1.21
8	Weed count at 1^{st} weeding /m^2	64	72	68	79	85	82	94	89	92
9	1^{st} Weeding labor hour, man h ha^{-1}	179:26	186.45	182.82	128:51	194.4	161.45	246:56	217.6	232.08

4.4 Yield and yield component

4.4.1 Crop parameters

Table 7 Effect of treatment on crop parameters at different site during 2010/11

Treatments	Plant height/cm	Panicle length/cm
Animal trampling	81.96	26.76
Animal drawn compactor	83.06	28.21
Not trampled	81.21	26.88
mean	82.07	27.28

Table 8 Effect of treatment on crop parameters at different site during 2011/12

Treatments	Plant height/cm	Panicle length/cm
Animal trampling	153.90	52.94
Animal drawn compactor	155.08	55.23
Not trampled	152.86	51.97
mean	153.94	53.38

The crop parameters especially the plant height and panicle length were measured at each plots during harvesting time and the result i.e. the ANOVA table show that there is no any significant difference among all treatments. The result was analyzed by ANOVA Duncan's multiple range test and means that showed significant difference were separated at probability level =0.05 Kwanchai G. A. et al. (1984).

Table 9 Effect of treatment on yield at different site during 2010/11

Treatments	Yield/kg ha^{-1}	Straw/kg ha^{-1}
Animal trampling	1352a	4946a
Animal drawn compactor	1122ba	4449a
Not trampled	871b	3597b
mean	1115	4331
CV	29.20	18.17

Note: *different letter means have significant difference with the 95% level of confidence.

At test sites Bahirdar (T1) and Burie (T2) and (T3) result shows the animal trampling and compactor have significant difference on yield and straw against not trampled practice. According to Haftamu et al. (2009) plowing frequency did not show any significant effect on tillering potential and stand cover of Teff. However, compaction has significant effect on these yield attributes. This may be due to its influence on absorption of nutrients and moisture by the crop. So the result revealed that the yield and yield components depend on the absorption of moisture and nutrients which is affected by the attachment of seed with soil.

Table 10 Effect of treatment on yield at different site during 2011/12

Treatments	Yield /kg ha^{-1}	Straw /kg ha^{-1}
Animal trampling	2398a	7882a
Animal drawn compactor	2557ba	7931a
Not trampled	2038a	6925a
mean	2331	7579
CV	17.36	15.44

Note: *different letter means have significant difference with the 95% level of confidence.

The draft force requirement of the compactor with the above type of soil and moisture did not exceed80 kgf which is under draft force on pair of animals Hopfen, (1969). At the first date of emerging, the compactor plots emerged two days before all plots (T1). It may be due to the leveling effect of the operation. The plant population was better and uniform in trampled and compactor at (T2 & T3).

During observation at the field, after 35 days of planting, the farmers comments on each plots were; at not trampled plot, 'Weeds infestation is high, the plants seems not stable and poor population'; at the compactor plot, 'The weeds infestation is low, the plant population is good and is stable compare to others'; in the animal trampled plot, 'The plants population is not that much, high weed infestation specially leaf types (T1). The same was true for all plots (T2 & T3).

In general the yield in all sites are not satisfactory, when compared to recommended yield, this happened because of natural accident (rain and ice at harvesting time in T1 and T3). Even though there was yield variation among treatments specially, not trampled is the least of all treatments in both sites. So trampling and compacting was very essential for Teff production (2010/11). When the results were analyzed independently on the site, the analysis result shows that animal trampling and compactor have significant difference over the non trampling in terms of yield at Burie (T1 and T2) sites, whereas at Bahirdar site there is no significant difference among all treatments. It may

be the whole plots were affected by natural accident and have minimum yield.

In the second year result (2011/2012), the compactor has significant difference among all treatments and animal trampled had significant difference over non trampled on yield, but the straw had no significant difference among all treatments.

5 Farmers comment and suggestion

The research was conducted based on FRG approach and the selected Farmers participated from problem identification to technology testing and evaluation. The animal drawn compactor weights were determined by the Farmers experience for the required compaction level. During testing most farmers were at the field and they commented that it is good for timeliness preparation of seeding Teff. Specially at Burie area, most Farmers in the area are grouping their animal (the number of animal used for trampling is 20-30) for trampling and making lottery system (chance) for getting prior date for seeding and sequence and then the last may get late planting and the consequence is decreasing in yield. So this technology will give solution for this. But, the technology should be improved to work at the mud condition and should have mud scraper and is better to have some pegs to make pocket (like animal hoofs) on the field; this may help to protect soil erosion and reserve moisture in the pocket to the field.Among the Farmers, 10 Farmers in each site ranked the experiment and 7 ranks the compactor 1st and 3 ranked the animal trampled 1st.The compactor field shows uniform plant population and weeds are infested than on the animal trampled. The plant population and the weeds are minimum on the animal trampled plots and the non trampled field showed poor population and more weed infestation. Generally, according to their selection, the compactor is superior to others due to the shortened time required to compact the field and operability. During demonstration and field day, most farmers commented the technology is useful and should be adopted for most areas. Some farmers suggested it may be useful also for trampling of finger millet production (finger millet production requires the practice of animal trampling after seeding).

6 Cost benefit analysis**

Assuming the following conditions and costs accordingly to the area:

Cost of hiring pair of animal in 8 h (1day)------40 ETB d^{-1}

Labor cost per days average value in all sites--20 ETB d^{-1}

The cost of compactor ----------2000 ETB

Working months per year -----1 month (20 working days)

Cost of compactor by calculating using straight line salvage cost analysis---20 ETB d^{-1}

Transportation of the compactor to the field----40 ETB d^{-1}

Cost of 100 kg Teff ----------10 ETB kg^{-1}

Note: *1 USD=18.90 ETB

** Costs of operation that can affect and apply with en our treatments are (compacting /trampling and 1st weeding) were considered, the others operations (land clearing, ploughing, weeding rather than 1st, harvesting…) were not included (assume as constant or apply equally for all treatments).

Table 11 Cost benefit values during first year (2010 /11)

SN	operation	Test sites	Treatments		
			Non trampled	Animal trampled	compactor
1	Compacting /trampling Cost/ETB ha^{-1}	T1	-	330	125
		T2	-	830	140
		T3	-	640	180
		T4	-	280	120
		T5	-	240	120
2	1st weeding cost/ETB ha^{-1}	T1	340	1642	1100
		T2	920	1042	1640
		T3	500	1120	1600
		T4	616.40	321.27	448.15
		T5	544.00	486	466.13
3	Average total cost of each operation		584.66	693.17	593.93
4	Benefit; yield kg ha^{-1}	T1	433	616	711
		T2	681	1280	1405
		T3	978	1980	1485
		T4	906	14.40	1095
		T5	3170	3360	4018
	Price of the yield /ETB	T1	4330	6160	7110
		T2	6810	12800	14050
		T3	9780	19800	14850
		T4	9060	14400	10950
		T5	31700	33600	40180
	Average total income of each system in ETB		12336.00	17352.00	17428.00

Benefit on non trampled = average total income – average total cost = 12336.00–584.66 = 11751.34 ETB

Benefit on animal trampled = average total income – average total cost = 17352.00–693.17 = 16658.83 ETB

Benefit on compactor = average total income – verage total cost = 17428.00–593.93 = 16834.07 ETB

In terms of economical benefit the highest expenditure shows in animal trampling and compactor than in non trampled plot. But the maximum profit is on animal trampled and compactor, than non trampled.

Limitation of the study:

- During evaluation, the soil loss and run off was not recorded

7 Conclusion

The animal drawn compactor should promote to different areas and collect the Farmers preference; it is useful for any type of crop production which requires trampling. It is better to evaluate the technology by incorporating soil loss and runoff measurment. Determination of different weight of compactor and bulk density ratio for different type of soil is required.

Acknowledgement

The authors acknowledge the financial support from the JICA FRGII project and Burie and Bahirdar Zuria Ketema Woreda Bureau of Agriculture Office Experts and Development Agents from Woreb and Wadra Keble for their information and technical support.

References

Ethiopian Agricultural Sample and Numeration (CSA), 2001/02 (1994 E.C). 2003. Results of Amhara Region Statistical Report on Area and Production of Crops Part 2A, Addis Ababa.

H. Gebretsadik, M. Haile, and C. F. Yamoah. 2009. Tillage frequency, soil compaction and N-fertilizer rate effects on yield of Teff (*Eragrostis Teff (Zucc) Trotter)* in Central Zone of Tigray, Northern Ethiopia. *Momona Ethiopian Journal of Science (MEJS)*, 1 (1): 82-94.

Hopfen H. J. 1969. Farm implements for arid and tropical regions. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

K. Neubauer, M. Friedman, J. Jech, J. Paltik, and F. Ptacek. 1989. Agricultural machinery for plant science (Slovaks Version) University of Agriculture Text Book, ISBN 80-209-0075-6. Prague.

Kwanchai, A. G., and A. A. Gomez. 1984. Statistical procedure for agricultural Research, Second edition, 1984.

Ministry of Agriculture (BOA). 2007. *Agricultural Statistics* (Amharic version). Addis Ababa, Ethiopia.

Seyfu Ketema. 1997. Tef. Eragrostis tef (Zucc.) Trotter. Promoting the conservation and

use of underutilized and neglected crops. 12. Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute, Rome, Italy.

T. Amare, G. Zeleke, and T. Feyisa. 2006. Quantifying the impacts of livestock trampling on runoff, soil loss and crop yield under traditional Teff cultivation system. Y. G.Silassie, E. Adgo, Z. Ayalew, A. Abiyu, and B.Tseganeh (eds). Proceedings of the 1st Annual Regional conference on completed Research activities on Natural Resources Management, 14-17August 2006, p 44-49, Bahir Dar, Ethiopia.

WWW.en.wikipedia.org/wiki/Bahirdar (Burie); Accessed date / May 21, 2011.