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Evaluation of conservation tillage methods for soil and water conservation, yield and yield components of maize under slope of 15-20% basketo special Woreda

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Abstract

Water erosion is the main agent of soil loss and land degradation in the steep slope areas of the Ethiopia. Continuous process of soil nutrient depletion is created on all over the mountain areas under the cause of poor water shed management, in appropriate farming system and intensive rain fall. The major constraints of farmer practice during at plough time could create rapid loss of soil organic matter, soil degradation and decline of environmental quality. There for it is substantial approach to create a better farming system to sustain environmental quality and agricultural production. So this study was accompanied in 3 farmer's fields to investigate the significance of different cultivation practice on soil loss and maize yield under slope of 19% during cropping season in 2009 and 2011 E.C at Motkesa Kebele Basketo special woreda. Trial was laid out a Randomized Complete Block Design (RCBD) through four treatments replicated three times on run off plots. Experimental treatments used in the area were (strip tillage, zero tillage, reduced tillage and farmer practice) with maize planting at spacing of 25 cm by 75 cm between plant and between rows respectively. According to the research result zero tillage decreased mean soil loss by 70%-74% compared with conventional tillage and zero tillage has a great potential of controlling soil erosion on steep lands. Additionally, zero tillage were effective in conserving soil moisture increased (36-42%) compared with conventional tillage practices. Depend with our research outcome we advise that in smallholder household farms, implementation of conservation agriculture had a cost-effective production management method, save raw materials, increase yield, and reduce manual labor. Other studies are encouraged in the same agro ecology to promote conservation agriculture system.

Keywords: Conservation tillage, Maize, Yield, Yield components, Soil loss

INTRODUCTION

Soil erosion in sloppy areas is an enduring problem for continuousness when the forest resource cover has been diminished and agriculture only depend on annual crops is implemented (Ahmed, 1984). FAO and Hurni also reported annual soil loss from Ethiopian highlands to be 200-300 tons ha −1 year −1. Similarly, Hurni et al., Dijo watershed is the largest watershed in Rift valley basin of Ethiopia (Acharya et al., 1994). Land degradation in the form of soil erosion is the major problems affecting agricultural productivity (Unit, 2007).

Conferring to Hurni et al., the original model effect due to erosion of cultivated fields in Ethiopia under normal condition was 42 ton/ha/year (Farid et al., 1988).

Soil erosion from the steep lands is the dominant cause of soil loss, disturbances and deterioration of the ecosystem and reduction of the crop production of the in our study areas (Faroooq et al., 2011). The reduction of soil quality that accompanies erosion can reduce the productivity of agricultural land (Kamwendo, 2009).

Conservation agriculture has greater impacts on soil erosion, run off and infiltration (Lanckriet et al., 2012).

The conservation tillage technique based on decomposable residue covered with zero tillage and subsoiling in the crop-free period can efficiently decrease soil disturbance of the plow layer, growth the surface cover and soil organic matter content and encourage the storage of soil moisture (Li et al., 2011). CA could be a solution to the problem of the steep slopes that how to produce annual crops without eroding the soil and does not necessarily needs heavy investments for its implementation, and can help small-scale farmers to stabilize their yields through time. Conservation practices also have to advance farmer production and profits and safeguard the production system against changes in climate and significant increase in yield from 3.6 to 4.4 t/ha in CA practices. Conservation agriculture has been encouraged and practiced as solution for agricultural sustainability problems causing from soil erosion and fertility decline and reduce farmers' exposure to drought, income and address low draught power ownership levels.

MATERIALS AND METHODS

Description of study area

The study was conducted in Basketo special woreda which is one of the four special Woreda of South Nation Nationalities and people regional state, its capital is Laska 626 km far from Addis Ababa (Rolf Derpsch, 2008). The average daily temperature ranges from 15°C-27°C and mean yearly rainfall ranges from 1000 mm-1400 mm (Thierfelder et al., 2009).

The special Woreda is located under from 780-2200 m above sea level within $6^0$18'00.5''N latitude and $36^0$33'41.9''E longitude. The special Woreda has three ecological zones; low land (54%), highland (1%) and mid land (45%) climatic zone (Figure 1).

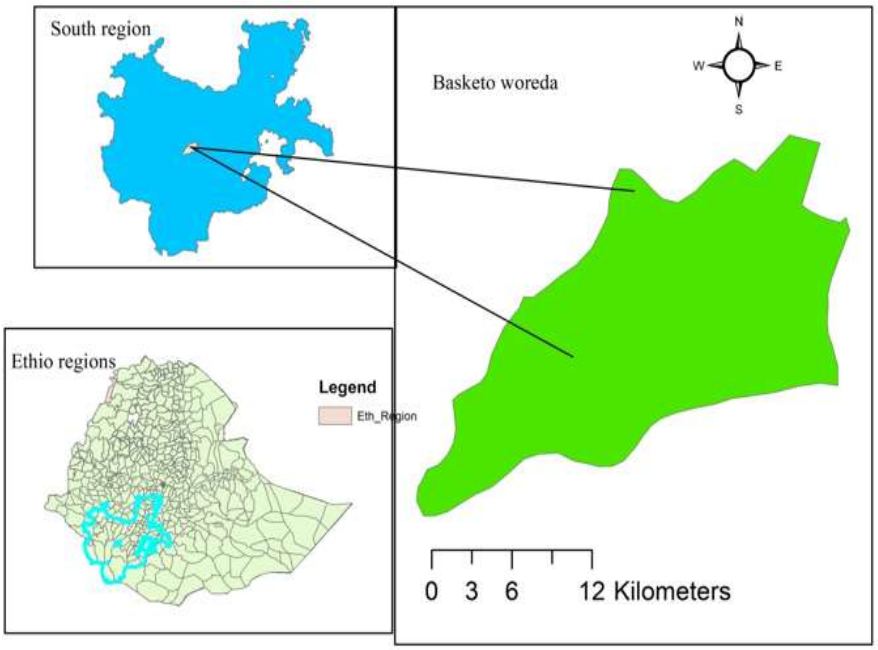

Figure 1. Map of the study area.

Experimental design and treatments

A field experiment was conducted on the effect of different tillage practice for soil loss and maize production under slope of 19% during cropping season in 2009 and 2011 E.C at Motkesa Kebele. The experiment has a Randomized Complete Block Design (RCBD) with four treatments replicated three times on run off plots. Experimental treatments used in the area were (strip tillage, zero tillage, reduced tillage and conventional tillage) with maize planting at spacing of 25 cm by 75 cm between plant and between rows respectively.

Strip tillage tilling a strip of about 40 cm wide and 30 cm deep on a seeding line only.

Zero tillage involved making a hole with a hand hoe for seed placement without primary tillage. This system involves opening a narrow slot only wide and deep enough to obtain proper seed coverage and with 30% mulch covering of planting area. Conventional tillage is making tillage frequency to plant maize 4 times plough land. Reduced tillage is a tillage type that was only two times plough land to plant maize. Planting of maize variety 540 was done during the main rainy season from begging of March up to end of April each season at spacing of 75 cm x 25 cm.

Methods of data collection

Determining of soil loss: The test field was built in February of 2009 on three farmers land in slope of 19%. Each runoff field (catch pit) had a length of 5 m, a width of 1 m, 0.5 m depth made from plastic sheet were set up in each plots and soil collected in the catch pit was measured after the end of rain fall. The plots were bounded by corrugated iron sheet, buried to a depth of 20 cm and protruding 10 cm above the ground to prevent run off water from outside the plots from entering the plots and that from run off plots from flowing out unmonitored.

Determining soil moisture content: The stored moisture contents in the soil were determined by gravimetric (mass) methods. The gravimetric water content is the mass of water in a unit mass of dry soil (g of water/g of dry soil). The wet weight of soil sample is determined; the sample is dried at 105°C for 24 hours to constant weight and reweighed.

Measuring soil moisture measurements was conducted at three periods (initial, development and mid stage) after rainfall of 10 days to evaluate the amount of soil water during at dry periods. Composite soil sample was taken by making "x" around the field to collect soil from various places on the field.

An auger was used for soil sampling from the depth of 0-20 cm and 20-40 cm because 70% of moisture extraction was taken from the rooting depth (0.4 m). The soil sample collected from the two different locations or depth was mixed in a plastic container. The amount of the wet soil measured and put in an oven at 105°C for 24 hours and then reweighted of dried soil samples. The soil water stored (%) in each 0.4 m incremental depth down was determined gravimetrically.

Volumetric water content can be calculated from gravimetric water using the following equation:

$$SMC = \frac{Ww - Wd}{Wd} * 100$$

Where:
SMC: Soil Moisture Content dry base (%)
W_w: Weight of the wet soil (gm)
W_d: Weight of the dry soil (gm)
Volumetric soil water content (cm^3/cm^3) is determined as:

$$\theta = w * \rho d$$

Where:
w=gravimetric water content
ρd=bulk density (g/cm^3)

Agronomic data parameters: Agronomic parameters including grain yield, above ground biomass, plant height data were collected. To measure plant height six stands from each plot were randomly selected and measured. Dried above ground biomass of the six plants from each plot was measured and it was converted to hectare base. From each plot the number of six plants randomly selected during at harvesting time was cut and grain yield threshed and weighted.

Statistical analysis of data: Data collected were processed using Microsoft Excel and statistically analyzed using Analysis of variance was performed using the GLM procedure of SAS Statistical Software Version 9.1. Effects were tested under (P=0.05). Means were separated using Fisher's Least Significant Difference (LSD) test.

RESULTS AND DISCUSSION

As shown in below Table 1 the mean soil loss of year one was significantly ($p<0.05$) difference between zero tillage (18.5 ton/ha^{-1}) and strip tillage

(26.2 ton/ha^{-1}) compared with conventional (69.2 ton/ha^{-1}) and reduced tillage (57.7 ton/ha^{-1}). But there was no significant difference ($p>0.05$) between reduced (57.7 ton/ha^{-1}) with conventional tillage (69.2 ton /ha/-1 year) and strip (26.2 ton/ha^{-1}) with zero tillage (18.5 ton/ha^{-1}).

Table 1. Soil loss means under different treatments in 2009 and 2011-year data E.C.

Treatments	**Soil loss data t/ha^{-1}/year^{-1} (2009)**	**Soil loss data t/ha^{-1}/year^{-1} (2011)**	**Combined analysis of soil loss for two years t/ha^{-1}/year**
Zero	18.6	24	21.33
Strip	27.33	29.33	28.33
Reduced	65.33	52.33	58.8
Conventional	71.66	58.66	65.16
Lsd (%)	26.43	18.22	14.27
Cv (%)	20.43	15.7	20

In year two there was also significant ($p<0.05$) difference between zero (27.8 ton /ha/-1) compared with conventional (58 ton/ha/-1) and reduced tillage (51.5 ton/ha/-1).

Significant ($p<0.05$) difference between strip (25.7 ton/ha^{-1}) compared with conventional (58 ton/ha/-1) but no significant ($p>0.05$) difference between reduced (51.5 ton/ha^{-1}). In both years, there was significant difference between zero and strip tillage compared with conventional tillage. These results shown that the soil loss was largest from conventional tillage and lowest from the zero and strip tillage. Soil loss was significantly affected by the tillage practices (Table 1). Studies showed that conservation tillage systems such as zero tillage with surface mulch, strip tillage and reduced tillage decreased mean soil loss by 74%, 62%, and 17% compared to conventional treatments under slope of 19% in first year and in second year 70%, 56% and 12% soil loss reduction in percent. In high rain fall area the soils are susceptible to soil erosion and fertility decline. Conservation agriculture consisting of a little disturbing the soil as possible, keeping the soil covered potential remedy to soil degradation. A number of studies revealed that conservation tillage (any tillage system that maintains at least 30% of cover on the soil surface, e.g. no tillage. Soil Science Society of America decreases soil erosion and improves soil structure.

Conventional tillage has been asserted to lead to land degradation resulting from common, but exploitative farming practices such as plough that destroys the soil structure and degrades organic matter, burning or removing crop residues, mono cropping among others. Soil erosion and the loss of organic matter associated with conventional tillage practices, which leave the soil bare and unprotected in times of heavy rain fall wind and heat.

Conservation agriculture has significant potential to improve rainfall use efficiency through increased water infiltration and decreased evaporation from the soil surface, with associated decreases in runoff and soil erosion.

Yield and yield components of maize

As shown in Table 2 below there was no significant ($p>0.05$) difference between the treatments for the first and second years with in maize yield and components. This result shown conservation agriculture improves farmers yield in the long term at the same time conserving the environment. Producers will discovery that the welfares of CA will get up later rather than earlier since CA takes time to accumulate enough organic matter and have soils become their own fertilizer, the process does not start to work over night.

But if producers make it through the first few years of production, results will start to become more satisfactory. Even though conservation agriculture has been successfully implemented in fertile soil, its performance on degraded soil remains unclear Siziba S.

Table 2. Means of maize yield and yield components under the different treatments.

	2009 year data			2011 year data		
Treatment	**Grain yield (Ton/ha)**	**Dry matter biomass (Ton/ha)**	**Plant height (CM)**	**Grain yield (Ton/ha)**	**Dry matter biomass (Ton/ha)**	**Plant height (CM)**
Zero tillage	4.97	7	198.4	4.75	8.87	209
Strip tillage	4.87	6.12	181.6	4.2	8.26	211
Reduced tillage	4.52	6.2	197.5	4.35	8.82	208
Conventional tillage	4.1	7.5	196.2	4.3	8.65	193
Lsd (%)	NS	NS	NS	NS	NS	NS
Cv (%)	23	21	7	16	24	11

Conservation agriculture most studies agree there are yield benefits in the medium to long term which are more pronounced in lower rain fall environment. CA not plough as conventional tillage thus do not incorporate the manure, which may lead to partial in efficiencies in the mobilization, access, up take and cycling of nutrients from manure.

In conventional tillage plough increases the amount of oxygen in the soil and increase aerobic process more nutrient are available for crops but soil loss depleted more quickly of its nutrients.

As a principle conservation tillage applied in semi-arid, humid and sub humid areas but it applied in wet lands or soil with poor drainage lands can make challenge adoption. CA increases yield over time but farmers may not see yields benefits immediately.

Comparisons made between local cultivation and SWC measures at experimental sites in Ethiopia showed that Soil loss is reduced significantly for the majority of SWC treatments, but, production rarely increased as a result of SWC in three to five year (Table 3).

Table 3. Effect of treatments on soil moisture conservation during at different seasons.

Treatments	**2009 years**	**2011 year**	
	At mid period SMC (%)	**At planting SMC (%)**	**At mid period SMC (%)**
Zero	53	27.75	59.5
Strip	44	29.75	52.5
Reduced	37	26.5	45.7
Conventional	33.7	26.33	34
LSD (%)	12.75	NS	13.3
CV (%)	13.7	15	12.5

As shown above the Table 3 there was significant ($p<0.05$) difference between zero with conventional and the others have no significant ($p>0.05$) difference between treatments in 2009 years at mid period in soil moisture content. In 2011 year there was also significant ($p<0.05$) difference between

zero with conventional tillage and reduced tillage but others have no significant differences between the treatments at mid period and at planting time there was no significant differences between the all treatments.

This results shows that zero tillage have potential for soil moisture holding capacity compared with others treatments. The advantage of CA over tillage agriculture in terms of the greater soil moisture-holding capacity and therefore duration of plant-available soil moisture is illustrated by Derpsch et al., who show that soil moisture conditions in rooting zones through growing seasons under CA are better than under both minimum and conventional tillage.

Thus crops under CA systems can continue towards maturity for longer than those under conventional tillage. In addition, the period in which available nutrients can be taken up by plants is extended, increasing the efficiency of use. The greater volume and longer duration of soil moisture's availability to plants (between the soil's field capacity and wilting point) has significant positive outcomes both for farming stability and profitability (Table 4).

Table 4. Estimated economic costs and benefit analysis of treatments.

Treatments	Grain yield (Ton/ha	Adjusted yield (ton/ha)	Unit price/kg	Gross field benefit (ha)	Total costs that vary (ha)	Net benefit/ ha	Benefit cost ratio
Zero	4.97	4.47	10	44,700	11890	32810	2.75
Strip	4.87	4.38	10	43800	13990	29810	2.1
Reduced	4.52	3.8	10	38000	15000	23000	1.5
Conventional	4.1	3.69	10	36,900	16990	19910	1.1

Economic analysis indicated that net benefit/ha of treatments among the different tillage systems zero tillage recorded was higher net return than conventional tillage systems. This indicates higher profit and lower expenditure in terms of lab our power.

As defined by Friedrich et al., CA is a concept for resource-saving agricultural crop production with acceptable profits high and sustained production levels while concurrently conserving the environment.

CONCLUSION

The results show that there were not shown significant difference ($p>0.05$) between treatments on maize yield and yield components within two consecutive years. However, zero tillage has shown better results in soil moisture content and soil loss in the study area. In the steep slope areas of cultivated land resulted high soil loss and soil erosion. The study result was shown that there was high soil loss with in conventional tillage which leaves the soil bare removing of crop residues and un protected in times of heavy rain fall and wind that destroys the soil structure and degrades organic matter. But, conservation tillage low soil loss (zero tillage and strip) consisting of little disturbing the soil keeping the soil covered potential remedy to soil degradation.

Zero tillage has significant potential to improve rainfall use efficiency in low rain fall area through increase water infiltration and decreased evaporation from the soil surface with associated decreases in runoff and soil erosion. It has been shown that zero tillage decreased mean soil loss by 70%-4% compared with conventional tillage have the potential of controlling soil erosion on steep lands.

Additionally, zero tillage were effective in conserving soil moisture increased (36-42%) compared with conventional tillage practices. Conservation tillage also has the advantages of reducing the need for terraces. In this regard zero tillage is recommended as a better solution for reducing soil loss and conserving soil moisture under drier areas with the slope of 19%. Hence, there is need to disseminate the results of the present study to the end users even though, further research should be carried out to put the recommendation on strong basis.

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