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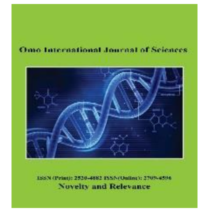

Research Paper

# Techniques for conservation tillage under 15–25% slope: soil and water conservation, maize yield and yield components in basketo zone, Southern Ethiopia

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## Abstract

In steeply sloping regions of Ethiopia, water erosion is the primary cause of soil erosion and land degradation. Poor management of watersheds, inappropriate farming practices, and heavy rainfall all contribute to a continuous process of soil nutrient depletion in mountainous places. A quick loss of soil organic matter, soil deterioration, and a decline in environmental quality could result from the main farmer practice restrictions during plowing. To maintain agricultural productivity and environmental quality, a better farming system is therefore a significant method. This study was conducted in 3 farmer's fields to investigate the significance of different cultivation practices on soil loss and maize yield under a slope of 19 % during cropping season in 2016 and 2018 at Motkesa Kebele of Basketo Zone, southern Ethiopia. The trial was laid out using a randomized complete block design 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 a spacing of 25cm by 75cm between plants and between rows respectively. According to the research result zero tillage decreased mean soil loss by 70% -74 % compared with conventional tillage ($P < 0.05$) and zero tillage has a great potential of controlling soil erosion on steep lands. Additionally, zero tillage was effective in conserving soil moisture increased (36-42%) compared with conventional tillage practices. According to the results of our research data, we advise that in smallholder household farms, the implementation of conservation agriculture has a cost-effective production management method, saves raw materials, increases yield, and reduces manual labor. Further studies are also encouraged in the same agroecology to promote the conservation agriculture system.

**Keywords**: Conservation tillage; Maize yield; Soil loss; Soil moisture

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https://doi.org/10.59122/13439yxz

Received February 20, 2023; Accepted May 28, 2023; Published June, 2023



## 1. Introduction

Soil erosion in sloppy areas is an enduring problem for continuousness when the forest resource cover has been diminished and agriculture only depends on annual crops is implemented (Tuahn et al., 2014). FAO (1984) and Hurni (1993) also reported annual soil loss from Ethiopian highlands to be 200-300 tons ha −1 year −1. Similarly, Hurni et al. (2008) Dijo watershed is the largest watershed in the Rift Valley Basin of Ethiopia. Land degradation in the form of soil erosion is the major problem affecting agricultural productivity.

Conferring to Hurni et al. (2008), the original model effect due to erosion of cultivated fields in Ethiopia under normal conditions was 42 tons/ha/year. Soil erosion from the steep lands is the dominant cause of soil loss, disturbances deterioration of the ecosystem and reduction of crop production in our study areas. The reduction of soil quality that accompanies erosion can reduce the productivity of agricultural land (Montgomery, 2007).

Conservation agriculture has greater impacts on soil erosion, runoff and infiltration (Leys et al., 2010). The conservation tillage technique based on decomposable residue covered with zero tillage and sub-soiling in the crop-free period can efficiently decrease soil disturbance of the plow layer, grow the surface cover and soil organic matter content and encourage the storage of soil moisture (David et al., 2005; Zhao et al., 2016).CA could be a solution to the problem of the steep slopes of how to produce annual crops without eroding the soil does not necessarily need heavy investments for its implementation, and can help small-scale farmers stabilize their yields over time (Erenstein, 2003). Conservation practices also have to advance farmer production and profits and safeguard the production system against changes in climate and a significant increase in yield from 3.6 to 4.4 t/ha in CA practices (Mkoga et al., 2010).

Conservation agriculture has been encouraged and practiced as a solution for agricultural sustainability problems caused by soil erosion and fertility decline (Bram et al., 2016) and reduces farmers' exposure to drought, income and address low draught power ownership levels (Mashingaidze et al., 2012). Therefore it is a substantial approach to create a better farming system to sustain environmental quality and agricultural production. This study was conducted in 3 farmer's fields to investigate the significance of different cultivation practices on soil loss and maize yield under a slope of 19 % during cropping season in 2016 and 2018 at Motkesa Kebele of Basketo Zone, southern Ethiopia.

## 2. Materials and Methods

### 2.1 Description of study area

The study was conducted in the Basketo zone which is one of the zones of South Ethiopia Regional State; its capital is Laska, which is 626 km from Addis Ababa. The average daily temperature ranges from 15 °C-27 °C and mean yearly rainfall ranges from 1000 mm-1400 mm. The Basketo Zone is located from 780-2200m above sea level within 6018'00.5''N latitude and

36033’41.9’’E longitude. The zone has three ecological zones; low land (54%), highland (1%) and midland (45%) climatic zone (Vaughan 2011, SNNPR, 2011).

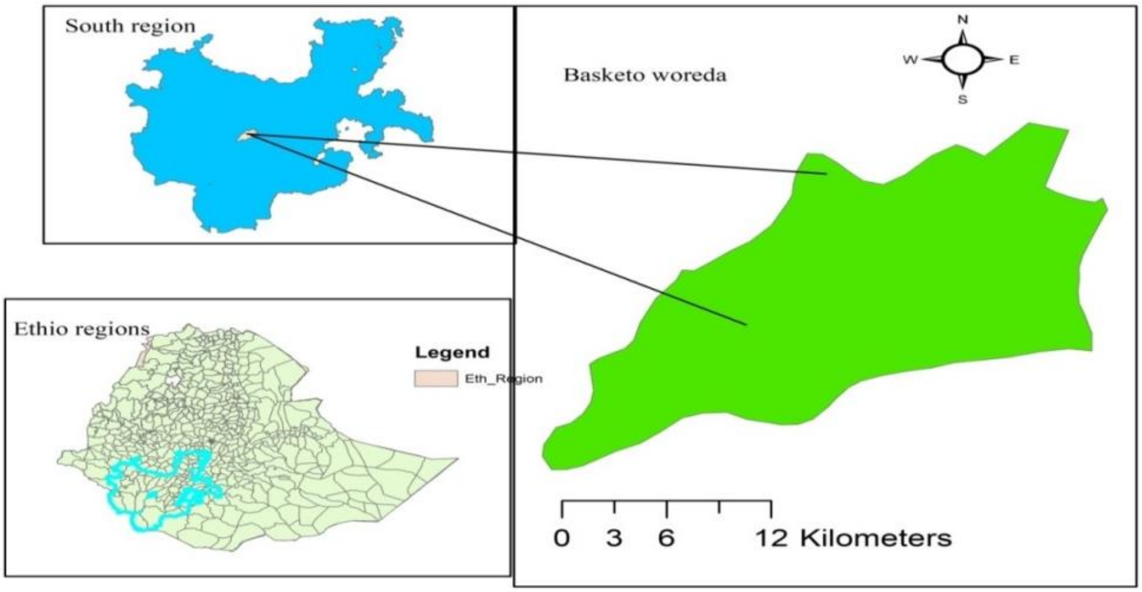


Figure 1. Map of the study area

2.2 Research Design

A field experiment was conducted on the effect of different tillage practices on soil loss and maize production under a slope of 19 % during cropping season in 2016 and 2018 at Motikesa Kebele of Basketo zone, southern Ethiopia. The experiment has a randomized complete block design 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 the spacing of 25cm by 75cm between plants and between rows, respectively.

Strip tillage tilling a strip of about 40cm wide and 30cm 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 with 30% mulch covering of planting area. Conventional tillage is making tillage frequency to plant maize 4 times plow land. Reduced tillage is a tillage type that was only two times plow land to plant maize. Planting of maize variety 540 was done during the main rainy season from the beginning of March up to the end of April each season at a spacing of 75cm × 25cm.

2.3 Methods of data collection

*2.3.1 Determining of soil loss*

The test field was built in February 2016 on three farmers' land on a slope of 19%. Each runoff field (catch pit) had a length of 5 m, a width of 1 m, and a 0.5m depth made from plastic sheets were set up in each plot and soil collected in the catch pit was measured after the end of rainfall. The plots were bounded by corrugated iron sheets, buried to a depth of 20cm and protruding 10cm above the ground to prevent runoff water from outside the plots from entering the plots and from runoff plots from flowing out unmonitored.

*2.3.2 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 the soil sample is determined; the sample is dried at 1050C for 24 hours to constant weight and reweighed (Gardner, 1986). 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 dry periods. The 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 0-20cm and 20- 40 cm because 70% of moisture extraction was taken from the rooting depth (0.4m). The soil sample collected from the two different locations or depths was mixed in a plastic container. The amount of the wet soil was 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 0.4m incremental depth down was determined gravimetrically. Volumetric water content can be calculated from gravimetric water using the following equation (Eq. 1):

$$SMC = \frac{Ww - Wd}{Wd} * 100 \quad (1)$$

Where, SMC = Soil moisture content, dry base (%), Ww = 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 Eq. 2:

$$\theta = w * \rho d \quad (2)$$

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

*2.3.3 Agronomic data parameters*

Agronomic parameters including grain yield, above-ground biomass, and 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 a hectare base. From each, plot the number of six plants randomly selected during harvesting time was cut and grain yield was threshed and weighted.

*2.3.4 Statistical analysis*

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.

## 3. Results and Discussion

3.1. Means of soil loss in the study site

As shown in below Table 1 the mean soil loss of year one was significant (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 in 2016 and 2018 year data

| Treatments | Soil loss data (2016) ($t/ha^{-1}/year^{-1}$) | Soil loss data (2018) ($t/ha^{-1}/year^{-1}$) | Combined analysis of soil loss for ($t/ha^{-1}/year$) |
|---|---|---|---|
| Zero | $18.6^{b}$ | $24^{b}$ | $21.33^{b}$ |
| Strip | $27.33^{b}$ | $29.33^{b}$ | $28.33^{b}$ |
| Reduced | $65.33^{a}$ | $52.33^{a}$ | $58.8^{a}$ |
| Conventional | $71.66^{a}$ | $58.66^{a}$ | $65.16^{a}$ |
| LSD, (%) | 26.43 | 18.22 | 14.27 |
| CV, (%) | 20.43 | 15.7 | 20 |

LSD=Least significant difference; CV= Coefficient of variation; $^{ab}$ means in the column with the same superscript are not significantly different (P < 0.05).

In year two there was also a significant (P < 0.05) difference between zero (27.8 ton /ha/-1) compared with conventional (58 ton/ha/-1) and reduced tillage (51.5ton/ha/-1). Significant (P < 0.05) difference between strips (25.7ton/ha-1) compared with conventional (58 ton/ha/-1) but no significant (P > 0.05) difference between reduced (51.5ton/ha-1). In both years, there was a significant difference between zero and strip tillage compared with conventional tillage. These results show that the soil loss was largest from conventional tillage and lowest from 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 a slope of 19 % in the first year and in the second year 70%, 56% and 12% soil loss reduction in percent. In high-rainfall areas, the soils are susceptible to soil erosion and fertility decline (Kagabo et al., 2013). Conservation agriculture consists of as little disturbing the soil as possible, keeping the soil covered potential remedy for soil degradation (Bayala et al., 2012). Several studies revealed that conservation tillage (any tillage system that maintains at least 30% of cover on the soil surface, e.g. no-tillage (Fusuo et al., 2007).

Conventional tillage has been asserted to lead to land degradation resulting from common, but exploitative farming practices such as plowing that destroys the soil structure & degrades organic matter, burning or removing crop residues, and mono-cropping among others (Rusinamhodzi et al., 2011). Soil erosion & the loss of organic matter are associated with conventional tillage practices (Chivenge et al., 2007), which leave the soil bare and unprotected in times of heavy rainfall wind & heat (Derpch, 2003). 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 (Thierfelder & Wall, 2010).

3.2 Yield and yield components of the maize

As shown in the table above there was no significant ($P > 0.05$) difference between the treatments for the first and second years within maize yield and components. This result shows conservation agriculture improves farmers' yield in the long term at the same time conserving the environment.

Table 2. Least square means of maize yield and yield components under the different treatments

| Treatment | 2016 year data | | | 2018 year data | | |
|---|---|---|---|---|---|---|
| | Grain yield (ton/ha ) | DMB (ton/ha) | PH (cm) | Grain yield (ton/ha ) | DMB (ton/ha) | PH (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 |

LSD=Least significant difference; CV= Coefficient of variation; NS = Non significant, DMB=Dry matter biomass, PH=Plan height

Producers will discover that the welfare of CA will get up later rather than earlier (Chivenge et al., 2007; Thierfelder & Wall, 2010) since CA takes time to accumulate enough organic matter and have soils become their fertilizer, the process does not start to work overnight. 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, 2008).

In conservation agriculture most studies agree there are yield benefits in the medium to long term which are more pronounced in lower rainfall environments (Pittelkow et al.,2015); Steward et al., 2018). CA not plow as conventional tillage and thus does not incorporate the manure, which may lead to partial efficiencies in the mobilization, access, uptake and cycling of nutrients from manure (Powell et al., 2004; Rufino et al., 2007).

In conventional tillage plough increases the amount of oxygen in the soil and increase the aerobic process more nutrient is available for crops but soil loss is depleted more quickly of its nutrients. As a principle of conservation tillage applied in semi-arid, humid and sub-humid areas but applied in wetlands or soil with poor drainage lands can challenge adoption. CA increases yield over time but farmers may not see yield 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 years (Herweg and Ludi, 1999).

3.3 Soil moisture content in the soil at different maize growth stages

As shown below in Table 3 there was a significant ($P < 0.05$) difference between zero with conventional and the others have no significant ($P > 0.05$) difference between treatments in 2016 years at mid-period in soil moisture content.

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

| Treatments | 2016 years | 2018 year | |
|---|---|---|---|
| | At mid period SMC (%) | At planting SMC (%) | At mid period SMC (%) |
| Zero | 53[a] | 27.75 | 59.5[a] |
| Strip | 44[ab] | 29.75 | 52.5[ab] |
| Reduced | 37[b] | 26.5 | 45.7[bc] |
| Conventional | 33.7[b] | 26.33 | 34[c] |
| LSD (%) | 12.75 | NS | 13.3 |
| CV (%) | 13.7 | 15 | 12.5 |

LSD=Least significant difference; CV= Coefficient of variation; NS= Non-significant, [abc] means in the column with the same superscript are not significantly different ($P < 0.05$).

In the 2018 year, there was also a significant ($P < 0.05$) difference between zero with conventional tillage and reduced tillage but there were no significant differences between the treatments at mid-period and at planting time there were no significant differences between all treatments. These results show that zero tillage has the potential for soil moisture-holding capacity compared with other 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. (1991), 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) have significant positive outcomes both for farming stability and profitability.

### 3.4 Cost and benefit analysis

Economic analysis indicated that the net benefit/ha of treatments among the different tillage systems zero tillage recorded was a higher net return than conventional tillage systems (Table 4). This indicates higher profit and lower expenditure in terms of lab power.

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 |

According to Friedrich et al. (2016), CA is a strategy for producing agricultural crops at high and sustained production levels with acceptable earnings while also protecting the environmet.

## 4. Conclusions

The findings indicate that, over the two consecutive years, there was no discernible difference ($P > 0.05$) between the treatments for maize yield and yield components. In the research area, zero tillage has, nevertheless, demonstrated superior outcomes in terms of soil moisture content and soil loss. There was a lot of soil erosion and loss in the farmed land areas on steep slopes. According to the current study's findings, conventional tillage causes a significant amount of soil loss, leaving the soil exposed after crop residues are removed and vulnerable to wind and rainstorms that erode organic materials and ruin the soil's structure. However, conservation tillage, which involves little soil disturbance and leaves the soil covered, is a viable treatment for soil deterioration. It involves zero tillage and stripping. By increasing water infiltration and reducing surface evaporation, zero tillage can significantly increase the efficiency of using rainwater in low-lying areas while simultaneously reducing runoff and soil erosion. It has been demonstrated that, in comparison to conventional tillage, zero tillage reduced mean soil loss by 70% to 74%. This suggests that zero tillage may be able to control soil erosion on steep terrain. In addition, compared to traditional tillage techniques, zero tillage proved successful in preserving an increase in soil moisture of 36-42%. One more benefit of conservation tillage is that it lessens the requirement for terraces. Under drier regions with a 19% slope, zero tillage is advised as a preferable way to minimize soil loss and preserve soil moisture. Therefore, even though further research needs to be done to provide a solid foundation for the advice, it is still necessary to share the findings of the current study with the end users.

## Conflict of Interest

The authors declare no conflict of interest.

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