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Full Length Research

Effects of tillage practices and cropping system on soil physical properties and in-situ water conservation in clay loam of Assosa, Ethiopia

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Soil tillage affects the sustainable use of soil resources through its influence on soil properties. Proper use of tillage can improve soil related constraints, while improper tillage may cause a range of undesirable processes. Conservation tillage like no tillage had been reported to improve the properties of the soil. Thus, the study had been carried out at Assosa Agricultural research center to evaluate the effects of tillage and cropping system on soil physical properties and in situ moisture conservation. Eighteen experimental runoff plots of 8 m long and 3 m wide each were framed with corrugated iron sheets. The experimental design used was randomized complete block design (RCBD) with six treatment in factorial combinations vis-à-vis three cropping systems (sole maize, sole soya bean and intercropping of maize with soya bean), with tillage system (minimum tillage and conventional tillage), that were replicated three times. The bulk density under conventional tillage was declined by 0.3g/cm^3, 0.3g/cm^3 and 0.23g/cm^3 and the in situ-water retained under conventional tillage was declined by 9.83% (18mm), 11.3% (21mm) and 7.76% (14.63mm) as compared to no tillage with mulch treatments for maize, soya bean and maize-soya bean intercropping respectively. Thesefinding illustratedthat the water retention capacity of no-tillage with mulch (conservation agriculture) than conventional tillage.

Keywords: Tillage, Soil, Cropping system, Bulk density, Porosity

1. INTRODUCTION

Agricultural production in the arid and semi-arid areas is highly dependent on rainfall because water for irrigation is scarce or farmers cannot afford the technology. In order to have successful rainfed crop production in these areas, rain water conservation is essential (Barron et al., 2003). The success of on-farm soil water conservation however depends upon many soil factors such as soil bulk density (BD), porosity, soil surface sealing and crusting, surface roughness, hardpans, hydraulic conductivity, and infiltration rates as they determine the hydrological properties of soil (Strudley et al., 2008). Soil compaction causes low porosity, reduced infiltration, increased penetration resistance and limited root growth. Soil tillage is among the important factors affecting soil physical properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid etal., 2006).

Tillage method affects the sustainable use of soil resources through its influence on soil properties (Hammel 1989). The proper use of tillage can improve soil related constrains, while improper tillage may cause a range of undesirable processes, e.g. destruction of soil structure, accelerated erosion, depletion of organic matter and fertility, and disruption in cycles of water, organic carbon and plant nutrient(Lal, 1993). Use of excessive and unnecessary tillage operations is often harmful to soil. Therefore, currently there is a significance interest and emphasis on the shift to the conservation and no-tillage methods for the purpose of controlling erosion process (Iqbal et al.,2005). Conventional tillage practices disturb soil structure by changing its physical properties such as soil bulk density, soil penetration resistance and soil moisture content. Annual disturbance and pulverizing caused by conventional tillage produce a finer and loose soil structure as compared to conservation and no-tillage method which leaves the soil in tact (Rashidi and Keshavarzpour, 2007). This difference results in a change of number, shape, continuity andsize distribution of the pores network, which controls the ability of soil to store and transmits air, water andagricultural chemicals. This in turn controls erosion, runoff and crop performance (Khanet al.,2001).

On the other hand, conservation tillage methods often result in decreased pores pace (Hill, 1990), increased soil strength (Bauder et al., 1981) and stable aggregates (Horne etal., 1992).The pore network in conservation tilled soil is usually more continues because of earthworms, root channels and vertical cracks(Cannel, 1985). Therefore, conservation tillage may reduce disruption of continue spores. Whereas, conventional tillage decreases soil penetration resistance and soil bulk density(Khan et al.,1999). This also improves porosity and water holding capacity of the soil. Continuity of pore network is also interrupted by conventional tillage, which increases the tortuousity of soil. This all leads to a favorable environment for crop growth and nutrient use (Khan et al.,2001). However, the results of no-tillage are contradictory (Iqbal et al.,2005). No-tillage methods in arid regions of Iran had an adverse effect on crop yields (Hemmat and Taki, 2001); while Ghuman and Lal (1984)comparing conventional tillage method to no-tillage method concluded that higher moisture preservation and 13% more income was obtained in case of no-tillage.

The objective of the study was to compare the effect of different tillage practices and cropping systems on bulk density, in situ -moisture content, total porosity and void ratio under uniform cropping systems.

2. MATERIAL AND METHOD

2.1. Description of the Study Area

The study was conducted at the Assosa Agricultural Research Center (ASARC), which is located in Assosa District at Benishangul-Gumuz Regional State (BGRS). The ASARC is located in the western part of Ethiopia from 10º 01' 25'' to 10º 02' 50'' north latitude and from 34º 33' 50'' to 34º 34' 35'' east longitude. The study area covers a total land area of 202.5 ha with geology of Tarmabe basalt, sometimes porphyritic of the Miocene to Pliocene period (Tefera*et al.* (1996). The Assosa District is characterized by hot to warm moist lowland plain with uni-modal rainfall pattern. The rainy season starts at the early May and lasts at the end of October with maximum rainfall in the months of June, July, and August. The total annual average (2000-2007) rainfall is 1316 mm. The annual mean minimum and mean maximum temperatures of the District for the periods from 2000 to 2008 were 16.75 and 27.92 ^{O}C, respectively. The soil type of the study area was characterized as Nitisol.

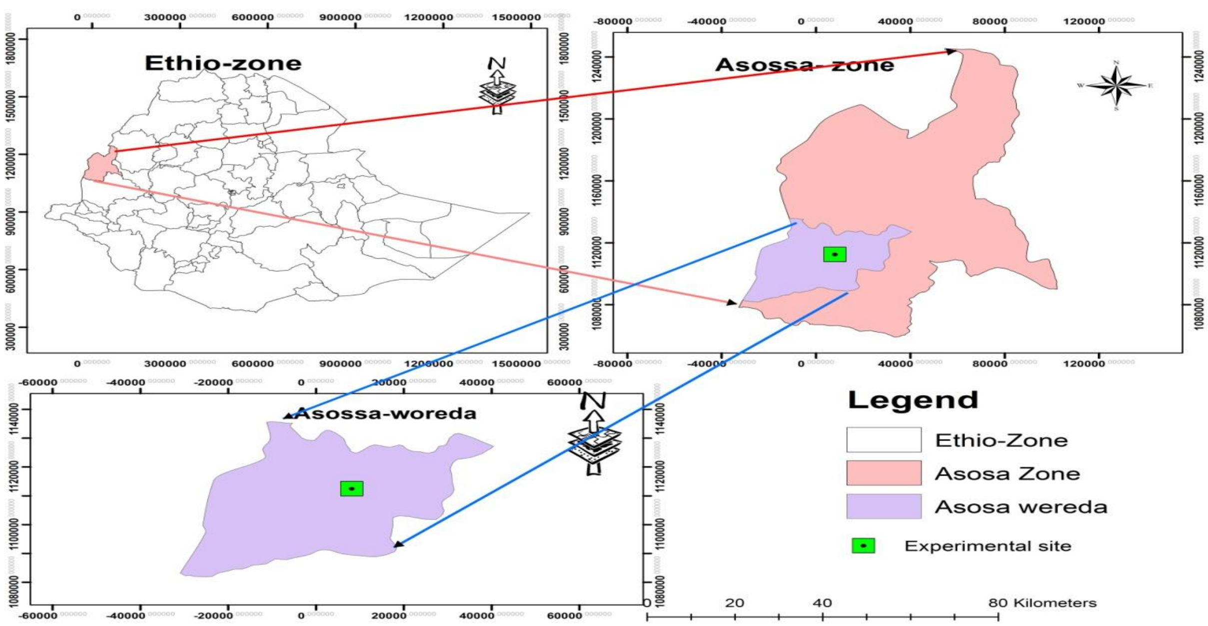
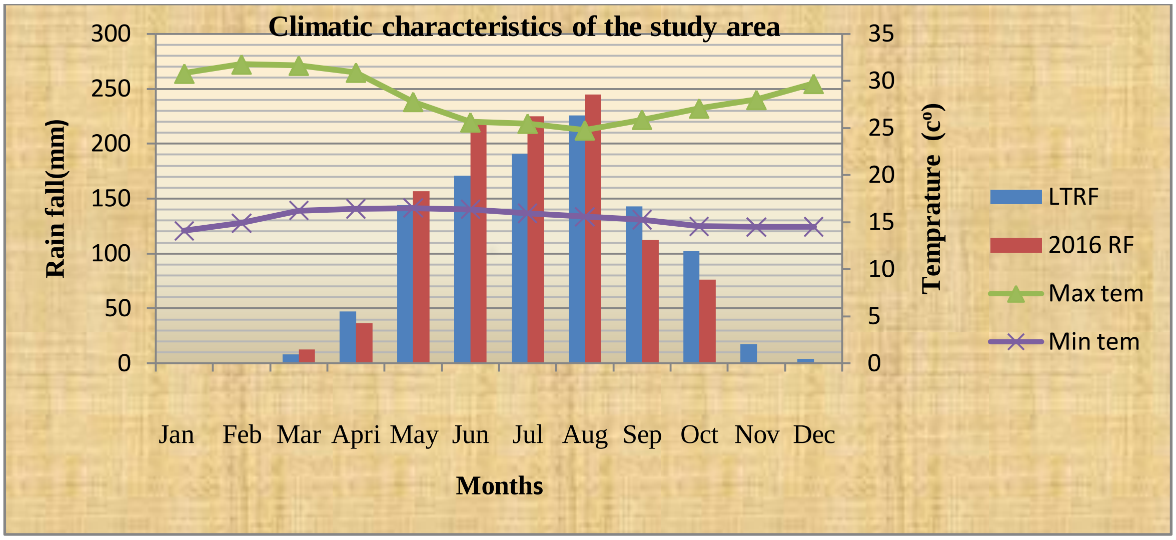


Figure 1: Location map of experimental site



LTRF= Long term rainfall, Max tem= maximum temperature, Min tem= minimum temperature, rf = rain fall

Figure 2: Long term (1983-2016) average rainfall and temperature and one year (2016) rainfall of Assosa Agricultural Research Center (1983 -2016)

2.2. Experimental Set up

The experiment had 6 treatments combinations and three replications with the total experimental plots of 18. The experimental plots were applied to runoff plots of 3m x 8m dimension that was laid out by completely randomized block design (RCBD) in factorial combination. The treatments were:

1. T1: Conventional tillage (the farmers local tillage practice to sow maize) + sole crop (maize)
2. T2: No tillage (tilling the place where to put the seed only, (2.5 t/ha)) + sole crop (maize)
3. T3: Conventional tillage (the farmers local tillage practice for both test crops) + Intercropping (maize +soybean)
4. T4: No tillage (tilling the place where to put the seed only, (2.5 t/ha) + Intercropping (maize +soybean)
5. T5: Conventional tillage (the farmers local tillage practice to sow soya bean was used) + sole soybean)
6. T6: No tillage (tilling the place where to put the seed only, (2.5t/ha)) + sole crop (soybean)

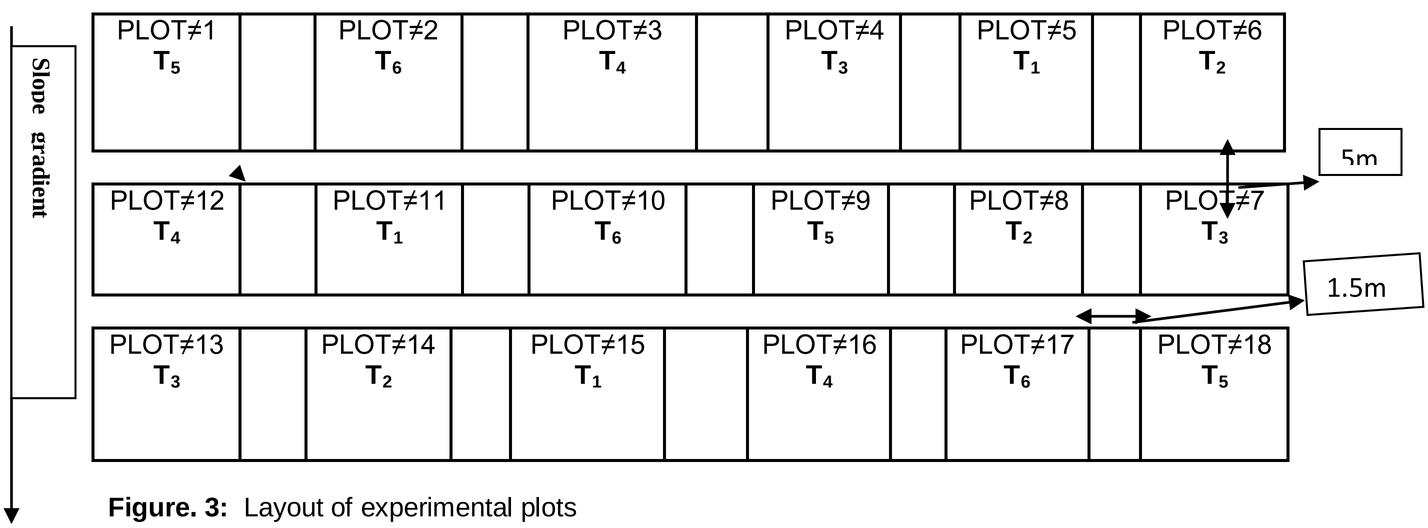
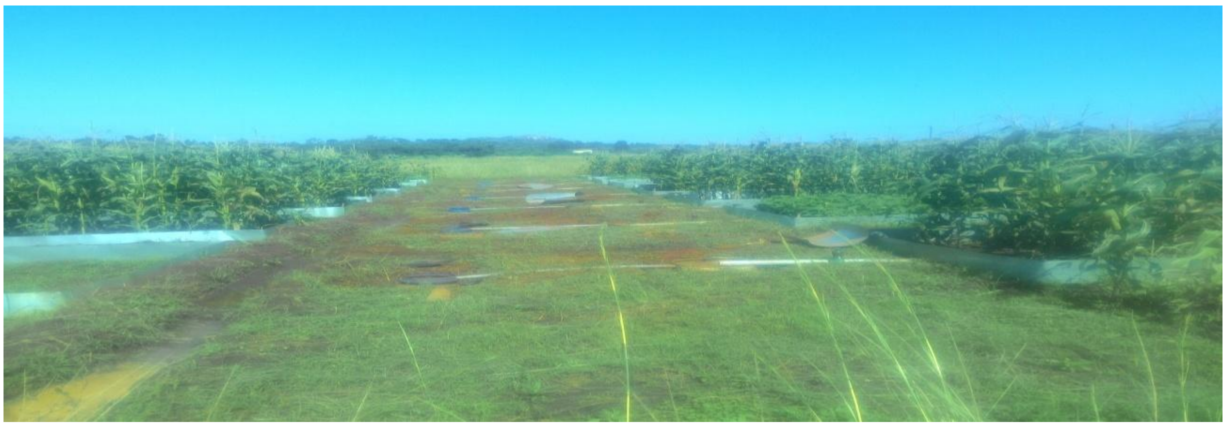


Figure. 3: Layout of experimental plots

2.3. Test plots Arrangement and Management Techniques

The study was carried out by using RCBD in factorial combination with different surface management practices and cropping system as the experimental factors on 7% slope of land. It had 6 treatment combinations with three replications. There were two tillage practices (no tillage along with 2.5 tonnes of soya bean straw mulch, conventional tillage (the farmers local practice for the test crop) and three cropping system (sole maize, sole soya bean, and intercropping of maize and soya bean). The study was carried out in hydrologically isolated experimental runoff plots of 3m x 8m.

The tillage operation used was oxen plow (Maresha) for conventional tillage practice of all cropping systems to a depth of 15 cm (triple passes) for maize and 12 cm (double passes) for soya bean, whereas pickaxe was used for all no tillage treatments at sowing for maize to a depth of 10 cm and hoe for soya bean to a depth of 7 cm. The tillage frequency used for soya bean and maize were two and three times as the farmer's local practice of the area for conventional tillage. Hand hoeing was used for weeding for all treatments.



a. Overview of runoff plots

Figure 4: Establishment of runoff plots

Meteorological parameters like precipitation, maximum and minimum temperature were collected from the meteorological station of Assosa Agricultural Research Center which was found in the vicinity of the experimental site. Precipitation is much more important than the other metrological parameters because rainfall has a direct relation with runoff and sediment generation from the experimental plots.

2.4. Data Collection

Particle size distribution: Five soil samples were randomly taken per runoff plot before and after harvest using augur from 0-20cm and 1Kg of composite soil from each plot were taken to laboratory to determined Particle size distribution using Bouyoucos hydrometer method (Bouyoucos, 1962) for each runoff plots before and after the experiment.

Bulk Density: Soil bulk density in the 0–10 cm layer was determined using the core method. Five soil samples were randomly taken per runoff plot before and after harvest using a stainless steel core sampler of dimension 5 cm diameter by 5 cm height. The collected soil cores were trimmed to the exact volume of the cylinder and oven dried at 105 ^oC for 24 hours .Precautions were taken to avoid compaction inside the core sampler. Bulk density was determined from the ratio of mass of dry soil per unit volume of soil cores.

ρ = Ms/Vt ……………………………………….(1)

Where, $\rho = bulk density of the soil$ (g/cm^3)
Ms = mass of dry soil (g)
V_T = total volume of the soil(cm^3)

Total Porosity: The total porosity of the soil in the 0–10 cm layerwas calculated from the values of the dry bulk density and an assumed particle density of 2.65 Mg m^{-3}using the following Equation (Chancellor, 1994). The result was multiplied by 100:

f = (1-$\rho b/\rho p$)*100…………………………….(2)

Where, f = porosity of the soil (percent)
ρb = bulk density (g/cm^3)
ρp = particle density (g/cm^3)

Void ratio: The void ratio of the soil in the 0–10 cm layer was calculated from the values total porosity as the following formula.

$e = f/1\text{-}f$……………………………………………(3)
Where, e = void ratio (dimensionless)
f = porosity (percent)

In-situ water conservation: The total depth of rainwater that was retained in-situ under each of the treatments was determined on the basis of runoff producing rainfall and runoff depth as:

Wc = RF-Ro .... (9)

where, WC= depth of water that was retained in the soil in-situ (mm)
RF= rainfall depth (mm)
Ro= runoff depth (mm)
Finally, the daily values of retained rainwater will be summed up to get seasonal values

Data analysis: All measured parameter were subjected to statistics' version 8 and treatment means was compared using the least significant difference at the 5% probability level (LSD0.05) where the variance ratio for treatment effects shows significance.

3. RESULT AND DISCUSSION

3.1 Soil physical properties prior to the experiment

As shown in Table 1, the soil of the study area had a textural class of clay with average sand, silt and clay contents of 41.1, 12.1 and 46.7 %, respectively. As indicated in Table 1, the texture of the surface soil (0-20 cm) in the experimental area was homogenously rich in clay (>44.2%). Clay soil has high water holding capacity and in turn low infiltration capacity which leads to high runoff and soil loss particularly when the surface is not covered with vegetation. The bulk density of surface soil of the experimental site varied from 1.14 to 1.15 with the mean value of 1.15 g/cm^3. The overall bulk density values indicate that the soil is not compacted to inhibit root development prior to the treatment application. There was no much difference between the tested properties, since the entire experimental site was relatively homogenous in terms of soil physical, chemical and topographic properties prior to the experiment

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Table 1: Some physical properties of experimental plots prior to the experiment

Treatments	Sand (%)	Silt (%)	Clay (%)	Textural class	Bulk density (g/cm^3)	Porosity (%)	Void ratio
Conven. with maize (T1)	36.8	16	47.2	C	1.15	56.73	1.27
Conven. tillage with soyabean (T5)	52.8	3	44.2	C	1.14	56.83	1.3
Conven. tillage with intercr.(T3)	36.8	16	47.2	C	1.15	56.73	1.27
Minimum tillage with maize (T2)	36.8	16	47.2	C	1.15	56.73	1.27
Minimum with soya bean (T6)	44.8	8	47.2	C	1.14	56.83	1.30
Minimum with intercropping (T4)	38.8	14	47.2	C	1.15	56.73	1.27
Mean	41.1	12.1	46.7		1.15	56.73	1.27
Cv(%)	15.8	44.8	2.62		0.45	0.08	1.21

C: clay, Cv: coefficient of variation

3.2 Effect of the treatments on soil physical properties after to the experiment

Independent effect of tillage resulted in non-significant variation forbulk density, porosity and void ratioas mentioned on (Table 2) showing high bulk density for no tillage as compared to conventional tillage practices and vice versa for porosity and void ration. Even though, there was no significant difference among tillage practices, no tillage had increased the bulk density by 0.1g/cm^3 as compared to conventional tillage. Using intercropping system had also reduced the bulk density as compared to sole cropping systems of maize and soya bean and vice versa for porosity and void ratio. As indicated in Table 4, under no tillage, bulk density had increased as compared to the result of prior of the experiment (Table 1) and conventional tillage treatments. The bulk density of the soil increased in no tillage treatments due to lack of loosening action of tillage. This study showed the increment of bulk density in the first year of no tillage introduction which in lines with the report of Ferreras*et al*. 2000, Logsdon and Cambardella, 2000

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Table 2: Independent effect of tillage practices and cropping systems on bulk density, porosity and void ratio

Factors of variation	Parameters		
	Bulk density (g/cm^3)	Porosity (%)	Void Ratio
Tillage types			
No tillage	1.42	46.32	0.91
Conventional tillage	1.34	48.65	0.98
Cropping systems			
Sole maize	1.41	45.53	0.85
Sole soya bean	1.41	46.35	0.93
Intercropping	1.32	50.58	1.04

The analysis of variance indicated that bulk density, porosity and void ratio of in-situ soil (5 to 10 cm of the top soil) were highly significant ($p<0.01$) due to interaction effect of the factors. The bulk density under conventional tillage was declined by $0.3 g/cm^3$, $0.3 g/cm^3$ and $0.23 g/cm^3$ as compared to no tillage with mulch treatments for maize, soya bean and maize-soya bean intercropping respectively (Table 3).

The result of bulk density obtained under no tillage treatments were above the tolerable limit of crop root growth for clay soil that ranges from $1.4 g/cm^3$ to $1.9 g/cm^3$ as reported by Campell and Henshall,1991 which had negative impact on root distribution thereby plant growth and yield reduction. High percentages of clay and silt fraction were observed under no tillage treatments, showing more nutrient retention than conventional tillage treatments which in lines with the study of Schiettecatte*et al.,* 2008.

Table 3:. Interaction effect of tillage and cropping systems on physical properties of in-situ soil after harvesting of the test crops

Treatments	Bulk density (g/cm^3)	Porosity (%)	Void ratio	Mechanical composition		
				Sand	silt	clay
Conventional tillage with maize (T1)	1.27^{b}	51.03^{a}	1.04^{ab}	34.2	19.9	45.86
Conventional tillage with soya. (T5)	1.27^{b}	52^{a}	1.19^{a}	49.9	7.57	42.53
Conventional tillage with intercrop.(T3)	1.2^{b}	54.8^{a}	1.27^{a}	30.3	23.5	46.23
No tillage with maize (T2)	1.57^{a}	40.03^{a}	0.67^{b}	30.5	25.6	43.86
No tillage with soya bean (T6)	1.57^{a}	40.1^{a}	0.67^{b}	42.8	14	43.2
No tillage with intercropping (T4)	1.43^{ab}	46.3^{ab}	0.87^{ab}	39.6	15.9	44.53
Lsd (0.05)	0.26	10.92	0.42	ns	ns	ns
Cv(%)	10.31	12.63	24.35	10.6	25.8	23.23

Cv: coefficient of variation Lsd : Least significant difference

3.3 In-situ water conservation

The analysis of variance revealed non-significant variation due to the interaction effect of tillage and cropping systems on in-situ water conservation and significant variation due to tillage practices. Independent effect of tillage resulted in significant variation ($p<0.0001$) as mentioned on (Table 4) showing high in-situ water conservation for no tillage as compared to conventional tillage. Tillage had a great impact on the amount of in-situ water conservation generated from each treatment. No tillage had increased in-situ water conservation by 9.6% (17.8mm) as compared to conventional tillage whereas, cropping systems didn't show significant variation on in-situ water conservation but showing the more advantage of intercropping of reducing in-situ water conservation by 2 %(7.33mm) and 4.04 % (3.5mm) than sole maize and soya bean (Table 4).

Table 4: Independent effect of tillage types and cropping systems on in-situ water conservation (mm)

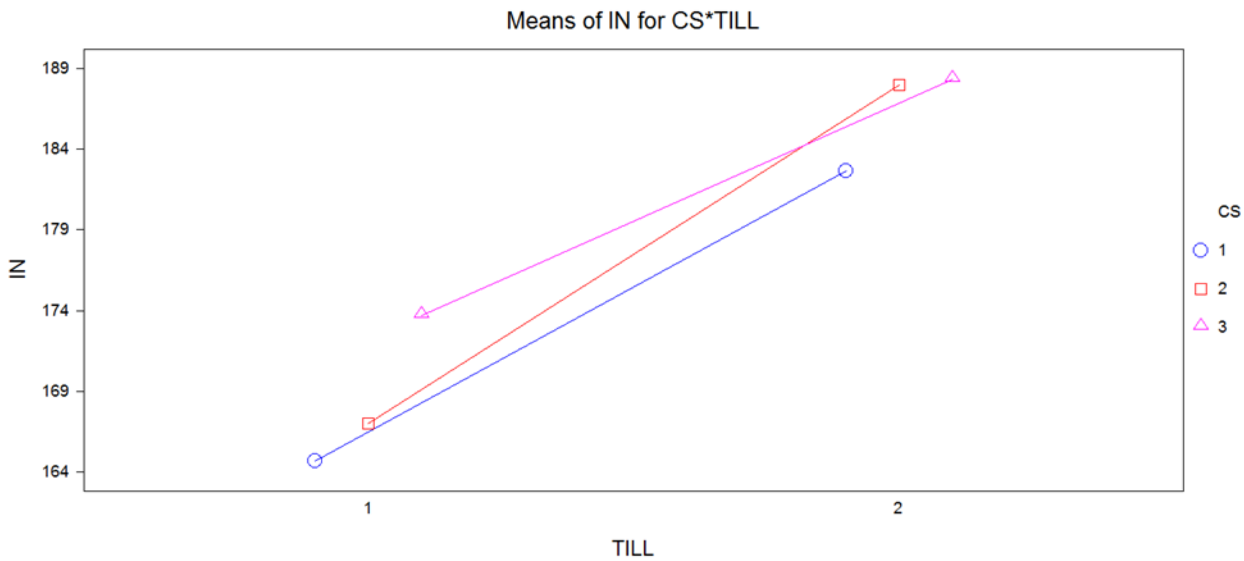
Factors of variation	Parameter
	In –situ water conservation (mm)
Tillage types	
No tillage	186.33[a]
Conventional tillage	168.44[b]
LSD (0.05)	6.06
Cropping systems	
Sole maize	173.67
Sole soya bean	177.5
Intercropping	181

Interaction effect of the factors had showed non-significant variation among treatments.The in situ-water retained under conventional tillage was declined by 9.83% (18mm), 11.3% (21mm) and 7.76% (14.63mm) as compared to no tillage with mulch treatments for maize, soya bean and maize-soya bean intercropping respectively (Table 5). The result obtained showed higher amount of retained water under zero tillage with residue management than conventional tillage.

Table 5: Interaction effect of tillage types and cropping systems on in-situ water conservation (mm)

Treatments	In-Wc (mm/plot)
Conventional tillage with maize (T1)	164.67
Conventional tillage with soya bean (T5)	167.00
Conventional tillage with intercropping (T3)	173.67
No tillage with maize (T2)	182.67
No tillage with soya bean (T6)	188
No tillage with intercropping (T4)	188.3
$Lsd_{(0.05)}$	ns
Cv (%)	3.25

Zero tillage with residue retention can increase infiltration, reduce runoff and evaporation by reducing the sun radiation compared to conventional tillage. Consequently, soil moisture is conserved and more water is available for crops. The amount of energy the soil surface receives is influenced by canopy and residue cover. The study coincides with the study of Kargas, Kerkides, and Poulovassilis (2012) observed that untilled plots retain more water than tilled plot. Sauer *et al*. 1996 , Blevins *et al.* 1971, Papendick*et al.* 1973 who also reported that the presence of residue on the surface reduced soil water evaporation by 34 to 50% and tillage disturbance of the soil surface increased soil water evaporation compared to untilled areas.



IN-in situ water conservation (mm), cs: cropping system 1 CS- Sole maize, 2 CS- Sole soya bean, 3CS- intercropping & 1 TILL- convectional tillage, 2 TILL-no tillage

Figure 5: Mean of in situ-water conservationin (mm) for interaction of cropping system and tillage practice

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