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Evaluation of tillage and planting method under conservation farming for soil and crop productivity in the Dryland areas of Tigray, Northern Ethiopia

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ABSTRACT

Moisture conservation, minimum tillage and residue retention are conservation farming management options that may enhance crop yield and soil fertility sustainably in the dry land areas of Ethiopia. Study on conservation farming (CF) was conducted in moisture deficit area of Tigray, Northern Ethiopia from 2013-2014 cropping seasons. The experiment conducted both on station and on farmers' field. Included treatments were; conventional tillage + fertilizer, conventional tillage without fertilizer, subsoiler + fertilizer, subsoiler + tie ridging + fertilizer subsoiler + tie-ridging + intercropping+ fertilizer, subsoiler + tie-ridging + intercropping + fertilizer, subsoiler + tie ridging + transplanting, subsoiler + planting basin +fertilizer and subsoiler + transplanting on planting basin+ fertilizer. Significantly, more variation was observed among the tillage practices for the studied agronomic traits. Higher mean Sorghum grain yield of 2.40 (+1.5 and 1.4 t ha^{-1} over the conventional treatments with and without fertilizer respectively and 2.50 t ha^{-1} (+1.6 and +1.5 t ha^{-1} over the conventional treatments with and without fertilizer respectively) were recorded from transplanted sorghum seedlings and directly planted sorghum seeds in planting basin respectively in the researcher managed conservation plots using early maturing 'Hormat' variety. Similarly, 2.40 t ha^{-1} and 2.38 t ha^{-1} grain yield were obtained from tie-ridging and transplanting at planting basin respectively, while the lowest mean grain yield of 0.94 t ha^{-1} was obtained from the conventional tillage without fertilize treatment in the farmers managed conservation plots. Mean Grain yield of 3.90 and 5.60 t/ha were also obtained from 'Kodem' and 'Abaere' Sorghum land races, respectively planted in basin at farmers field. Some soil chemical properties (like total nitrogen, available phosphorus and organic carbon) on the conservation treatments show increment. Participating farmers also select transplanting and direct planting on planting basin tillage techniques first and second respectively based on over all crop performance. Planting basin supported conservation tillage packages can enhance crop, water and soil productivity in sustainably and help mitigate the effects of prolonged dry spells in the moisture deficit of Tigray.

Keywords: Conservation farming, Conventional tillage, planting basin, Tie-ridge, Mulching

INTRODUCTION

The problem of food insecurity has become more intensely pronounced in recent years with the threat posed by climate change, water and rainfall scarcity as well as ecosystems and biodiversity degradation. In Sub-Saharan Africa (SSA), most rural communities are languishing in poverty yet, the agricultural practice being promoted there has unacceptably high environmental, economic and social costs (Bolwig & Gibbon, 2007). Nearly 80% of the population in SSA countries lives in rural areas with 90% of population being directly dependent on rainfed agriculture (Wiggins, 2009; Wiggins and Sharada, 2013; Rockström, 2003). However; rainfall is poorly distributed (Ngigi, 2003) and high losses occur due to high surface runoff, poor crop rooting conditions, past and present soil erosion and evaporation losses from soil and crop canopy (Rockström, 2003).

The impact of climate change on agricultural productivity is severe in SSA due to low adoption of key agricultural production technologies that enhance adaptation to climatic change, enhance, soil, water, and crop productivity. It is thus against this scenario and statistics that, rural farmers have to consequently adopt farming practices that conserve fragile soils and improve its healthy and fertility for improving crop production in moisture deficit areas rainfall area.

Ethiopia's economy and ecological system are very vulnerable to impact of climate change (César and Ekbom, 2013). Food security is highly sensitive to climate risks and rainfall is one of the climatic determinants of food production in Ethiopia. However, rainfall is highly erratic and unreliable (Stroosnijder and Van Rheenen, 2001; Mesfin *et al*., 2009) in respect to mainly delay in the onset and early cessation. This intermittent long dry spells throughout the growing season has a tremendous influence crop production (Rockstrom, 2000; Abdelkdair and Richard, 2005) and it is the main risk contributing to food insecurity and overall vulnerability of households. The vulnerability to climate-related hazards and food insecurity is closely linked to land degradation, in which about 85% of the land surface in Ethiopia is considered susceptible to moderate, or severe soil degradation and erosion. Moreover, the main reasons for dryland cropland degradation in Ethiopia include complete removal of crop residues at harvest, aftermath overgrazing of livestock, frequent tillage, drought and inefficient use of technologies and practices (Manado, 1997; Taddese, 2001). Farmers in the study areas plough their land 3-5 times for Sorghum and maize crops per season using traditional tillage equipment known as 'Maresaha'. Repeated tillage with the same soil depth hurries SOC decomposition (Doran and Smith, 1987) and water runoff and soil erosion (Derpsch *et al*., 1991), and other physic-chemical and biological soil degradation (Benites, 2008; Kerte´ sz *et al*., 2008), and it has been repo stated to be the utmost cause of land degradation in Ethiopia (Tefera, 2002).

The challenges of climate change to agricultures and food security demands a holistic and strategic approach to linking knowledge with action. Among the solutions, conservation farming (CF) practices hold the promise of providing both a strategy for mitigating climate change and working as an adaptive mechanism to cope with climate change. CF is mainly to keep the soil covered (at least 30% residue), to have minimal soil disturbance and to mix and rotate crops as well as local in-situ soil and water conservation practices (Bradford and Peterson, 2000; Verhulst *et al*., 2010; Rockstrom *et al*., 2003). It maintains cover of vegetation, raises the organic matter content of the soil, improving fertility (Kidane, 2014) protects the soil from erosion and leads to positive changes in the physic-chemical and biological properties of a soil (Bescanca *et al*., 2006). CF practices emphasize maximum use of available water resources through early and timely planting, soil protection through ground-cover plants. This reduces long-term dependency on external inputs, enhances environmental management, and improves water use efficiency. Positive contribution of CF on crop yields compared to traditional tillage management was also reported by Hine and Pretty (2008), increases in yields of maize (from 3000 to 5000 kg ha^{-1}) and soya (from 2800 to 4700 kg ha^{-1}) and bread wheat (+82% over conventional) in Brazil.

Keeping conservation farming scenario in view, the present study aimed evaluation of CF technologies implication for enhancing productivity of dry land soils by improving fertility and increasing water productivity in drought prone reas of Tigray

MATERIALS AND METHODS

2.1. The Study Areas:

The study was conducted in moisture deficit areas of Raya Azobo and Raya Alamata) districts of Tigray, northern Ethiopia from 2013 and 2014 main cropping season.

The study was conducted from Sebtember, 2014 to April, 2016 at sheka tekli, Gimtsua irrigation schemes, central Tigray Zone (Northern Ethiopia).

A semi-arid type of climate characterizes the study areas receiving highly variable rainfall. Rainfall is bimodal, with a short rainy season from February-March (Belg) and the main rainy season from June-September ('Kareem'), but potential evapotranspiration exceeds annual rainfall amount in most of the year. The study areas have annual mean rainfall ranges between 350 and 700 mm. Monthly rainfall distribution of the study sites in in the study period and 7 year mean (for Raya Azobo) and 17 year mean(for Raya Alamata) in presented in figure 1.

2.3. Experimental Treatments, Design and Procedure

The on-station experiment was layout in randomized complete block design with treatments applied to the same experimental units (Permanent plot) each year. Gross plot size was 10mx10m for each experimental unit. The varieties used in the experiment were long maturing local cultivars (180-210 days maturing) 'Abaere', Medium maturing (150-180 days maturing) 'Kodem' and early maturing improved variety (100-120 days maturing) Hormat. For the conventional/farmers practice plots, tillage and fertilizer application methods was done as per the farmers' practice by farmers' local plowing equipment 'Maresha' without cropresidue retentions and moisture conservations.

Table 1: Geographical location of research districts

Woreda	Districts (PA)	Altitude (m.a.s.l)	Longitude (E)	Latitude (N)
Raya Azobo	Genetie	1567-1595	39° 37' 31"	12° 46' 36"
	Tsigea	1578-1600	39° 38' 38''	12° 47'59'' N
Raya Alamata	Garjalle	1520-1559	39° 34' 01"	12° 23' 03"
	Tao	1560-1569	39° 33' 01"	12° 22' 05

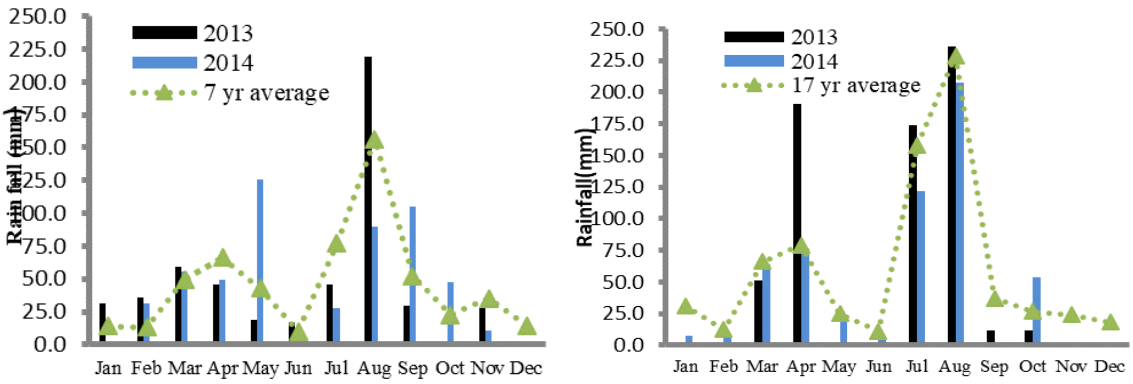

Figure 1: Monthly rainfall (mm) distribution at Raya Azobo (left) and Raya Alamata (right) during the study periods and mean monthly rainfall distribution

Table 2: The treatments used in the onstaion experiments

S/N	Treatments	Incorporated packages
1.	Conventional tillage without fertilizer	5 times tillage using 'maresha'
2.	Conventional tillage +64/46 N/P_20_5 kg/ha	
3.	Subsoiler/Ripper+64/46 N/P_20_5 kg/ha	Mulching of residue Seed hydro priming Residue retentions
4.	Subsoiler + Tie-ridge +64/46 N/P_20_5 kg/ha	
5.	Subsoiler + Tie-ridge + inter cropping +64/46 N/P_20_5 kg/ha	
6.	Subsoiler + Tie-ridge + inter cropping without fertilizer	
7.	Subsoiler + Tie-ridge +Transplanting +64/46 N/P_20_5 kg/ha	
8.	Direct planting on basin + 64/46 N/P_20_5 kg/ha	
9.	Transplanting on basin + 64/46 N/P_20_5 kg/ha	

Table 3: The treatments used in the onstaion experiments

S/N	Treatments	Remark
1	Conventional tillage +64/46 N/$P_2 0_5$ kg ha^{-1}	Tested on 20 farmers using Hormat, kodem and Abaere variety
	Subsoiler + Tie-ridge +64/46 N/$P_2 0_5$ kg ha^{-1}	
2	Direct planting on basin + 64/46 N/$P_2 0_5$ kg ha^{-1}	Tested on 20 farmers using Hormat, kodem and Abaere variety
	Conventional tillage +64/46 N/$P_2 0_5$ kg ha^{-1}	
3	Transplanting on basin + 64/46 N/$P_2 0_5$ kg ha^{-1}	Tested on 17 farmers using Hormat variety
	Conventional tillage +64/46 N/$P_2 0_5$ kg ha^{-1}	

Planting basins are pits used for planting many types of crops used to conserve soil and moisture in conservation agriculture and they were prepared at dimension of 0.75x0.25 x0.2cm length, depth and width using hoe which is suitable for sorghum crop planting in a dry land areas. Tie-ridger is an improved tie ridging drawn by animal attached on the 'Maresha' using a pair of metal rods and tying unit and creates a series of basins in the field to retain soil and water. Subsoiler is a modified 'Maresha' where the wooden wings ('Deger') replaced by a pair of rods and rings used to break the soil hard pans that are created after continuous plowing at the same depth of soil.

Data collection

Grain yield (kg/plot): Grain yield was taken from each plot by excluding the border rows by adjusting to 12.5% moisture level, and then converted to hectare basis.

Rainwater use efficiency (RWUE): Rainwater use efficiency was calculated according to Oweis (1997) as the percentage of total grain yield (t/ha) to growing season precipitation (mm):

$$\mathrm{RWUE}(\%) = \left(\frac{\mathrm{GY}}{\mathrm{RF}}\right) * 100$$

Percent deviation (D): The Percent deviation of conservation farming (CF) from the conventional tillage (CT) was calculated as-

$$\mathrm{D}\ (\%) = \left(\frac{\mathrm{CF}}{\mathrm{CF} - \mathrm{CT}}\right) * 100$$

Where CF and CT represent the measured data (grain yield, straw yield, soil and net benefit) obtained in the CF and its corresponding value in the CT treatments respectively.

Farmers' insight: The cumulative crop performances in each of the plots were evaluated with 57 local farmers from 2012 -2014 cropping season. The farmers carried group discussion during their visit to each treatment to evaluate the overall crop overall performance. The farmers gave grading having one corresponding to the best crop performance while with nine to the lowest one.

Soil sampling, sample preparation and analysis: composite surface soil samples were collected using standard Auger from five spots from each experimental block (0-20 cm depth)) to form one composite soil sample per block for initial soil fertility evaluation of the experimental fields (0-20 cm depth). Similarly, soil samples were collected after crop harvest from each plot and then composited by replication to obtain one representative sample per treatment. Particle-size distribution was determined using hydrometer method (Pawluk et al. 1992). Soil pH and electrical conductivity (EC) were measured in soil: water extracts (1:2.5) (Rhoades, 1982). Soil Organic matter (SOM) content was determined by the Walkley and Black method (Walkley and Black, 1934). Total nitrogen (TN) content was analyzed by Kjeldhal method (Bremner, et al., 1982). Available phosphorus (Av.p) was Analysed using Olsen method (Olsen et al., 1954). One molar neutral ammonium acetate (pH = 7) was used to determine the exchangeable cations (Ca, Mg, K and Na) (Cottenie, 1980).

Statistical Analysis

The Analysis of Variance on the selected agronomic traits were computed using SAS software version 9.4 (SAS, 2013) following the standard procedures of ANOVA for randomized complete block design (Montgomery, 1991) for the on-station trial. The differences among the treatments were considered significant if the P-values were ≤ 0.05 and Least Significance Difference was used to compare among treatments. For the on farm trials analysis was done using descriptive analysis.

Partial Budget Analysis

Mean grain and biomass yield data for the CF effect was subject to economic analysis using the CIMMYT (1988) partial budget techniques to evaluate the economic profitability CF techniques. Costs for NP fertilizer, costs for seed, costs of weeding and costs for preparation of tie ridge, ripper and basins was analyzed separately by calculating gross benefit, total variable costs and net benefit.

RESULT AND DISCUSSION

Soil physical-chemical properties

According to the soil pH rating developed by Tekalign (1991), the mean pH values of the composite surface soil samples of the experimental sites was falls under the slightly neutral soil reaction class. The soil organic matter (SOM) contents were in the range of 1.15–2.87 % on the surface soils (Table 2) thus, these values fall under low to moderate range based on the ratings of soil test values established by Tekalign (1991). Total nitrogen (TN) levels of the study sites ranges between 0.098 and 0.16 % and taken as low while those below 0.1 % are very low for tropical soils (Beyene, 1988). It, therefore soils of the study areas are low to very low in their total nitrogen status (Table 2). Moreover, according to Phosphorus rating developed by Olsen et al. (1954), the available phosphorus (Av.P) contents of the soil of the experimental site fall under the medium phosphorus status (Table 5). This indicate the low level of fertility status of the soil aggravated by long term cereal based cultivation, lack of incorporation of organic materials in to the soils through mulching or crop residues retention after harvest and frequent tillage. Continuous mono cropping and inadequate replacement of nutrients removed in harvested materials or lose through erosion and leaching has been the major causes of soil fertility decline (Matson et al., 1998). The electrical conductivity (EC) ranged from 0.01 to 0.21 dSm^{-1} indicating that these soils have a low content of soluble salts and that there is no danger of salinity in the study areas (Table 4).

Table 4: physical and chemical properties of the study sites before planting

Site	Avai.P	Total N	pH	SOM	EC	CEC	Ex.K	Ex.Na	Ex .Ca	Ex. Mg	Textural class
	ppm	%	H_20	%	ds/m	Meq/ 100gm	ppm		Meq ca/L	meqMg /L	
Gargalle	10.50	0.098	7.03	1.15	0.05	44.70	571.5	128.8	7.70	4.50	Clay loam
Genetie	17.83	0.15	7.18	2.87	0.21	11.93	710.3	141.0	5.60	5.00	Clay loam
Tsigea	16.73	0.16	7.01	2.40	0.15	16.79	680.4	126.8	4.28	2.43	Clay loam
Tao	25.06	1.13	7.39	47.5	0.19	47.50	2.6	0.13	4.4	2.6	Clay loam

Where: Ex is exchangeable

Table 5: Effect of conservation tillage (CF) on some soil chemical properties of the study sites (Garjalle)

Tillage type	Organic Mater %	Total Nitrogen (%)	Available phosphorus (ppm)	CEC meq/ 100gm soil	pH
Susoiler/Tieriger + 64/46 N/P_20_5 kg/ha	1.26	0.12	15.4	39.5	7.1
Susoiler + Tie-ridge + 64/46 N/P_20_5 kg/ha	1.21	0.11	10.9	42.3	6.9
Susoiler + Tie-ridge + inter cropping without fertilizer	1.46	0.10	9.2	46.4	7.0
Susoiler + Tie-ridge + inter cropping + 64/46 N/P_20_5 kg/ha	0.97	0.12	10.3	42.7	7.0
Susoiler + Tie-ridge + Transplanting + 64/46 N/P_20_5 kg/ha	1.23	0.11	11.9	44.2	6.9
Direct planting on planting basin + 64/46 N/P_20_5 kg/ha	1.01	0.12	10.0	39.8	7.1
Transplanting on planting basin + 64/46 N/P_20_5 kg/ha	1.55	0.10	9.0	41.8	7.2

Table 6: Effect of CF on agronomic traits of sorghum at Garjalle in 2013 and 2014

Tillage system	Grain yield (t ha^{-1})			RWUE (%)		
	2013	2014	Mean	2013	2014	Mean
Conventional without fertilizer	0.3	1.6	0.9	0.1	0.5	0.3
Conventional +64/46 N/P_2O_5 kg/ha	0.2	1.8	1.0	0.1	0.5	0.3
Subsoiler +64/46 N/P_2O_5 kg/ha	0.2	2.1	1.2	0.0	0.7	0.3
Subsoiler + Tie-ridge +64/46 N/P_2O_5 kg/ha	0.8	2.2	1.5	0.2	0.7	0.4
Subsoiler + Tie-ridge + intercropping +64/46 N/P_2O_5 kg/ha	1.0	1.8	1.4	0.2	0.6	0.4
Subsoiler + Tie-ridge + intercropping without fertilizer	0.9	1.9	1.4	0.2	0.6	0.4
Subsoiler + Tie-ridge + Transplanting + 64/46 N/P_2O_5 kg/ha	0.7	1.9	1.3	0.2	0.6	0.4
Direct planting on basin + 64/46 N/P_2O_5 kg/ha	2.6	2.3	2.5	0.6	0.7	0.7
Transplanting on basin + 64/46 N/P_2O_5 kg/ha	2.2	2.7	2.4	0.5	0.8	0.7
CV (%)	37.5	5.6		36.5	5.8	
LSD (5%)	0.64	0.19		0.16	0.06	

Where: RWUE=Rain water use efficiency

The total nitrogen content of the conservation plots had increased from 0.06 to 0.12% and from 1.15 to 1.55 % in soil organic matter content. Thus, increment of the some soil properties in the study site is mainly from mulching of different weeds, nitrogen fixation from the intercropped cowpea, and residue retentions from the conservation plot after first year experimentation. Desale (2014) reported a research findings conducted on highland of Ethiopia on the effect of tillage 0.30 % increment of SOMC content for no-tillage over conventional tillage soil total nitrogen content was increased by 0.03% in no-tillage over conventional tillage method.

Effect of Conservation Farming on Yield And Yield and Related Traits of Sorghum

On Station Trial

Grain yield (GY) and Rain Water Use Efficiency (RWUE) were significantly (P<0.05%) affects by tillage methods and planting system (Table 3).

Direct planting sorghum seeds and transplanting of sorghum seedling at planting basin with 64/46 kg ha^{-1} N/P_2O_5 fertilizer micro dosing in CF plots recorded mean Sorghum grain yield of 2.5 t ha^{-1} (+150% and +178% % than conventional tillage with and without fertilizer respectively) and 2.4 t ha^{-1} (+140% and 166 % than conventional tillage with and without fertilizer respectively). In agreement to these study research findings, reported by Belay et al. (1998), Lal (2000) and Temesgen et al. (2008) indicate that the main reasons for the increment of in yields were better soil moisture availability, enhanced soil fertility and better crop root growth because of conservation tillage techniques. Similar result on ripping + sub-soiling techniques resulted in 60% maize grain yield enhancement (Temesgen et al., 2009). Other findings in semi-arid areas of Zimbabwe planting basins + 10–30 kg ha^{-1} of N (micro-dose) were superior to farmers practice in 59% of the experiments (Nyamangara et al, 2014).

In the 100:50 sorghum/cowpea intercropped plots, mean cowpea grain yield of 1.7 ha^{-1} was obtained in addition to the sorghum grain yields in the on station trial. However, the major benefit of legumes incorporation in CF farm is in improvement of SOM and TN content and protects soil form exposing to sun light. According to the research findings by Reddy et al. (1992) in pearl millet-cowpea, intercrop the SOM was increased (by 29%) compared to the sole crop of pearl millet. Research output in semi-arid Kenyan conditions, cowpea intercrop recycles 30 kg N ha^{-1} (Rao & Mathuva, 2000). Similarly, intercrops shown to give substantial enhancement in water use efficiency (Reddy & Willey, 1981; Mukhala, 1998; Morris & Garrity, 1993).

Conservation farming technologies are relevant, especially with increasing variability in rainfall, due to the effects of ELNO and climate change, which will lead to an increase in both inter- and intra-seasonal drought events and high uncertainty about the onset of the rainy seasons. Mostly crops use only 36–64% of the seasonal rainfall on average (Barron et al. 2003), while the remaining proportion (50%) of nonproductive water (Nyamadzawo et al. 2012), which is relevant for stable plant growth if properly managed by CF techniques in moisture stressed areas like Tigray.

The mean rainwater use efficiency (RWUE) of Sorghum was found significantly ($p<0.05$) higher at transplanted sorghum seedlings in planting basin under the conservation farming and direct planting on basin, compared to other treatments (Table 6). The 2-yrs average was higher at planting basin (direct either planted or transplanted) compared to CT and other treatment while, the lowest RWUE was recorded in the conventional tillage.

Partial Budget Analysis

Partial budget analysis was computed for the conservation and conventional plots. Hence, 24,437 (+325 %) & over the conventional) and 20,519 (+256% over the conventional) ETB birr net return was obtained from direct planting and transplanting at planting basin respectively. Although the cost of producing sorghum was higher under the CF basin system, the higher net returns achieved with this technology resulted in significantly better returns in production compared to the conventional tillage system. Hassane et al. (2000) evaluate the impact of planting basin conservation tillage and use of fertilizer and farmyard manure on millet crops in Niger and reported that yield increment of up to 511%. It is easy to make and use planting basins, elderly people, children and disabled people can all use them to grow the food they need. The required equipment (a hoe) is readily available for every male and female farmer in the community.

Farmers' insight

Different field visits, experience sharing and group discussions were held at different plant growth stages each districts with farmers, Development Agents (DA), experts, and local NGOs representatives working on agriculture. Thus, the respondent have selected direct planting and transplanting on planting basin first and second respectively based on population stand of the crop, stay green, biomass and yielding potential (Table 8). Participants observed good performance, increased plant height, more grain yield, soil healthy, soil moisture and both sorghum planted using conservation farming methods. Our results also show that local farmers' evaluation of overall crop stand under treatments is increasing with increasing yield.

Table 7: Partial budget analysis for different tillage system

S/N	Tillage system	GY adjusted (t ha^{-1})	GB From GY (ETB ha^{-1})	BY (t ha^{-1})	GB From BY (ETB ha^{-1})	Total GB(ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})
1	Conventional without fertilizer	0.261	2349	13.0	5200	7549	1800	5749
2	Conventional +64/46 N/P_2O_5 kg/ha	0.207	1863	14.7	5880	7743	4100	3243
3	Subsoiler+64/46 N/P_2O_5 kg/ha	0.162	1458	13	5200	6658	2700	3958
4	Subsoiler+tiridger+64/46 N/P_2O_5 kg/ha	0.747	6723	17.8	7120	13843	2700	11143
5	Subsoiler+tiridger+Intercropping+64/46 N/P_2O_5 kg/ha	0.909	8181	16.9	6760	14941	3100	11841
6	Subsoiler +tie-ridger+Intercroping without fertilizer	0.792	7128	17.2	6880	14008	2700	11308
7	Subsoiler+tie-ridger+Tranplanting+64/46 N/P_2O_5 kg/ha	0.657	5913	9.2	3680	9593	2700	6893
8	Direct planting on basin+64/46 N/P_2O_5 kg/ha	2.313	20817	19.8	7920	28737	4300	24437
9	Transplanting on basin+64/46 N/P_2O_5 kg/ha	1.971	17739	17.7	7080	24819	4300	20519

Where: GY=grain yield, BY=biomass yield, GB=Gross benefit (ETB ha^{-1}), TVC=Total variable cost (ETB ha^{-1}) and NB=Net benefit.

Table 8: Pair wise ranking of the tillage method (n=35)

	Conv.W/F	Con.WF	SS+F	SS+T+IC	SS+T+F+IC	SS+T+F	SS+T+TP	TPB+F	DPB+F	Total score	Priority order
Conv.W/F										0	9
Con.WF	Con.WF									1	8
SS+F	SS+F	SS+F								2	7
SS+T+IC	SS+T+IC	SS+T+IC	SS+T+IC							3	6
SS+T+F+IC	SS+T+F+IC	SS+T+F+IC	SS+T+F+IC	SS+T+F+IC						4	5
SS+T+F	SS+T+F	SS+T+F	SS+T+F	SS+T+F	SS+T+F					5	4
SS+T+TP	SS+T+TP	SS+T+TP	SS+T+TP	SS+T+TP	SS+T+TP	SS+T+TP				6	3
TPB+F	TPB+F	TPB+F	TPB+F	TPB+F	TPB+F	TPB+F	TPB+F			7	2
DPB+F	DPB+F	DPB+F	DPB+F	DPB+F	DPB+F	DPB+F	DPB+F	DPB+F		8	1

Where: Conv.W/F=conventional without fertilizer, Con.WF= Conventional with fertilizer, SS+F= Subsoiler + fertilizer, Subsoiler +T+IC= Subsoiler +tieridger intercropping without fertilizer, Subsoiler +T+F+IC= Subsoiler +tieridger + intercropping fertilizer, Subsoiler +T+F= Subsoiler +tieridger with fertilize Subsoiler +T+TP Subsoiler + tieridger + Transplanting, TPB+F= Direct planting on basin + fertilizer and DPB+F= Transplanting on basin + fertilizer.

Table 9: Effect of planting basin tillage on grain yield of different sorghum variety (N=57) in 2012-2014 cropping season

Variety	Tillage system	Grain yield (t/ha) + Se	Remark
Kodem	Direct planting on planting basin	3.90±0.77	Medium maturing local land race
	Conventional tillage	2.77±0.84	
	Subsoiler + Tie ridging	3.55±0.11	
	Conventional tillage	3.1±0.20	
Hormat	Transplanting on planting basin	2.38±0.04	
	Conventional tillage	0.94+0.18	Early maturing variety
	Subsoiler + Tie ridging	2.39±0.15	
	Conventional tillage	1.19±0.38	
Abaere	Direct planting on planting basin	5.6±0.56	
	Conventional tillage	2.60±0.15	late maturing local land race
	Subsoiler + Tie ridging	4.60±0.20	
	Conventional tillage	2.90±0.33	

Fertilizer was applied uniformly at rate of 64/46 kg/ha N/P_2O_5 for all plots

Table 10: Farmers perceptions on CF (n=35)

Contribution of the practice	Farmers response	
	Agree (%)	Dis agree (%)
Conservation farming increase soil fertility	90	10
Conservation farming conserve soil moisture	100	0
Conservation farming can reduce soil erosion	100	0
Conservation farming save labor and cost	30	65
Conservation farming decrease weed problem	0	100
Conservation farming increase yield	86	14

Farmers managed on farm trial

On farm evaluation of selected conservation tillage practices were conducted at Raya Alamata (Garjalle and Tao), Raya Azobo (Genetie and Tsigea) areas on 57 volunteer farmers' field in 2012-2014 cropping seasons. Direct planting of sorghum seeds at planting basin gave more grain yield 3.90 t/ha (+40% over conventional) and 5.60 t/ha (+120% over conventional) for the land races Kodem and Abaere respectively (Table 9). Transplanting of 30 days old seedling Hormat variety at planting basin also gave 2.38 t/ha (+150 % than conventional). Similar research findings indicated that, the grain yield of transplanted sorghum gave an extra grain yield of 1043 and 1797 kg ha^{-1} at Mehoni and Alamata area respectively (Assefa et al., 2007). Raising sorghum seedlings in nurseries using small amounts of water and transplanting the seedlings 28-30 days old could be a way of extending the growing season and to couple the late onset and early off rain fall characteristics of the rainfall in the study areas. Rainfed smallholder agriculture in low rainfall area is subject to numerous constraints including low rainfall with high spatial and temporal variability, and significant loss of soil water through evaporation and erosions have limited crop production.

In the tie ridging conservation tillage grain yield of 4.60 t/ha (+36 % over the conventional) and 2.40 t/ha (+100% over the conventional) were recorded from variety Abaere and Hormat respectively (Table 6). This related to greater crop water availability with tied-ridge tillage. This in agreement with Brhane et al. (2006) research findings at Abergelle, northern Ethiopia, indicate that Tie-ridging improved sorghum grain and biomass yield and resulted in greater soil water availability than other traditional tillage practices. Gebrekidan and Uloro (2002) reported that maize yield improvement of 15 to 50% due to tied ridges and 15 to 38% for sorghum on eastern Ethiopia.

Most of the farmers also explained that contribution of conservation farming plots over the conventional/Farmers practice for soil fertility enhancement, soil moisture increase; reduce soil erosion and finally yield improvement. However, some farmers also suggest their fear for CF difficult for weed control and need more labor in the first year.

CONCLUSION AND RECOMMENDATIONS

Even if the rainfall is the study districts is the low and erratic, planting basins tillage methods under the conservation farming consistently gave the more grain yield with optimum net returns for all local land races and improved sorghum varieties. Planting basin (direct planting of sorghum seeds or transplanting of sorghum seedlings) and tie ridging with micro dosing of 64/46 kg/ha N/P_2O_5 fertilizer in under conservation farming can further help mitigate the effects of prolonged dry spells and enhance crop yield and soil fertility and rainwater use efficiency sustainably.

REFERENCES:

Abdelkdair A and Schultz R (2005) Water harvesting in a 'runoff-catchment'agroforestry system in the dry lands of Ethiopia. *Agroforestry systems*, *63*(3), pp.291-298.

Assefa D, Belay M, Tsegay D, and Haile M (2007) Transplanting sorghum as a means of ensuring food security in low rainfall sorghum growing areas of northern Ethiopia. Drylands Coordination Group (DCG) Report No. 48, Drylands Coordination Group c/o Miljøhuset G9.

Barron J, Rockström J, Gichuki F and Hatibu N (2003) Dry spell analysis and maize yields for two semi-arid locations in east Africa. *Agricultural and forest meteorology*, *117*(1), pp.23-37.

Belay A, Gebrekidan H, Uloro Y (1998). Effect of tied ridges on grain yield response of Maize (Zea mays L.) to application of crop residue and residual N and P oil two soil types at Alemaya, Ethiopia. S. Afr. J. Plant Sci. 15(4): 123-129.

Benites J (2008). Effect of no-tillage on conservation of the soil and soil fertility. In: Goddard, T., Zo¨ bisch, M.A., Gan, Y.T., Ellis W, Watson, A., Sombatpanit, S. (Eds.),

Bescansa P, Imaz M J, Virto, I, Enrique, A and Hoogmoed, W B (2006). Soil water retention as affected by tillage and residue management in semiarid Spain. *Soil and Tillage Research*, *87*(1), pp.19-27.

Beyene D (1988). Soil fertility research on some Ethiopian Vertisols. In *Proceedings of a Conference Held at ILCA on the management of vertisols in Sub-Saharan Africa* (pp. 223-231).

Blowing S, Gibbon P, Dike M, Taylor A (2007). Certified organic export production–implications for economic welfare and gender equity amongst smallholder farmers in tropical Africa. Policy brief (to be published by UNCTAD).

Bradford JM, Peterson GA (2000). Conservation tillage. Handbook of soil science. 2000:247-70.

Bremner J M and C S Mulvaney (1982). Total nitrogen. In : A.L. Page. R.H. Miller. and D.R. Keeney, Methods of Soil Analysis, Part 2. Argon. Mongr. ASA and SSSA,Madison.

Brhane G, Wortmann CS, Mamo M, Gebrekidan H, Belay A (2006). Micro-basin tillage for grain sorghum production in semiarid areas of Northern Ethiopia. Agronomy journal 98(1):124-8.

César E and Ekbom A (2013). Ethiopia environmental and climate change policy brief. *Sida's Helpdesk for Environment and Climate Change*.

CIMMYT Economics Program(1988). *From agronomic data to farmer recommendations: an economics-training manual* (No. 27). CIMMYT.

Cottenie A (1980). *Soil and plant testing as a basis of fertilizer recommendations* (No. 38/2).

Desale KA(2014). Conservation tillage implementation under rainfed agriculture: Implication for soil fertility, green water management, soil loss and grain yield in the Ethiopian Highlands.International Journal of Agricultural Sciences Vol. 4 (9), pp. 268-280.

Doran JW, Smith MS (21987). Organic matter management and utilization of soil and fertilizer nutrients. Soil fertility and organic matter as critical components of production systems. 53-72.

Gebrekidan H and Uloro Y (2002). Soil and water conservation (tied ridges and planting methods) on cultivated lands: The case of eastern Ethiopian. *Soil and Water Management Research Program, Alemaya University (AU)*.

Hassane A, Martin P, Reij C (2000). Water harvesting, land rehabilitation and household food security in Niger: IFAD's soil and water conservation project in Illéla District

Hine R. and Pretty J (2008). *Organic agriculture and food security in Africa*. United Nations Conference on Trade and Development (UNCTAD) and United Nations Environment Programme (UNEP): Geneva and New York.

Kertesz K, Badonyi K, Madarasasz B and Csepinszky B (2008). Environmental aspects of conventional and conservation tillage-results of the SOWAP project in Hungary. *No-till Farming Systems"(T. Goddard, MA Zo bisch, YT Gan, Ellis W, A. Watson and S. Sombatpanit, eds.)*, pp.1-554.

Kidane D (2014). Conservation tillage implementation under rainfed agriculture: Implication for soil fertility, green water management, soil loss and grain yield in the Ethiopian Highlands. *Int. J. Agric. Sci*, *4*(9), pp.268-280.

Lal R (2000). Mulching effects on soil physical quality of an alfisol in western Nigeria. *Land Degradation & Development*, *11*(4), pp.383-392.

Mando A (1997). The effect of mulch on the water balance of Sahelian crusted-soils. *SoilTechnology,* **11**:121-138.

Matson PA, Naylor R and Ortiz-Monasterio I (1998). Integration of environmental, agronomic, and economic aspects of fertilizer management. *Science*, *280*(5360), pp.112-115.

Mesfin T, Tesfahunegn GB, Wortmann CS, Nikus O and Mamo M (2009). Tied-ridging and fertilizer use for sorghum production in semi-arid Ethiopia. *Nutrient cycling in agroecosystems*, *85*(1), pp.87-94.

Montgomery DC (1991). Design and analysis of experiment.3rd edition. John Wiley and Sons, New York. USA.

Morris RA, Garrity DP. Resource capture and utilization in intercropping: water. Field Crops Research. 1993 Sep 1;34(3-4):303-17.

Ngigi NS (2005). Rainwater harvesting for improved food security, promising technologies in greater Horn of Africa. Published by Kenyan rainwater, Nairobi, Kenya. No-till Farming Systems. Special Publication No. 3, World Association of Soiland Water Conservation, Bangkok, Thailand, pp. 1–554.

Nyamangara J, Nyengerai K, Masvaya EN, Tirivavi R, Mashingaidze N, Mupangwa W, DimesJ, Hove L, and Twomlow S (2014). Effect of conservation agriculture on maize yield in the semi-arid areas of Zimbabwe. *Experimental agriculture*, *50*(02), pp.159-177.

Olsen S R, C V Cole, F S Watanabe and L A Dean (1954). Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA Circular 939:1-19.

Oweis T (1997). *Supplemental irrigation: A highly efficient water-use practice*. ICARDA.

Pawluk RR, Sandor JA and Tabor JA (1992). The role of indigenous soil knowledge in agricultural development. *Journal of soil and water conservation*, *47*(4), pp.298-302.

Rao, MR and Mathuva MN (2000). Legumes for improving maize yields and income in semi-arid Kenya. *Agriculture, ecosystems & environment*, *78*(2), pp.123-137.

Reddy MS and Willey RW (1981). Growth and resource use studies in an intercrop of pearl millet/groundnut. *Field Crops Research*, *4*, pp.13-24.

Rhoades JD (1982). Cation exchange capacity. *Methods of soil analysis. Part 2. Chemical and microbiological properties*, (methodsofsoilan2), pp.149-157.

Rockstrom J (2000). Water resources management in smallholder farms in Eastern and Southern Africa: an overview. *Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere*, *25*(3), pp.275-283.

Rockström J, Barron J and Fox P (2003). Water productivity in rain-fed agriculture: challenges and opportunities for smallholder farmers in drought-prone tropical agroecosystems. *Water productivity in agriculture: Limits and opportunities for improvement*, *85199*(669), p.8.

Rockström J, Kaumbutho P, Mwalley J, Nzabi AW, Temesgen M, Mawenya L, Barron J, Mutua J and Damgaard-Larsen S(2009). Conservation farming strategies in East and Southern Africa: yields and rain water productivity from on-farm action research. *Soil and Tillage Research*, *103*(1), pp.23-32.

SAS institute (2013). The statistical analysis software system for windows. Version 9.4, SAS institute INC.,Cary NC., USA.

Stroosnijder L and van Rheenen T(2001). Agro-silvo-pastoral land use in Sahelian villages.

Taddese G (2001). Land degradation: a challenge to Ethiopia. *Environmental management*, *27*(6), pp.815-824.

Tefera B (2002). *Nature and causes of land degradation in the Oromiya Region: A review* (Vol. 36). ILRI (aka ILCA and ILRAD).

Tekalign T, Haque I and Aduayi EA (1991). Soil, plant, water, fertilizer, animal manure and compost analysis. *Working document*, (13).

Temesgen M, Rockstrom J, Savenije HHG, Hoogmoed WB (2009). Conservation tillage implements and systems for stallholder farmers in the semi-arid Ethiopia. Soil Till. Res., 104: 185-191.

Temesgen, M., Rockstrom, J., Savenije, H.H.G., Hoogmoed, W.B. and Alemu, D., 2008. Determinants of tillage frequency among smallholder farmers in two semi-arid areas in Ethiopia. *Physics and chemistry of the earth, parts A/B/C*, *33*(1), pp.183-191.

Verhulst, N., Govaerts, B., Verachtert, E., Castellanos-Navarrete, A., Mezzalama, M., Wall, P., Deckers, J. and Sayre, K.D., 2010. Conservation agriculture, improving soil quality for sustainable production systems. *Advances in soil science: food security and soil quality. CRC Press, Boca Raton*, pp.137-208.

Walkley A and Black IA (1934). An examination of the method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science*, *37*(1), pp.29-38

Walkley A and Black IA (1934). An examination of the method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science*, *37*(1), pp.29-38.

Wiggins S (2009). Can the smallholder model deliver poverty reduction and food security.

Wiggins S and Keats S (2013). Looking Back, Peering Forward: Food Prices and the Food Price Spike of 2007/08. *London: Overseas Development Institute, www. odi. org/sites/odi. org. uk/files/odi-assets/publications-opinion-files/8339. pdf (accessed 10 July 2015)*.