American-Eurasian Journal of Scientific Research 10 (3): 134-140, 2015
ISSN 1818-6785

DOI: 10.5829/idosi.aejsr.2015.10.3.22283

Evaluation of Conservation Farming: Implications for Food Security and Climate Change Mitigation Options in the Moisture Deficit Areas of South Tigray, Ethiopia

[1]*Assefa Workineh,* [2]*Niguse Hagazi,* [1]*Teklay Abebe,* [3]*Kiros Meles,*
[1]*Adhena Mesele and* [1]*Tsehaye Berhane*

[1]Tigray Agricultural Research Institute (TARI),
Alamata Agricultural Reseach Center, P.O.Box 56, Alamata, Ethiopia
[2]Tigray Agricultural Research Institute (TARI), Mekelle, Ethiopia
[3]Mekele University, Mekelle, Ethiopia

Abstract: Study to investigate conservation farming was conducted in low rainfall areas of Raya Alamata district of south Tigray, Ethiopia from 2013-2014 main cropping seasons. The treatments used in the experiment were conventional tillage with and without fertilizer, ripper with fertilizer, ripper + tie-ridger + fertilizer, ripper + tie-ridger + intercropping with and without fertilizer, ripper + tie-ridger + fertilizer + transplanting, direct planting on basin + fertilizer and transplanting on basin + fertilizer and arranged randomized complete block design with three replicates. Analysis of variance for grain yield shows significantly more variation among the farming (tillage and planting methods) practices. Higher grain yields of 2.42 t/ha and 2.485 t/ha (+158 % and 160 % more than the conventional) were recorded from transplanting and direct planting at planting basin respectively. Soil chemical properties like total nitrogen, available phosphorus and organic carbon on the conservation treatments show dramatic increment within two years. Farmers also ranked transplanting on basin and direct planting on basin first and second respectively. Planting basin supported with micro dosing of fertilizer, transplanting of early maturing sorghum variety and mulching can further help mitigate the effects of frequent dry spells in the dryland areas of Tigray. This finding provides evidence to demonstrate the adoption of conservation farming in a dryland region of Tigray; can help to control soil nutrient depletion and replenish the long term degraded soil and allowing farmers to produce their staple food crops in the low rainfall areas.

Key words: Conservation farming · Sorghum · Basin · Tie ridge · Mulch

INTRODUCTION

In the dry lands of Ethiopia, food insecurity, degradation of natural resources, declining agricultural productivity and climate change effects remained as a major concern mainly due to insufficient and erratic nature of precipitation, soil erosion [1-2] and poor soil management using repeated plowing by the traditional plow'Maresha' [3-5].

In Tigray region, sorghum covers a significant amount of cultivated land and ranked first [6] both in areas of production and productivity. Sorghum grain plays the first role in the daily diet of the people used as food and local beverages. The stalk is used for animal feed, house construction and even as a cash source by selling it for fuel in towns. Despite its importance, sorghum productivity and production remained very low (<2.5 t/ha, CSA 2014) owing to different biotic and abiotic production constraints. Low soil fertility, poor crop management practices and sorghum pests are the major sorghum production constraints. Erratic and unreliable rainfall is the most serious physical constraint for sorghum production in dryland areas [7]. Under these conditions there is a considerable risk of crop failure. Rainfall is highly variable throughout the growing season in respect to mainly the delay in the onset and early cessation of the main rainfall [8], intensity, volume and withdrawal patterns and has a tremendous influence on

Corresponding Author: Assefa Workineh, Tigray Agricultural Research Institute (TARI),
Alamata Agricultural Reseach Center, P.O.Box 56, Alamata, Ethiopia.

the sorghum production. This intermittent long dry spells throughout the growing season affects rain-fed crops, particularly sorghum even in seasons of moderate rainfall [8].

Moreover, the main reasons for dryland, cropland degradation in Ethiopia include complete removal of crop residues at harvest, aftermath overgrazing of livestock, frequent tillage, repeated occurrence of drought and inefficient use of technologies and practices like conservation farming [9]. Particularly, in the Raya Alamata district, farmers plough their land 3-6 times for Tef and 3-5 times per season for Sorghum with continuous mono-cropping with no or minimal fertilizer application. In this district there is also a high number of cattle estimated to be 14 livestock/family [10] which graze freely on cropland which facilitates erosion and completely removal of crop residue.

As an important technology, conservation farming is mainly to keep the soil covered (>30% residue), to have minimal soil disturbance and to mix and rotate crops as well as in-situ soil and water conservation practices [11-15]. It maintains a cover of vegetation or mulch on the surface, raises the organic matter content of the soil, improving fertility [3], reducing the amount of CO_2 that is produced and protects the soil from erosion. Hence the present study was initiated to evaluate the effect of conservation farming on dryland soils and rainwater productivity.

MATERIAL AND METHODS

Area Description: Raya Alamata is located in an area dominated by plains, undulating mountains and rugged terrain. A semi-arid type of climate characterizes it and receiving bi-modal, but highly variable rainfall. The long rains usually occur during July and extend up to September, while the short rains usually come during February to May. The study site is located between latitude of 39° 34' 01" and 12° 23' 03" longitude and having an elevation range from 1585 to1600 meters. The study area receives annual average rainfall between 450 and 700 mm with annual temperature between 16 and 26°C. The soil is mostly clay loam and most of the fertility level is below the critical (Table 1).

In the study area, land preparation is done using traditional oxen drawn implement known as 'Maresha'. The major crops grown in the area are Sorghum (*Sorghum bicolor (L).Moench*.), Maize (*Zea mays* L.) and Teff (*Eragrostis tef*). To reduce risks of unexpected drought periods at any time of the growing season, whenever available flooding of (spate irrigation) field crops through diverted runoff water is widely practiced by farmers to extend the crop growth for a certain period during the drought periods. Run off irrigation is widely practiced around Mahoni and Alamata in Tigray, the Gato valley in north Omo, parts of eastern and western Hararghe and many other places [16] of Ethiopia.

Soil Sampling and Analysis: Soil samples were taken at a depth of 0-30 cm before planting (2012/2013) and after harvest (2013/2014) and analyzed for texture, organic carbon, Cation Exchange Capacity (CEC), PH, total nitrogen and available phosphorus. The results of the laboratory analysis of some physico-chemical properties of the soil on which the experment conducted are presented in Table 1. The methods used for physico-chemical analysis were: Organic matter content was determined by oxidation of organic carbon with acidic potassium di-chromate ($K_2Cr_2O_7$) by the Walkley and Black method [16, 17]. Total nitrogen was analyzed by Micro-Kjeldhalmethod [18]. Soil PH was determined in 1:2.5 (weight/ volume) soil to water dilution ratio [17]. Cation exchange capacity was measured after saturating the soil with 1N ammonium acetate (NH_4OAC) and displacing it with 1N NaOAC [19]. Available phosphorus was determined using Olsen method [20].

Experimental Design and Procedure: The experiment was conducted during 2013 and 2014 cropping seasons. The experiment was laid out in Randomized Complete Block Design (RCBD) in three replications with treatments applied to the same experimental units each year. Gross plot size was 10mx10m. Variety Hormat which is an early maturing sorghum variety was used for the trial. For the control plots, plowing was done as per the farmers practice by farmers' equipment 'Maresha' with no mulching and moisture conservation practice done.

The treatments used in the experiments were:

- Conventional tillage with and without fertilizer
- Ripper with fertilizer
- Ripper + Tie-ridger + fertilizer
- Ripper + Tie-ridger + sorghum/cow pea inter cropping with and without fertilizer
- Ripper + Tie-ridger + fertilizer + transplanting
- Direct planting on basin + fertilizer
- Transplanting on basin + fertilizer

In addition all the conservation plots were mulched with localy available weeds. Planting basins are small pits in the ground used for planting many types of crops used to reserve moisture and they were prepared with 75cm length, 75cm spacing, 25cm depth and 20cm width. Tie-ridger is an improved animal drawn tie ridging implement attached on the 'Maresha' using a pair of metal rods and tying unit and creates a series of basins in the field to retain water in place and reduce runoff. Ripper/subsoiler is a modified 'Maresha' where the wooden wings ('Deger') are replaced by a pair of rods and rings. It is useful to break hard pans that are created after repeated plowing at the same depth and hence water infiltration and root growth are improved. Sorghum seedling was raised in the nursery for one month and was transplanted at 30 days age [21-30].

All the Phosphorus fertilizer and 1/3rd of the nitrogen fertilizer was applied at a rate of 100 kg/ha with micro dosing at 7-10cm depth along the furrows at planting. The seed of sorghum was planted at 3-5m depth and 15cm plant spacing and then a total of 5 plants was maintained per basin after thinning.The seeds of sorghum were soaked in water for 10 hours before sowing to facilitate germination. Cow pea was intercropped at 100:50% sorghum cow pea ratio. 2/3rd of the nitrogen fertilizer was applied 35-40 days after planting at a 50kg/ha rate and placed 5cm below and to the side of the seed.

Data Collection and Statistical Analysis: Agronomic data like, days to heading, days to physiological maturity, grain filling period, plant height, grain filling rate and grain yield were collected according to their standard procedure.

The Analysis of Variance (ANOVA) on the agronomic traits was computed using the GLM procedure of SAS version 9.2 [21] following the standard procedures of ANOVA for Rnadomized Complete Block Design (RCBD) [22]. The differences among farming practices were considered significant if the P-values were = 0.05 and Leas Significance Difference (LSD) was used to compare among tillage systems.

RESULT AND DISCUSSION

Soil Result: Laboratory analytical results of selected physicochemical properties of the soils on which the experiments were conducted are presented in Tables 1 and Table 2. Soils in the study area are dominantly clay loam in texture and vary from neutral to slightly basic. The soil organic carbon contents and total nitrogen was low, indicating the low fertility status of the soil aggravated by continuous cereal based cultivation, lack of incorporation of organic materials in to the soils through mulching or crop residues and frequent tillage. The cation exchange capacity (CEC) of the experimental site was 39 Meq/100 kg soil. The available phosphorus was also below critical.

In agreement to this finding [23], indicate continuous removal of crop residues coupled with minimal use of farmyard manure results in the mining of nutrients, organic matter depletion and weakening of soil structure.

Soil chemical properties of the conservation plot had increased from 0.064 to 0.11% in total nitrogen content, 1.15 to 1.53 % in organic matter content and the pH level of the conservation plot reduced from 7.73 to 7.0 over the conventional plot. The dramatic increment of the chemical soil properties is mainly from mulching of weeds, nitrogen

Table 1: Soil physical-chemical properties of the study site before planting

Avai.p (ppm)	Total N %	PH	% OM	CEC(meq)	% Sand	% Silt	% Clay	Textural class
10.5	0.064	7.73	1.15	39.8	33	47	20	cay loam

Table 2: effect of conservation tillage on some soil chemical properties of the study sites

Tillage type	OM %	Total N %	Avai.P (ppm)	CEC meq/100gm soil	PH
Ripper + fertilizer	1.25	0.116	15.43	39.53	7.08
Ripper + Tie-ridger + fertilizer	1.20	0.106	10.93	42.33	6.95
Ripper + Tie-ridger + I/F	1.45	0.099	9.23	46.40	7.04
Ripper +Tie-ridger + IF	0.96	0.122	10.27	42.73	6.99
Ripper + Tie-ridger + TP+ fertilizer	1.23	0.107	11.89	44.20	6.91
Direct planting on basin + fertilizer	1.01	0.116	9.99	39.80	7.08
Trans planting on basin + fertilizer	1.53	0.096	8.99	41.80	7.20

Where: I/F=inter cropping with out fertilizer, IF= inter cropping with fertilizer and TP=Transplanting.

Table 3: Effect of conservation farming Techiniues on days to heading, physiological maturity and grain filling period

Tilage system	Days to heading	Days to maturity	Grain filling period
Conventional tillage without fertilizer	72	113	41.5
Conventional tillage with fertilizer	73	118	45.5
Ripper + fertilizer	72	119	47.17
Ripper + Tie-ridger + fertilizer	72	123	50.8
Ripper + Tie-ridger + I/F	69	118	49.8
Ripper + Tie-ridger + IF	70	115	45.8
Ripper + Tie-ridger + TP+ fertilizer	71	124	53.0
Direct planting on basin + fertilizer	71	124	52.8
Trans planting on basin + fertilizer	75	129	53.8
CV (%)	5.57	3.20	10.7
LSD(5%)	4.6	4.0	5.79

Where: I/F=inter cropping with out fertilizer, IF= inter cropping with fertilizer and TP=Transplanting.

Table 4: Effect of conservation farming Techiniues on grain yields and grain filling rate(GFR)

	Grain yield (t/ha)		
Type of tillage	Sorghum	Cow pea	GFR (kg grain/ha/day)
Conventional tillage without fertilizer	0.935		23.505
Conventional tillage with fertilizer	1.02		22.785
Ripper + fertilizer	1.155		24.65
Ripper + Tie-ridger + fertilizer	1.52		30.61
Ripper + Tie-ridger + I/F	1.42	1.37	28.965
Ripper + Tie-ridger + IF	1.38	1.31	29.645
Ripper + Tie-ridger + TP+ fertilizer	1.335		25.905
Direct planting on basin + fertilizer	2.445		46.645
Trans planting on basin + fertilizer	2.42		45.875
CV (%)	47		51.0
LSD	0.8		18.45

Where: I/F=inter cropping with out fertilizer, IF= inter cropping with fertilizer and TP=Transplanting.

Table 5: Farmers (n=35) evaluation of the treatments

Type of treatment	Preference rank
Conventional tillage without fertilizer	9
Conventional tillage with fertilizer	8
Ripper + fertilizer	7
Ripper + Tie-ridger + fertilizer	6
Ripper + Tie-ridger + I/F	5
Ripper + Tie-ridger + IF	4
Ripper + Tie-ridger + TP+ fertilizer	3
Direct planting on basin + fertilizer	2
Trans planting on basin + fertilizer	1

Where: I/F=inter cropping with out fertilizer, IF= inter cropping with fertilizer and TP=Transplanting.

fixation from the intercropped cow pea and residue left (30%) from the conservation plot after first year experimentation. [3] discussed a research findings conducted on highland of Ethiopia on the effect of tillage practice on soil chemical properties; increment of soil organic matter content for no-tillage over conventional tillage were 0.30 and 0.28% at 0-15 cm and 15-30 cm soil depths, respectively and soil nitrogen was increased by 0.03% in no-tillage over conventional tillage.

Days to Heading, Physiological Maturity and Grain Filling Period: Grain filling period is an important trait in sorghum that ultimately affects the overall grain yield by influencing seed weight. It ranged from 41 to 53 days with a mean value of 47. Significant (P<0.0.5) (Table 3) tillage variation is observed in the number of days for filling the grains, indicating the presence of sufficient variability among the tillage practices for the moisture conservation so as to extend the grain filling period of the crop. The tested crop in the conservation tillage practice at ripper + tie-ridging + fertilizer + transplanting took longer grain filling period (53 days) and trans planting on basin

(53 days) than other tillage and while the conventional tillage practice with and without fertilizer filled their grain in a relatively few days (41-45days) and forced mature with out proper fillig its grain with assimilates. Post-anthesis moisture deficit stress results in accelerated leaf senescence which reduces the current supply of assimilates to the grains; shorter grain filling period of the conventional tillage in this situation is most probably the result of plants adjustments (escape) to the prevailing water deficit conditions. The phenological stages of the sorghum in the planting basin was longer than other farming practice tested.

Grain yield and Grain Filling Rate: There were significant ($P<0.05$) (Table 4) differences in the grain filling rate of the treatments, suggesting the presence of sufficient variability among the tested planting method and tillage system in the study area. Direct planting and transplanting at basin had significantly more grain filling rates (46.6 and 45.8 kg grain/ha/day respectively) than the other conventional treatments in the area. Final grain dry weight is determined by the rate and duration of grain filling rate. Although the plants may have had continued access to deeper water [24], the effects of soil water depletion during the grain-fill period are reflected in small grain size and finaly low grain yield.

Direct planting and transplanting of sorghum at basin supported with mulching and crop residue in the second year recorded 2.44 and 2.42 t/ha (more than 160% and 158 % grain yield superior than conventional tillage with and without fertilizer respectively) respectively. In the treatment ripper + tie-ridger + intercropping of cow pea at 100:50% sorghum cow pea ratio, mean grain yield of 1.42 t/ha sorghum and 1.31 t/ha cow pea was obtained. Mean grain yield of 1.37 t/ha cow pea was also obtained from the intercropping without affecting the main crop plant population (sorghum). The Overall crop performance was generally worst for conventional tillage this may to no organic matter residue incorporation, frequent tillage practice which facilitates soil erosion and nutrient depletion.

Research findings from [25] report increases in maize yields (+34%) and soya (+11%) in Argentina. In other research resut also state that the major reasons for the increase in yields were better moisture availability, improved soil fertility and better root growth as a result of conservation tillage application [26-28]. Similarlly deep ripping and sub-soiling techniques results in 60% yield increments, as they increased water infiltration and reduce surface runoff [29]. [30] showed evidence that adoption of reduced tillage have impact on agricultural productivity on low rainfall areas.

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 farmers.

Farmers Evaluation: As part of participatory evaluation and selection of planting method and tillage practices, field days and group discussion were held at different plant growth stages. The panelist farmers /participant farmers were then given chance to evaluate the technology in terms of overall crop performance.

CONCLUSION

Access to water in rainfed farming, particularly in areas receiving low and erratic type of rainfall can be improved through a package of conservation farming techniques. Despite low and erratic ainfall in the study area (450-700 mm) planting basins (using both direct and or transplanting methods) consistently gave the higher grain yield. Planting basin combined with a package component like with micro dosing of fertilizer and mulching can further help mitigate the effects of frequent dry spells than conventional type of farming.

REFERENCES

1. Mitiku, H., K. Herweg and B. Stillhardt, 2006. Sustainable Land Management-A New Approach to Soil and Water Conservation in Ethiopia, pp: 269.
2. Warren, A. and M. Khogali, 1992. Assessment of Desertification and Drought in the Sudano-Sahellan Region 1985-91, UNSO, New York.
3. Desale Kidane Asmamaw, 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, 4(9): 268-280.
4. Aune, J.B., T. Matewos, G. Fenta and A. Abyie, 2001. The ox ploughing system in Ethiopia: can it be sustained? Outlook Agric, 30: 275-280.
5. Central Statistical A gency (CSA), 2014. Agricultural sample Sample survey 2013 / 2014 (2006 e.c.). Report on crop and livestock product utilization. Statistical bulletin. Adis Ababa, Ethiopia, pp: 128.

6. Stroosnijder, L. and T. Van Rheenen, 2001. Agro-sylvo-pastoral land use in Sahelian villages. Advance in GeoEcology 33, Catena Verlag GMBH, Reiskirchen, pp: 408.
7. Assefa, D., M. Belay, D. Tsegay and M. Haile, 2007. Transplanting sorghum as a means of ensuring food security in low rainfall sorghum growing areas of northern Ethiopia. Drylands Coordination Group Report No. 48, Drylands Coordination Group c/o Miljøhuset G, pp: 9.
8. Mando, A., 1997. The effect of mulch on the water balance of Sahelian crusted-soils. Soil Technology, 11: 121-138.
9. Central Statistical Agency (CSA), 2011. Agricultural sample Sample survey 2010 / 2011 (2003 e.c.). Report on crop and livestock product utilization. Statistical bulletin. Adis Ababa, Ethiopia, pp: 128.
10. Bradford, J.M. and G.A. Peterson, 2000. Conservation Tillage in: M.E. Sumner (Ed.), Handbook of soil science, CRC Press, Boca Raton, FL, USA., pp: 247-269.
11. Verhulst, N., B. Govaerts, E. Verachtert, A. Castellanos-Navarrete, M. Mezzalama, P.C. Wall, A. Chocobar, J. Deckers and K.D. Sayre, 2010. Conservation agriculture, improving soil quality for sustainable production systems in: R. Lal, Stewart B.A. Food and soil quality. Boca Raton: CRC Press, Adv. Soil Sci., in press.
12. Rockstrom, J., J. Barron and P. Fox, 2003. Water Productivity in rain-fed Agriculture: Challenges and Opportunities for smallholder farmers in drought-prone tropical agro-ecosystems. Stockholm University, Stockholm Sweden.
13. Miller, W.R. and L.R. Donahue, 1997. Soils in our environment. Seventh edition, prentice hall of India private limited, New Delhi.
14. Rockström, J., 2001. Green water security for the food makers of tomorrow: windows of opportunity in drought-prone savannahs. Water Science and Technology, 43(4): 71-78.
15. Benites, J.R. and J.E. Ashburner, 2001. FAO's role in promoting conservation agriculture. In: World Congress on Conservation Agriculture, Madrid, 1-5 October, 2001. XUL Avda. Medina Azahara 49, pasaje, 14005 Cordoba, Spain, pp: 133-147.
16. Ngigi, N.S., 2005. Rainwater harvesting for improved food security, promising technologies in greater Horn of Africa. Published by Kenyan rainwater, Nairobi, Kenya.
17. Jackson, M.L., 1967. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi.
18. 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.
19. Chapman, H.D., 1965. Cation Exchange Capacity by Ammonium Saturation. In: C.A. Black, L.E. Ensminger and F.E. Clark (Eds). Method of Soil Analysis. American Society of Agronomy. Madison Wisconsin, USA, pp: 891-901.
20. 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.
21. SAS institute, 2000. The statistical analysis soft ware system for windows. Version 9.2, SAS institute INC.,Cary NC., USA.
22. Montgomery, D.C., 1991. Design and analysis of experiment. 3rd edition. John Wiley and Sons, New York. USA.
23. Burayu, W., S. Chinaowong, R. Suwanketnikom, T. Mala and S. Juntakool, 2006. Conservation Tillage and Crop Rotation: Win-Win Option for Sustainable Maize Production in the Dryland, Central Rift Valley of Ethiopia., *Kamphaengsaen Academic* J., 4(1): 48-60.
24. Nakayama, F.S. and C.H.M. Van-Bauel, 1963. Root activity distributionpatterns of sorghum and soil moisture conditions. Agron. J., 55: 271-274.
25. Hine, R. and J. Pretty, 2008. Organic agriculture and food security in Africa. Geneva and New York, United.
26. Belay, A., H. Gebrekidan and Y. Uloro, 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.
27. Lal, R., 2000. Mulching effects on soil physical quality of an Alfisol in western Nigeria. Land Degrada. Dev., 11: 383-392.
28. Temesgen, M., J. Rockstrom, H.H.G. Savenije and W.B. Hoogmoed, 2009. Conservation tillage implements and systems for stallholder farmers in the semi-arid Ethiopia. Soil Till. Res., 104: 185-191.

29. Temesgen, M., J. Rockstrom, H.H.G. Savenije, W.B. Hoogmoed and D. Alemu, 2008. Determinants of tillage frequency among smallholder farmers in two semi-arid areas in Ethiopia. Physi. Chem. Earth, 33: 183-191.

30. Menale Kassie, J. Ender, M. Yesuf, G. Köhlin, R. Bluffstone, P. Zikhali and Elias Mulugeta, 2008. Sustainable land management Practices improve agricultural productivity: Evidence on using reduced tillage, stone bunds and chemical fertilizer in the Ethiopian highlands, Environment for development (EfD) Policy Brief.