



Evaluation of Conservation Farming Practices in Improving Sorghum Yield at Tanqua Abergelle Wereda, Northern Ethiopia

Meresa Weleslasie^{1*} and Guesh Assefa¹

¹*Abergelle Agricultural Research Center, Tigray Agricultural Research Institute, P.O.Box 44, Abi-Adi, Ethiopia.*

Authors' contributions

This work was carried out in collaboration between both authors. Author MW designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author GA managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ASRJ/2020/v3i3330073

Editor(s):

(1) Dr. Alessandro Buccolieri, Università del Salento, Italy.

Reviewers:

(1) Chagonda Ignatius, Midlands State University, Zimbabwe.

(2) Ahmet Sivacioğlu, Kastamonu University, Turkey.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/56645>

Original Research Article

Received 23 February 2020

Accepted 28 April 2020

Published 13 June 2020

ABSTRACT

Traditional farming, particularly tillage has long been used by farmers to loosen the soil, make a seed bed and control weed. However, it has been discovered that tillage operations, overtime, cause a decline in soil fertility and overall productivity resulting from deterioration of soil physical, chemical and biological properties. The purpose of the study was to evaluate the effect of minimizing soil disturbance on sorghum yield. The research was conducted at Tanqua Abergelle Wereda in specific localization called Gereb Giba testing site. Six treatments replicated three times according to Randomized Complete Block Design (RCBD) and plot size of 3.75 m x 4 m were used. The conservation farming practices used were basin and tie-ridger, one month earlier from its sowing date. Moreover, sorghum seeds were sown on nursery in the month of June, and was latter transplanted to field experiments. Agronomic data were collected for three consecutive years (2014 to 2016) and subjected to analysis of variance (ANOVA). The obtained result indicates that there was significant difference (0.05%) between treatments especially with comparison to conventional tillage. The highest grain yield (1.41 t/ha) was obtained in the treatment (Ripper + tie-ridger + transplanting), followed by basin + transplanting, Ripper + tie-ridger + inter-cropping, Ripper + tie-

*Corresponding author: E-mail: meresa04@gmail.com;

ridger and conventional tillage with 1.33 t/ha, 1.21 t/ha, 1.16 t/ha and 0.95 t/ha respectively and the lowest was obtained from basin 0.72 t/ha, due to sandy soils, i.e siltation affects at initial growth stage. Therefore, using tie-ridger and basin with transplanting are more important in low receiving and erratic type of rainfall, due to moisture stress prone areas and to increase grain yield. Though, practicing such kinds should be taken as compulsory issue particularly in dry land areas.

Keywords: Conservation agriculture; sorghum; productivity; tie-ridger and inter cropping.

1. INTRODUCTION

The Ethiopian economy is dependent mainly on rain-fed agriculture, which is exposed to many different environmental risk factors. Tigray, the northern-most region of the country, suffers from extreme land degradation as steep slopes have been cultivated for many centuries and are subject to serious soil erosion [1]. The problem of food insecurity has become more intensely pronounced in recent years with the threat posed by recent trends, such as climate change, water and rainfall scarcity, as well as ecosystems and biodiversity degradation.

The effect of rainfall on soil erosion and the associated soil nutrient losses is expressed by the widespread of poor soil fertility and crust prone soils of cultivated land [2]. Sorghum is one of the leading traditional food crops in Ethiopia comprising 15-20% of the total cereal production in the country and also accounted for about 14.5% of the total cultivated area in the Tigray region [3,4]. However, its average yield per unit area is not more than 1.0 t ha^{-1} [3], which is below the world average of 2.3 t ha^{-1} [5].

Repeated ploughing to achieve fine seed bed using traditional tillage implement (Maresha), almost complete removal of crop residues after harvesting and insufficient application of manure are major contributors for soil degradation in our country, similarly in our experimental testing site. Tillage has long been used by farmers to loosen the soil, make, a seed bed, and control weeds. However, not all results of this practice are positive; it has been discovered that tillage operations, overtime, causes a decline in soil fertility and overall productivity resulting from deterioration of soil's physical, chemical, and biological properties [6]. Among the solutions, which are being considered to mitigate the impact of climate change is adapting to droughts through sustainable farming methods. Conservation farming (CF) practices providing both as a strategy for mitigating and also working as adaptive mechanisms to cope with climate change.

The three underlying principles behind CF are minimum soil disturbance through tillage ("Conservation Tillage"), maintenance of permanent or semi-permanent soil cover ("Plant Residues") and regular crop rotations ("Crop Rotation"). Besides, CF is a system that promotes balance application of chemical inputs (only as required for improved soil quality and healthy crop and animal production). CF emphasizes maximum use of available water resources and reversing a persistent trend in many production systems of reduced infiltration capacity of soils due to compaction and crust formation and reduced water holding capacity due to oxidation of organic materials (due to excessive turning of the soil), [7].

Integrated soil and crop management practices should be addressed simultaneously in order to reduce runoff and soil erosion associated nutrient losses, increase water infiltration, and nutrient availability for crop production [2]. Tie-ridging increased sorghum grain yield and soil water by more than 40 and 25%, respectively, as compared to the traditional tillage practice (shilshalo) in northern Ethiopia [8]. However, improper use of tie-ridging can result in problems such as ridge over -topping, ridge failure, water logging, and total loss of the crop in severe storms [9,8]. Hence, the overall objective of the study was to evaluate/establish the effect of minimizing soil disturbance on sorghum productivity.

2. MATERIALS AND METHODS

2.1 Study Area Description

The study was held at Tanqua Abergelle Wereda in a specific location called Gereb-Giba research testing site. Tanqua Abergelle is located in central zone of Tigray regional state. It is located at $13^{\circ} 14' 06''$ N latitude and $38^{\circ} 58' 50''$ E longitudes. It is agro-ecologically characterized as hot warm sub- moist low land (SM1- 4b) [10] below 1500 m.a.s.l. The rain fall pattern of the district is monomodal with a wet season of falling during the months from July to August. The

mean annual rain fall and temperature ranges are 350-700 mm and 24- 41°C respectively. According to the laboratory textural analysis the coverage of the different soils varies from sandy loam (63.73%), clay loam (30.47%) to silt loam (5.8%) and the fertility level is below the critical (unpublished data of ATA).

2.2 Treatments, Experimental Design and Procedure

The experiment was conducted for three consecutive years (2014 to 2016). Sorghum seeds (Chare variety) were sown at nursery and the raised seedlings were later transplanted (i.e for treatment Ripper + tie-ridger + transplanting and basin + transplanting) to the field experiments after the onset of “kiremti” rainy season. A Completely Randomized Block Design (RCBD) was used, in such a case tillage practice is a blocking factor and the plot size was 3.75 m x 4 m (15 m²). The spacing between plots, rows, blocks and plants were 50, 75, 100 and 20 cm respectively. The following six treatments were used to commence the experiment and replicated three times.

- T1: Ripper + Tie-ridger
- T2: Ripper + Tie-ridger + Transplanting
- T3: Ripper + Tie-ridger + Inter-cropping

- T4: Basin
- T5: Basin + Transplanting
- T6: conventional tillage

Basin was constructed two months ahead of the sowing date, so as to conserve moisture. As its dimension can vary according to its soil stability, for this study it was prepared to be a length of 35 cm, width 15 cm and depth 20 cm. The spacing between basins was 20 cm and the recommended blanket amount of Di-Ammonium Phosphate (DAP) (46%P₂O₅ and 18%N) which is 100 kg/ha at sowing date and Urea (46%N) (50 Kg/ha) at development stage (after 35 days) was applied according to banding method of application in all treatments. Thirty percent (30%) of the crop residue was left on the surface of the plot in all treatments except for conventional tillage (without crop residue) in order to improve soil fertility and moisture conservation purpose. The tie-ridger is an improved animal drawn tie-ridging implement attached ‘Maresha’ using a pair of metal rods and typing unit and creates 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 wings, which is used to break hard pans that are created after repeated plowing at the same depth.

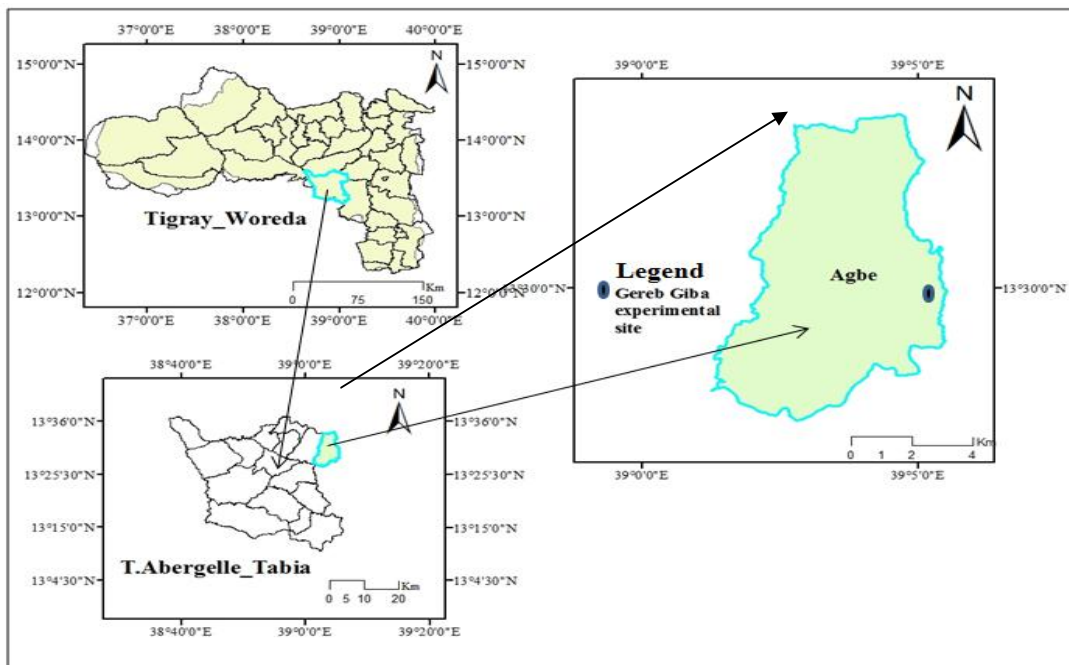


Fig. 1. Map of the study site

2.3 Data Collection and Analysis

Once the experiment was commenced, data such as plant height, panicle length, grain yield, thousand seed weight, biomass yield, weeding frequency, observed diseases and pests were collected for three consecutive years. Moreover, composite soil sample were collected after harvesting each year, from plough layer (0-30 cm) at each plot and submitted to Mekelle soil laboratory for analysis. The collected data were then subjected to one way analysis of variance (ANOVA) for detecting the difference between treatments at ($p=0.05$) probability level. As the experiment was held at the research testing site, it was assumed that the source of variation between treatments and external factors was kept minimum. Hence, LSD mean separation was used to evaluate if there was a statistically significant difference in yield and other parameters between treatments.

3. RESULTS

3.1 Rainfall Distribution

This showed the monthly amount and distribution of precipitation at the study area (Fig. 2). At the season, annual rainfall in 2014, 2015 and 2016 were 505, 701 and 455 mm respectively. The last year was drought year (Elino year) almost throughout the world and consecutively, low grain yield was obtained as compared with the previous year putted below (Fig. 2).

3.2 Soil Properties

The soil in the study site is mostly dominated by sandy soil which is texturally classified as sandy loam soil (Table 1) and has low water holding capacity. The total nitrogen and organic carbon content of the experimental plots were similar. The soil pH of all experimental plots was more than the neutral (Table 1), which is not very suitable for agricultural production. Therefore, it needs liming for sorghum production, since the pH range for most crops is 4.5-6.5. Moreover, the electrical conductivity (EC) of the soil was similar in all plots. However, there is statistically significant difference in cat-ion exchange capacity (CEC) of the plots. Basin and conventional tillage were shown lower cat-ion exchange capacity while, basin with transplanting and tie-ridger with inter-cropping have the highest cat-ion exchange capacity of the soil.

3.3 Sorghum Grain Yield

Here the box plot (Fig. 4) below show sorghum yield in each year. During the first and second year cropping seasons there was a significant difference in yield between treatments (Table 2), while no yield difference was observed between groups in the third year (2016).

The analysis result indicated below (Table 2) showed that, the yield obtained from the conservation tillage is significantly different (at $P < 0.05$) from the conventional tillage used in the experiment. As the analysis result indicated that,

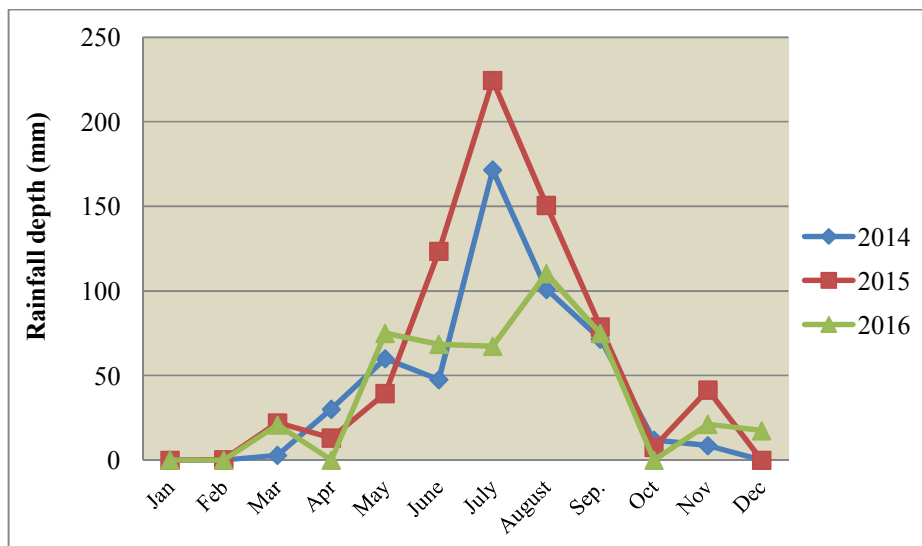


Fig. 2. Monthly rainfall distribution at the study area

Table 1. Soil characteristics of the experimental plots

Treatments	Soil parameters						Soil texture (%)			Textural classification
	pH	EC (ms/cm)	OC (%)	TN (%)	AV.P (ppm)	CEC (meq/100gm)	Sand	Silt	Clay	
T1	7.23	0.23	0.43	0.036	2.18	3.6	70	10	20	Sandy Loam
T2	7.35	0.11	0.42	0.041	3	6.4	74	12	14	
T3	7.35	0.09	0.44	0.038	1.44	4.1	76	12	12	
T4	7.31	0.1	0.52	0.042	1.58	6.7	68	16	16	
T5	7.26	0.12	0.55	0.042	6.08	2.5	60	28	12	
T6	7.39	0.14	0.46	0.056	2.04	0.6	68	14	18	

pH: Power of hydrogen, EC: Electrical conductivity, OC: Organic carbon, TN: Total nitrogen, AV.P: Available phosphorus and CEC: Cation exchange capacity

Table 2. Analysis of sorghum yield and yield components in response to conservation farming practices

S/N	Treatments	Parameters				
		Plant height (cm)	Panicle length (cm)	Biomass Yield (t/ha)	TSW (g)	Yield (t/ha)
1	Ripper + Tie-ridger	204.67 ^a	17.4 ^{bc}	3.3 ^b	29.67	1.16 ^b
2	Ripper +Tie-ridger + transplanting	191.67 ^{bc}	19.46 ^a	2.6 ^{bc}	31.83	1.41 ^a
3	Ripper + Tie-ridger + Intercropping	190.5 ^{bc}	17.63 ^b	4.5 ^a	29.33	1.21 ^{bc}
4	Basin	182.67 ^c	18.43 ^{ab}	2.7 ^{bc}	29	0.72 ^e
5	Basin + Transplanting	188.83 ^c	19.46 ^a	3.1 ^b	30.5	1.33 ^{ac}
6	Conventional Tillage	201.3 ^{ab}	15.72 ^c	3.2 ^{bc}	27.5	0.95 ^d
	P- value (0.05)	0.014	0.003	0.03	0.19	0.000

Letters which are not connected by the same letters are significantly different

tie-ridger with transplanting obtained the highest grain yield which is 1.41 t/ha. The biomass yield obtained from each treatment was also analyzed as it is a very important selection criterion of the farmers for their livestock forages. Hence, the highest biomass yield was obtained using tie-ridger with intercropping followed by tie-ridger with direct sowing and basin with transplanting. However, the lowest biomass yield return was obtained from tie-ridger with transplanting followed by basin using direct sowing of the sorghum seeds.

4. DISCUSSION

4.1 Soil Properties

The study indicated that the total nitrogen and organic carbon content of the experimental plots were similar. This indicates neither the decomposition of sorghum residue nor the soil disturbance has an effect on total nitrogen and organic content of the soil. The soil available phosphorus content in the conventional tillage is significantly higher than the other treatments (Table 1). The highest soil available phosphorus contents at conventional tillage could mean that the uptake of this mineral is low. This could partly be explained by the soil disturbance that leads to low moisture content of the soil. This hinders the uptake of phosphorus by the crop and hence, decreases its availability in the soil.

4.2 Grain Yield

Even though, no statistically significant difference in yield was obtained in the third year, the result of the combined analysis reveals that there was

a significant difference in yield between treatments (Table 2). In addition to this, application of in-situ moisture retention measures such as tie-ridging and basin can support for crops by improving both soil water and nutrient uptake to skip the shortage of soil water at the germination and vegetative stage of the crop. Soil water shortage at these crop stages are the frequently noted problems in the semi-arid areas. Hence, thirty percent (30%) of the crop residue was left on the surface of the plot in all treatments except for conventional tillage (without crop residue) helps to maintain soil moisture and even keep the soil fertility in place (Fig. 3). When the crop residue decomposes it also contributes organic carbon to the soil that improves the soil structure and water holding capacity [11].

Highest grain yield (1.41 t/ha) was obtained in tie-ridger with transplanting. These results are in agreement with those obtained by [8], which is 1.45 t/ha from 'chibal' sorghum variety and 1.31 t/ha 'woitozira' in T/Abergelle area, who indicated that tie-ridging before or at planting resulted in the best soil water status and the best crop performance, especially when planting was in-furrow. Basin with transplanting gave more grain yield (1.33 t/ha) and the lowest (0.72 t/ha) grain yield was obtained from basin.

Growing of sorghum seedlings at nursery and transplanting later to the field is very important in coping the adverse effects of climate variability. When the onset of rainfall is delayed, growing of sorghum seedlings at nursery is very crucial which would later be transplanted to the field when, certainty about the onset of rainfall is



Fig. 3. The crop residue left on the experimental plots

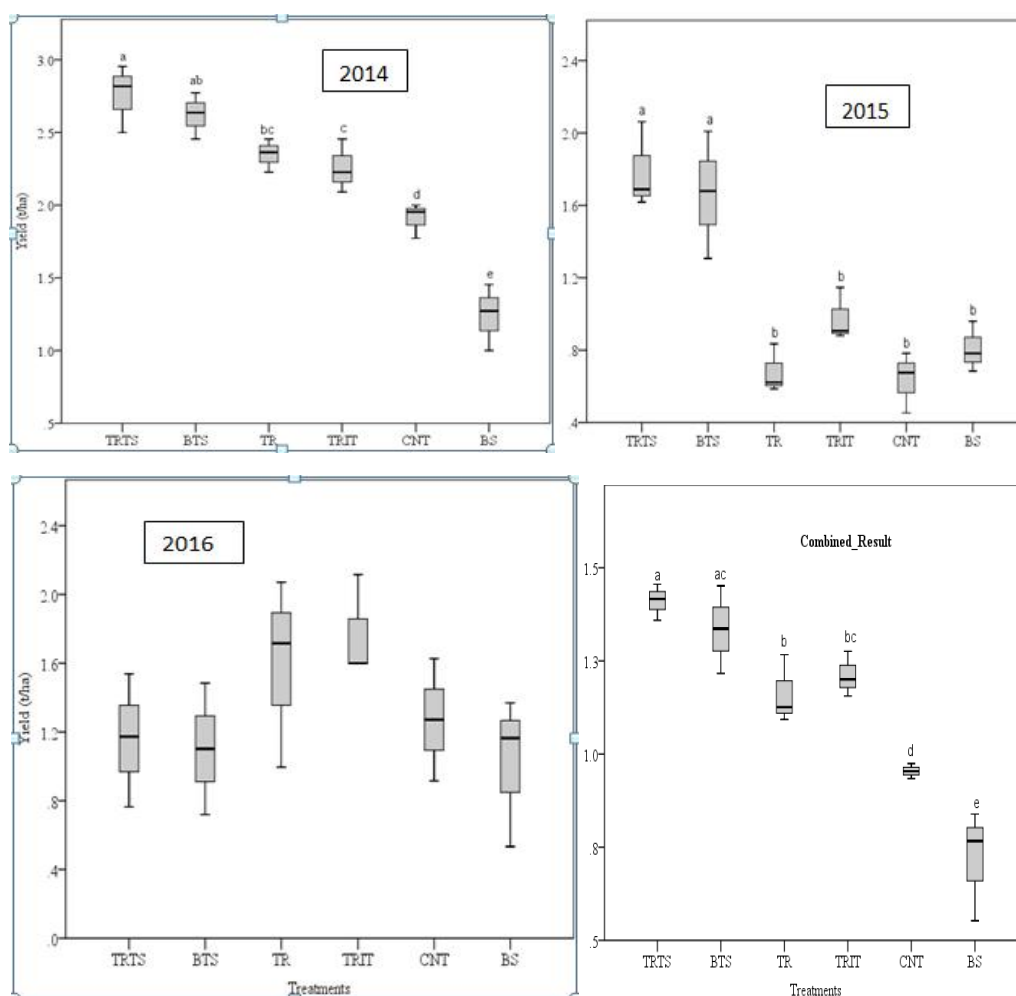


Fig. 4. Box plot presentation of sorghum yield under different cropping season and treatments
 Where: TRTS = Tie-ridger + transplanting; BTS = Basin + transplanting; TR = Tie-ridger; TRIT = Tie-ridger + intercropping; CNT = conventional tillage; BS = basin

there. Rain-fed smallholder agriculture in low rainfall area of study district 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 [12].

5. CONCLUSION AND RECOMMENDATION

Conservation farming (CF) technologies are more and more important in low receiving and erratic type of rainfall, due to this moisture stress areas, appropriate moisture harvesting techniques such as tie-ridger and basin were essential to increase soil moisture for crop establishment and grain filling and this could be

very effective when nursery raised seedlings are used for transplantation purposes.

Ripper + tie-ridger with transplanting gave significantly the highest (1.41 t/ha) yield. The next successive technique basin with transplanting also gave significantly higher grain yield, whereas basin gave lower grain yield.

With the current change in global climate, adaptation methods like the use of conservation farming approaches are very essential if the agriculture sector is to continue to meet the ever increasing food demand especially in developing countries like Ethiopia. In order to enhance crop production in dry areas, the traditional tillage practice has to be replaced by conservation tillage practices.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Wolde M, Veldkamp E, Mitiku H, Nyssen J, Muys B, Kindeya G. Effectiveness of exclosures to restore degraded soils as a result of overgrazing in Tigray, Ethiopia. *J. Arid Environ.* 2007;69:270–284.
2. Breman H, Groot JJ, Van Keulen RH. Resource limitations in Sahelian agriculture. *Global Environmental Changes.* 2001;11:59-68.
3. Central Statistics Authority (CSA). Agricultural sample survey 1999/2000. Report on area and production for major crops (private peasant holdings, main season). Statistical Bulletin No. 227. Addis Ababa, Ethiopia; 2000.
4. Wortmann CS, Martha Mamo, Girma Abebe, Kaizzi K, Mburu C, Letayo E, Xerinda S. An atlas of sorghum production in Eastern Africa; 2006. Available:<http://intsormil.org> (Accessed 15 June 2010)
5. Benti T, Ransom JK. Proceedings of the first National maize work shop of Ethiopia. 5-7 May, 1993, IAR/CIMMYT/, Addis Ababa, Ethiopia; 1993.
6. Scott D. Plant introduction trials: Genotype environment analysis of plant introductions for the high country. *Proc. N.Z. Grassl. Assoc.* 1985;48:151-156.
7. Benites JR, Ashburner JE. FAO 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. 2001;133-147.
8. Gebreyesus Brhane, Charles SW, Martha Mamo, Heluf Gebrekidan, Amare Belay. Micro-basin tillage for grain sorghum production in semi arid areas of Northern Ethiopia. *Agron. J.* 2006;98:124-128.
9. Jone OR, Clark RN. Effects of furrow dikes on water conservation and dryland crop yields. *Soil Sci. Soc. Am. J.* 1987;51:1307-1314.
10. SAERP. Household level socio-economic survey covering all administrative zones/woredas of Tigray region. VOL. XX. UNDP SAERP WARDIS Project, Addis Ababa, Ethiopia; 1997.
11. Ghosh P, Das A, Saha R, Kharkrang E, Tripathy A, Munda GC, Ngachan SV. Conservation agriculture towards achieving food security in North East India. *Current Science.* 2010;99(7):915-921.
12. Nyssen J, Poesen J, Mitiku H, Moeyesons J, Deckers J. Tillage erosion by the traditional plough of the Ethiopian highlands. *Soil and Tillage Research.* 2000;57:115-127.

© 2020 Weleslasie and Assefa; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here:

<http://www.sdiarticle4.com/review-history/56645>