Irrigation & Drainage Systems Engineering

Research Article Open Access

Evaluating the Effect of Soil Moisture Conservation and Management Practices on Yield and Yield Components of Maize Crop in the Midlands of Bale Zone, Southeastern Ethiopia

Chimdessa GC[1]*, Bedaso N[1] and Eshetu M[2]

[1]*Soil and Water Engineering Research Team, Sinana Agricultural Research Center, Bale Robe, Ethiopia*
[2]*Soil Fertility Improvement Research Team, Sinana Agricultural Research Center, Bale Robe, Ethiopia*

Abstract

A field experiment was undertaken from 2015 to 2017 G.C., during Gana (from August to December) cropping season to study the effects of *in situ* moisture conservation and management on yield and yield components of improved maize variety (Melkasa II) at lowland of Bale (Goro and Ginnir districts), southeastern Ethiopian. The experimental design was randomized complete block design (RCBD) using three treatments (flat bed, ridging and furrow with ties, and ridging and furrow without ties (open furrow)) with three replications. The plot size for the treatments was 8 m × 6 m (48 m^2). The results revealed that out of the different *in situ* moisture conservation measures ridging and furrow with ties for Goro District and ridging and furrow without ties (open furrow) for Ginnir district resulted in significantly higher yield improvement over the famers' practice (flatbed). The highest maize biomass yield of 6.0 t ha^{-1} which is 29% higher and grain yield of 5.3 t ha^{-1} which is 28% over flatbed was recorded under ridging and furrow with ties for Goro district. Whereas ridging and furrow without ties (open furrow) gave the highest grain yield of 8.8 t ha^{-1} (64%) and 11.6 t ha^{-1} (28%) for Harawa I and Ebisa of Ginnir district. Moreover, practices of *in situ* moisture conservation of both ridging and furrow with ties for Goro and open furrow for Ginnir districts resulted in significantly higher plant height, number of ear per plant, ear length, number of kernel per ear (NKPE), biomass, grain yield, thousand kernel weight of "Malkasa II" maize variety. The present study recommended both ridging and furrow with ties and furrow and furrow without ties (open furrow) for mitigation of low moisture at Goro and Ginnir districts, respectively for production of maize.

Keywords: Moisture conservation; Ridging furrow; Ties

Introduction

Soil moisture and nutrients conservation are the most essential factors for plant growth in Ethiopia. The proper use of soil moisture conservation structures helps to reduce the runoff rate, nutrient losses from soil and improve the soil moisture and nutrient availability for plant growth which in turn, boost the productivity of land and plants. In Ethiopian highland, the agricultural productivity is low due to low soil fertility. The problem is directly related to periodic low soil moisture due to erratic and poorly distributed rainfall, severe soil erosion and runoff loss of water [1].

In situ soil and water conservation measure plays a great role in alleviate the two extremes of rainfall conditions such as erosion and drought. The loss of water as runoff coupled with periodic drought during the cropping season on degraded lands supporting rain-fed crop production was also equally important [2]. The causes rainfall extremities is due to inadequate efforts and absence of technologies proved to conserve the soil and water resources, the consequence of which is the need to increase productivity on limited and marginal land and water resources. As rainfall erosivity, soil erodibility and landform are inherent properties of climate, soil and land, respectively, only little can be done to modify their effects appreciably. Therefore; moisture conservation practices play a vital role for successful and sustainable crop production in drought prone areas. Kumar and Rana [3] reported that adequate soil moisture is the key to successful crop production in dry land areas. The practice of judicial water conservation undoubtedly plays a significant role in increasing agricultural production in arid, semi-arid and sub-humid areas where agriculture is hampered by periodic droughts and low soil fertility [1].

The erratic rainfall distribution makes cropping to be possible only with the use of water conservation techniques. The use of *in situ* moisture conservation techniques should get sufficient attention. It has been effective in reducing surface runoff and increasing soil water storage in different countries as reviewed by Gebreyesus [4]. In many parts of Ethiopia, particularly in the eastern Ethiopian highlands, it was reported that, Proper mechanical soil and water conservation schemes increased maize grain yield by 35.8 % over farmer practice [5]. Asfaw et al. [2] also reported maximum maize yield increases of 10, 18 and 23% on Entisols and 54, 35 and 26% on Vertisols of eastern Ethiopia, with crop residue, with residual NP and with both crop residue and residual NP, respectively, due to the combinations of tied ridges and furrow planting over flat planting. Thus, the efficiency of the physical soil and water conservation techniques depends on the soil type, climate, the crop grown and the cropping methods followed.

Soil moisture is the foremost factor that limits the productivity of rain fed cereal crops. However, rainwater harvesting is an important factor for crop production, the use of *in situ* moisture conservation for crop production is not well known. To maintain required soil moisture in rain fed lands, strategies should be focused on conserving much amount of rainwater as *in situ*. Thus the objective of the experiment was to see and evaluate the effect of different *in situ* moisture conservation practices on water use efficiency, and yield and yield component of maize at Goro and Ginnir districts of Bale Zone.

***Corresponding author:** Chimdessa GC, Soil and Water Engineering Research Team Sinana Agricultural Research Center, Bale Robe, Ethiopia, Tel: +251921180694; E-mail: cchimdessa@gmail.com

Received October 22, 2019; **Accepted** May 24, 2019; **Published** May 31, 2019

Citation: Chimdessa GC, Bedaso N, Eshetu M (2019) Evaluating the Effect of Soil Moisture Conservation and Management Practices on Yield and Yield Components of Maize Crop in the Midlands of Bale Zone, Southeastern Ethiopia. Irrigat Drainage Sys Eng 8: 234.

Materials and Methods

Description of the study area

The experiment was conducted at Goro and Ginnir (Harawa and Ebbisa site) district of Bale Oromia Region. The study areas for Goro lie at Latitude 6°59'20.97"N and Longitude 400 29'45.16" while The study area for Ginnir lies at Latitude 70 10'42.02"N and Longitude 4042'58.64"E. Elevation of the study area varies between 1600 masl (Goro) and 2000 masl (Ginnir) (Figure 1).

The rainfall pattern for both area is bimodal type, which divide the year into two main seasons: a main rainy season Kiremt (June to October) and short rainy season Belg (March to May).The mean annual rainfall for Goro is between 800 and 1000 mm with Mean maximum annual temperature 26.5°C and mean minimum temperature 12.4°C, while The mean annual rainfall for Ginnir is between 1000 and 1200 mm with Mean maximum annual temperature of 24.5°C and mean minimum annual temperature of 13.3°C according to the 15 years meteorological data of the area (Figures 2 and 3).

Method and design used

The design used was RCBD in three replications. The treatments included flatbed (T1) as a control treatment that practiced commonly by farming community in the study areas, *in situ* rainwater harvesting practices (ridging and furrow with ties (T2), and ridging and furrow without ties (open furrow) (T3). The treatments identified as T2 and T3 were applied two week before planting; T0 was applied at planting time. Melkas II variety of maize was used as a test crop. Each treatment was applied on a plot size of 8 m × 6 m (48 m^2), the distance between blocks and within plots are 2 m. The spacing between plants within a row 0.25 m, between rows 0.75 m, between tied ridges 0.75 m and between ties was 2 m. An oxen plow tied ridger implement was used for constructing ridges of 0.3 m height. The time of application of all recommended P rate was at planting but N was applied in split: 1/2 at planting, 1/2 after 35 days after sowing. The seeding rate used was 25 kg ha^{-1}. All cultural management practices (such as two times hand weeding during the cropping season) were equally made for all plots. Data of Meteorology for computing water use efficiency of maize (daily rainfall amount until crop to the harvesting), soil moisture from 0-0.3 m soil depth using soil auger at sowing and harvesting of crop. Data of Agronomic parameters of maize that include plant height, ear height (PH), number of ears per plant(NEPP), ear length(EL), number of rows per ear (NRPE), number of kernels per row (NKPE), biomass (BY), grain yield (GY), thousand kernel weight (TKW) were collected.

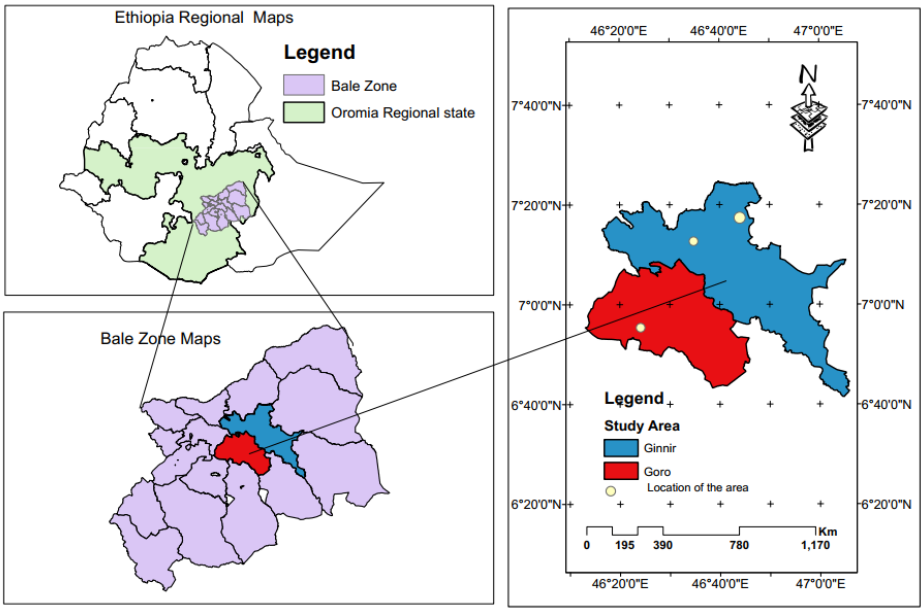


Figure 1: Location of the study Area (the white dot was the study place in the districts).

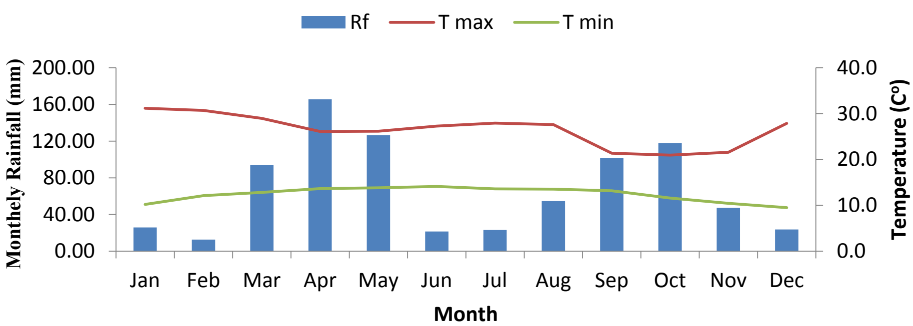


Figure 2: Mean monthly rainfall and maximum and minimum temperature of the study at Goro.

Finally, all soil water and agronomic data were recorded in EXCEL and subjected to ANOVA using GLM procedures of SAS (2004) and LSD was used to compare treatments mean (Figure 4).

Results and Discussion

Results of the effect of different method of moisture conservation practices on yield and yield components (PH, NEPP, EL, NKPE, BM, GY, and TKW) of maize at Goro district of Bale zone indicated that there were statistically higher significant differences (Table 1). of treatments on maize yield and yield components such as were observed due to ridging and furrow with ties, Plants grown on ridging and furrow with ties had the highest PT, NEPP, EL, NKPE, BY, GY, and TKW. Accordingly, the result of analysis of variance indicated that out of the different *in situ* moisture conservation techniques used in this study treatment, ridging and furrow with ties showed significantly higher yield improvement over ridging and furrow without ties (open furrow) and the farmers' practice at Goro district. On the other hand, ridging and furrow without ties (open furrow) resulted in significantly higher values of "MalkasaII" maize yield and yield components at Ginnir district. The highest maize BY of 6.0 t ha^{-1} which is 32.8% and GY of 5.3 t ha^{-1} which is 28.3% higher were recorded under ridging and furrow with ties over the flat bed. Generally, across all moisture conservation trial areas, maize grown on ridging and furrow with ties, and furrow and ridge without ties had better yield advantage as compared to farmer practices. That means farmers' moisture conservation practices resulted in lowest yield and yield components, which is due to the problem moisture shortage. According to Heluf and Yohannes [1] findings, which support this experiment result, tied ridge has resulted in yield increments of 15 to 50% on maize and increment of 15 to 38% on sorghum was recorded on different soil types of eastern Ethiopia. Similarly, Heluf [6] stated that the increased yield of sorghum using tied ridge moisture conservation method could be attributed to the reduced surface runoff, reduced risk of erosion and soil nutrients, and also due to increased water holding capacity of the soil. Another advantage of tied ridge was decreasing surface runoff from the field and increase water retention capacity of the field. Similar finding was reported by Macartneyet al. [7] who reported that tied ridging in Tanzania gave higher maize yields in high rainfall areas although this

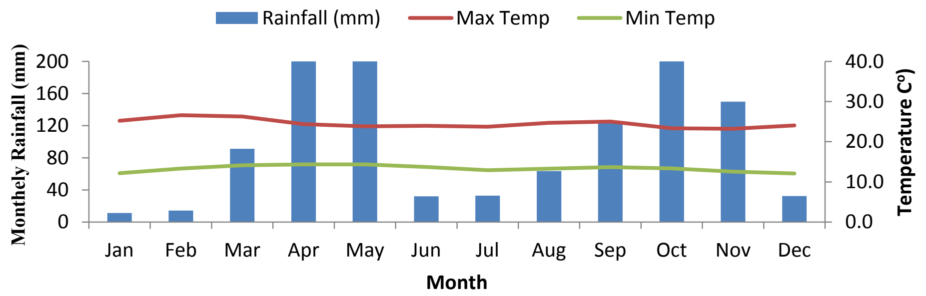
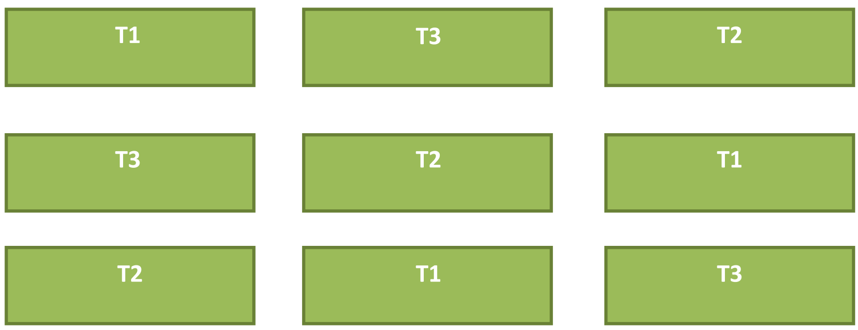


Figure 3: Mean monthly rainfall and maximum and minimum temperature of the study at Ginnir.



NB: T1=Farmer practice, T2 =Ridge and Furrow with ties and T3 =Ridge and furrow without ties

Figure 4: Experimental set up of the study area.

Treatments	PH (cm)	NEPP	EL (cm)	NKPE	BY (t ha^{-1})	GY (t ha^{-1})	TKW
Flat bed (control)	145.52	18.96	1.0	33.27	4.67	4.13	221.27
Ridging and furrow with ties	171.59	25.11	1.61	35.92	6.0	5.30	284.45
Furrow and Ridge without ties	162.26	22.18	1.28	35.08	5.61	5.08	256.19
Mean	159.79	22.08	1.30	34.76	5.43	4.84	253.97
CV (%)	7.73	13.01	19.89	7.09	12.92	21.78	12.66
LSD (0.05)	12.03	2.80	0.25	2.40	0.68	1.02	31.28

PH: Plant Height, NEPP: Number of Ear Per Pant, EL: Ear Length, NKPE: Number of Kernel Per Ear, BY: Biomass Yield, GY: Grain Yield, TKW: Thousand Kernel Weight

Table 1: The combined analysis results of the effect of *In-situ* moisture conservation practice on yield and yield components of maize, at Goro District at "*Gana*" cropping seasons during 2015-2017.

was an exceptional case. According to Et-Swaify et al. [8] summaries, the system in Africa has been beneficial not only for reducing run-off and soil loss, but also for increasing crop yields (Table 1).

Effect of moister conservation practices on soil moisture (after 75 days of planting)

Different moisture conservation practices were also affected soil water storage at 0.3 m. Greater soil moisture was recorded by tied ridge (17.4%) which was 18% over farmers practice, followed by furrow and ridge 16.2% which is 10% higher moisture content over the flat bed thereby improving growth and yield of maize. At flowering stage maize crop experienced moisture stress in the case of flat bed (Figure 5).

As shown in Figure 2, water use efficiencies under the different moisture conservation practices differed significantly higher as compared to flat bed. In this study Tied ridge resulted in 56% moisture conservation advantage over the farmers practices; followed by furrow and ridge which is 37% higher water use efficiency. Similarly, Tied-ridging increased sorghum grain yield by more than 40% and soil water by more than 25% in northern Ethiopia [4]. The tie act as a barrier for the rain water movement and increases contact time available for infiltration thus enhances the availability of soil moisture to the crops [9]. Studies also showed that lack of greater response to applied N and P fertilizer in Ethiopia was probably due to soil water deficit which is the major yield-limiting factor and profitable crop response to applied nutrients depends on soil water availability [10].

Effect of moisture conservation practice on yield and yield component at Ginnir district

As indicated in Tables 2 and 3, statistically significant difference were recorded on BY and GY for the ridge and furrow treatments at both locations of Ginnir district (at Harawal during 2015 and 2016, and Ebisa during, 2016 of "Belg" (April-July) cropping seasons); Flatbed resulted in lowest grain and biomass yield. From this study results ridging and furrowing increased the yield of maize over the flat bed. Similarly, Channappa and Ashoka [11] reported that there was 11.67 per cent increase in yield of Sorghum in the ridge and furrow system over the flat method of sowing. There was 40.8 per cent higher yield of pod in the ridge-furrow method than the flat bed sowing systems (Table 2).

Generally the experiment results indicated that maize yield and yield components were affected by different moisture conservation practices. Hence significant maize crop yield increment resulted from ridging and furrowing moisture conservation practice. The current study therefore, recommended that ridging and furrow with ties for mitigation of low moisture stress at Goro for production of maize. As future recommendation need to disseminate the results of the present

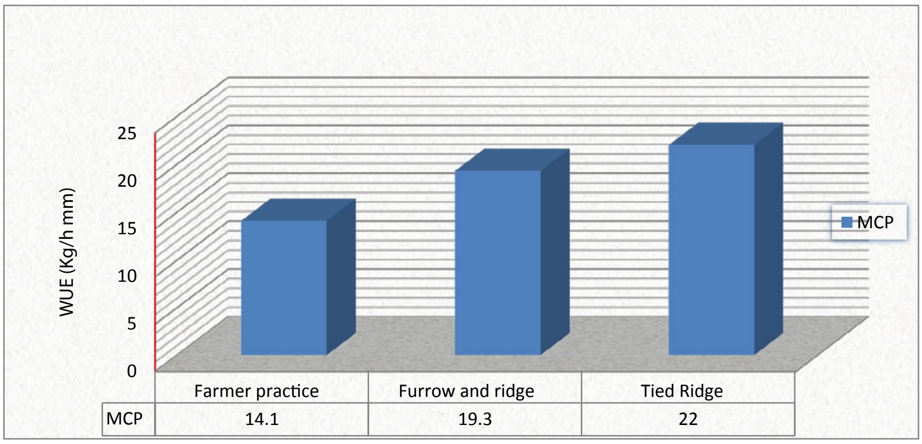


Figure 5: Effect of moisture conservation practice on water use efficiency of Maize during 2015 at Goro.

Treatments	PH (cm)	NEPP	EL (cm)	NKPE	BY (t ha^{-1})	GY (t ha^{-1})	TKW
Flat bed (control)	157.21	1.0	19.82	26.55	6.01	5.39	305.26
Ridging and furrow with ties	170.05	1.56	21.72	33.89	8.13	7.47	347.75
Furrow and Ridge without ties	196.27	2.26	26.85	37.78	9.73	8.81	437.95
Mean	174.51	1.61	22.79	32.74	7.96	7.22	363.66
CV	17.24	14.02	14.22	11.34	9.60	13.30	13.40
LSD (0.05)	37.03	0.28	3.99	4.57	0.94	1.18	59.82

Table 2: Effect of moisture conservation practice on yield and yield component of maize at Harawa one of Ginnir District (Ganacropping season 2015-2016).

Treatments	PH (cm)	NEPP	EL (cm)	NKPE	BM (t ha^{-1})	GY (t ha^{-1})	TKW
Flat bed (control)	186.25	1.25	28.33	34.25	11.81	9.04	259.33
Tied Ridge (with ties)	182.5	1.33	29.08	34.04	13.54	9.92	362
Furrow and Ridge (without ties)	188.75	1.63	28.48	34.71	15.14	11.57	370
Mean	185.83	1.40	28.63	34.33	13.49	10.18	330.44
CV	7.55	11.88	3.37	4.19	5.61	10.69	20.96
LSD (0.05)	ns	0.33	ns	ns	1.51	2.17	ns

Table 3: Effect of moisture conservation practice on yield and yield component of maize at Ebisa site of Ginnir District during 2016.

study to the end users was low moisture stress is the limiting factor for sustainable crop production in the low land of Bale at large.

Conclusion and Recommendation

Moisture stresses caused by shortage of rainfall, irregular distribution of rainfall and erratic rainfall characteristics as well as excessive infiltration rate are the major limiting factor for crop production at rain fed agricultural system. However, the problem of moisture stress for rain fed agricultural systems can be mitigated by moisture conserving practices that improved storage of soil moisture at root zone and by wisely using rain water integrating with different crop management practices. In this respect, the uses of tied ridges showed significant difference at these specific areas (specific climate and soil type). Hence, the use of moisture conservation method might be affected by climatic condition and soil type of the area. Therefore, the authors' recommend the use of closed end tied ridges and ridges and furrow at Goro and Ginnir districts; respectively. In addition, strong extension work for demonstration and popularization of the determined technologies should have great attention to overcome problem of moisture stress condition and to improve land productivity for rain fed maize production in the study area. On the other hand the recommended moisture conservation methods can be extrapolated to other area with similar climatic condition and soil type.

Acknowledgements

The authors would like to thanks all staff of Soil and water Engineering Research team and Soil fertility improvement Research team of Sinana Agricultural Research center for their contribution towards the success of the study and Sinana Agricultural Research Center for providing necessary logistic support. Oromia Agricultural Research Institute is also gracefully acknowledged.

References

1. Heluf G, Yohannes U (2002) Soil and water conservation (tied ridges and planting methods) on cultivated lands: The case of eastern Ethiopian; Soil and Water Management Research Program, p: 154.
2. Asfaw B, Heluf G, Yohannes U (1998) Effect of tied ridges on grain yield response of Maize (Zea mays L.) to application of crop residue and residual N and P on two soil types at Alemaya, Ethiopia; South African Journal of Plant and Soil 15(4): 123-129.
3. Kumar A, Rana KS (2007) Performance of pigeon pea + green gram intercropping system as influenced by moisture conservation practices and fertility level under rainfed conditions. 52: 31-35.
4. Gebreyesus B, Wortmann CS, Martha M, Heluf G, Amare B, et al. (2006) Micro-basin tillage for grain sorghum production in semiarid areas of northern Ethiopia. Agron J 98: 124-128.
5. Bagegnehu B, Abiy D, Ademe G (2018) On-farm Verification of the Soil Moisture and Yield Response of Tied Ridge on Maize Production in Dry Areas of SNNPR, Ethiopia
6. Heluf G (2003) Grain Yield Response of Sorghum (Sorghum bicolor) to Tied Ridges and Planting Methods on Entisols and Vertisols of Alemaya Area, Eastern Ethiopia Highlands. Journal of Agriculture and Rural Development in the Tropics and Sub Tropics 104(2): 113-128.
7. McCarthey J, Northwood P, Degg M, Dawson R (1971) The effect of different cultivation techniques on soil structure conservation and establishment and yield of maize at Kongwa, Central Tanzania 48(1): 9-23.
8. El-Swaify SA (1983) Conservation-Effective Farming Systems for the Semi-Arid Tropics, ICRISAT, Hyderabad, India.
9. Rana DS (2007) Integrated Water Management, Management of Rain fed Agriculture. Indian Agricultural Research Institute
10. Tewodros M, Gebreyesus B, Wortmann CS, Nikus O, Mamo M, et al. (2009) Tied-ridging and fertilizer use for sorghum production in semi-arid Ethiopia. Nutr. Cycl. Agroecosys 85: 87-94.
11. Channappa TC, Ashoka HG (1992) Effect of Moisture Conservation Practices on yield and yield component of Sorgum. Indian J Soil Conserv 20: 1-8.