

Evaluation and Selection of Different Physical Soil and Water Conservation Techniques for Early Mature Sorghum Root Zone Moisture Retention at Harari Regional State, Erer Research Station

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Abstract

The experiment was conducted at Babille district, during 2018 and 2019 main cropping season at Erer Research Station. Erer research sub site is located latitude of 09° 10' 41.5" north and longitude of 042° 15' 27.3". The objectives of the experiments were to evaluate and select best methods of root zone moisture retention and soil conservation techniques suited for early mature sorghum. The treatments of experiments were, Control (no soil and water conservation measures), open ended tied ridge, level soil bund, contour furrow, closed ended tied ridge, Broad bed, Semi-circular and mulch respectively. The design of the experiment was RCBD with three replication. Genstats 18th editions was used for data Analysis. Statistically there is highly significant variation among the treatments in terms of all parameters at 5% significance level across three planting years. First year, the highest plant height was obtained from the treatment with Broad bed followed by closed ended tied ridge. On other hand, the lowest plant height was recorded from the treatments with soil bund followed by control (no conservation structure). This is because of no more top fertile soil disturbance during first year. During the second and third planting year, the highest, plant height (132.86cm) and the longest panicle diameter (6.5) was recorded, from the treatments with open ended tied ridge, followed by soil bund and contour furrow respectively. That was because of soil and water conservation (swc) structures design and the extra moisture harvested in those structure than rest treatments. The highest grain yield was obtained from the mulch followed by open ended tied ridge treatment during first year. This is because of no and slight top soil disturbance during the construction stage. During the third year, the maximum grain yield was obtained from contour furrow followed by open ended tied ridge (2130.9 and 2000) kg ha⁻¹) respectively. The lowest grain yield was obtained from no conservation measures followed by mulching (1125 and 1232.1 kg ha⁻¹). The most probable reason for this variation could be due to the amount of the moisture harvested in the root zone of sorghum because of conservation structure. So contour furrow and open ended tied ridges are suitable swc measures for the area.

Keywords: swc- physical soil and water conservation, sorghum, moisture.

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INTRODUCTION

Agriculture is the main economic activity in sub-Saharan Africa (SSA) supporting over 67% of the population, out of which 60% depends on rain fed agricultural practices; generating 30-40% of the country's Gross Domestic Product (Rockström, 2002).

However, rainfall is poorly distributed in these countries (Ngigi, 2003). High losses occur due to high surface runoff during high intensity rains, poor crop rooting conditions, past and present soil erosion and evaporation losses from soil, and crop canopy in particular during pre-planting and early crop stages (Rockström, 2003). Uncontrolled runoff can cause damaging flash floods; severe erosion; increased water turbidity. It has been estimated that, a sixth of the world's land area, nearly 2 billion hectares, is now degraded as a result of overgrazing and poor farming practices. Water resources for agricultural purposes are getting scarce, and there are hardly any land reserves to be brought into production to widen the agricultural base. By 2025, close to three billion people in 48 countries will be affected by critical water shortage for all or part of the year. Water is the most limiting factor for agricultural production in these regions and the low annual rainfall is often a major reason for food insecurity. Poor yields together with a large population growth have often led to severe food shortages. To improve rural livelihood there is a big need for improved farming methods and increased yields.

Generally the soil can not absorb the amount of water which falls in such a short time, causing intense surface runoff. This climatic factors means that it is important to use the limited amount of rainfall as efficiently as possible. By increasing soil water content supply and retention, crop yields can be improved significantly, and successful crop production can be made possible even in areas of very limited production potential (Yitebitu, 2004).

Increasing water availability for crop production can be achieved by irrigation, but due to the lack of available water resources this is not often an option in arid regions of Ethiopian dry lands. A more realistic

option is to try and utilize rainfall amounts as efficiently as possible for crops.

In the arid, regions where access to irrigation and insufficient rainfall is prevailing to meet the water demands of crops, water can be harvested in order to increase the available water for crops. Water harvesting and soil moisture retention are cheap and simple options for increasing soil moisture. Water harvesting makes use of surface runoff for productive purposes, while soil moisture retention aims at preventing runoff and keeping rainwater as much as possible in place where it falls (FAO, 2001).

In-situ water harvesting techniques such as furrow ridges, tied ridges and contour ridges improve soil moisture stored within the root zone, improve the agronomic components and produce higher grain yields (Mikias et al.2018).

Tied ridges or basins are a variation of the ridge and furrow system in which cross-ties are constructed at intervals across the furrows. The cross ties retain rainwater by restricting lateral flow of the accumulated runoff and so allow longer time for infiltration. By constructing the cross ties lower than the ridges, excess accumulated runoff can drain away. Contour ridges are, small earthen banks, with a furrow (ridges) on the higher side which collects runoff from the catchment area between the ridges. The catchment area is left uncultivated and clear of vegetation to maximize runoff. Crops can be planted on the sides of the furrow and on the ridges. Plants with high water requirements, such as beans and peas are usually planted on the higher side of the furrow, and cereal crops such as maize and millet are usually planted on the ridges. Sorghum (*Sorghum bicolor*) is an essential to diets of poor people in the semi-arid tropics where droughts cause frequent failures of other crops. It is one of the most important cereal crops of the tropics grown extensively over wider areas with elevation range from 1400 to 2100 meters above sea level (m.a.s.l). Its ability to adapt to adverse environmental conditions has made sorghum a popular crop worldwide. It is the major source of energy and protein for millions of people living in semi-arid tropical Africa and Asia. It remains to be the primary source of food in Ethiopia where poor harvest due to drought is common (Kidane, 1982). It is a major food crop grown in both Eastern and western Hararghe.

Basic bottle neck moisture stress is the major hazards that affect the livelihood. Moisture stress affects crops in the livelihood zone every year either due to inadequate rainfall (in terms of total volume) or due to irregular distribution of showers during the growing period. Disruptions in the amount and regular pattern of rainfall significantly affect crop production. Rainy season lasts for about one and a half months and a long rainy season that lasts for more than two months. Even though, the rainfall pattern is not easily predictable and has shown yearly fluctuations. Due to the rainfall pattern, Babille district is considered as food insecure. Though the area is moderately productive for agriculture, soil degradation, erratic rainfall and farmland fragmentation contribute to lowered productivity in the area. Therefore to combat the hazard and food insecurity, the best way is enforcing existing rain drop harvesting technique like in-suit and ex-suit water harvesting and soil conservation by incorporating improved sorghum variety is uncompressible solution. Consequently, the Evaluation and Selection of different physical soil and water conservation techniques for early mature sorghum root zone moisture retention at Harari regional state, Erer research station was initiated with the objectives of evaluate and select best methods of root zone moisture retention and soil conservation techniques suited for early mature sorghum and compare effects of selected soil and water conservation techniques on yield and yield components early maturing sorghum.

Objectives

1. to evaluate and select best methods of root zone moisture retention and soil conservation techniques suited for early maturing sorghum
2. to compare effects of selected soil and water conservation techniques on yield and yield components early maturing sorghum.

MATERIAL AND METHODS.

Description of Study area

The experiment was conducted at Babille district, Erer research station for three consecutive growing years of 2017, 2018 and 2019. The agro-climatic condition of the area is semi-arid, Arid. Erer research sub site is geographically located at latitude of 09° 10' 41.5" (N) and longitude of 042° 15' 27.3" east, and the area is in the vicinity of extreme lowlands in the range of altitude of 1200 – 1300m. The area is also characterized by very short rainy season of 3 to 4 months (single quarter of the year), with all its intermittent condition and erratic distribution. Even though, the rainfall pattern is not easily predictable and has shown yearly fluctuations. Due to the rainfall pattern, the woreda is considered food insecure. The annual maximum and minimum temperatures are 26 and 20°C, respectively, and the mean annual temperature was 24°C. The soil

is clay loam in texture and medium in organic matter content and high in exchangeable potassium

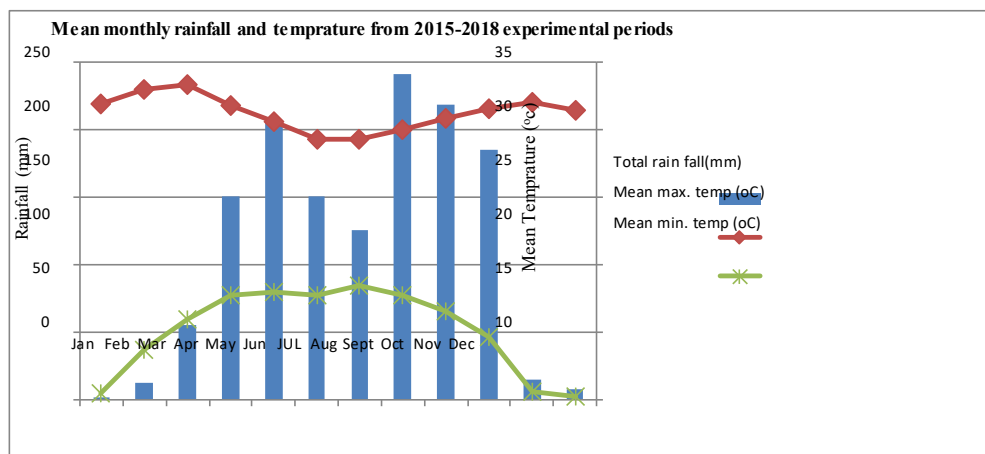


Figure 1. Mean monthly rainfall and temperature during experimental period of Erer, based on 2017-2019 meteorological data at Fadis Agricultural Research Center.

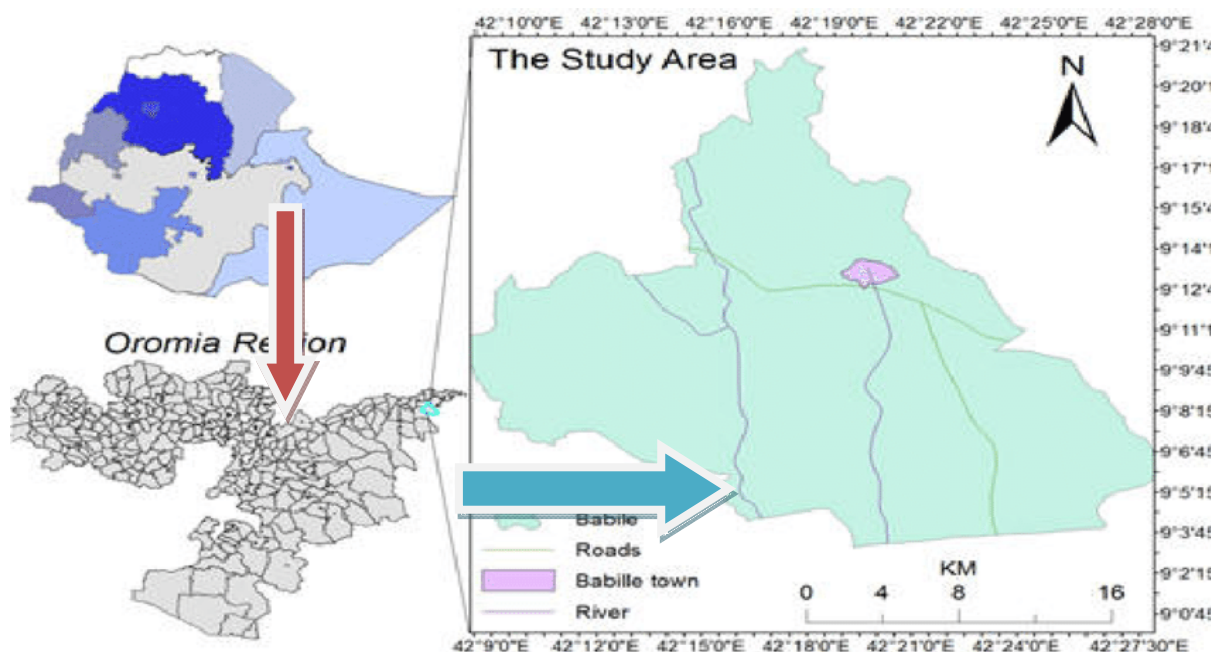


Figure 2. Map representing the study area (Babile District).

Experimental Design and Treatments.

The experimental design was laid out in Randomized Complete Block Design (RCBD) with three replication. The improved and early mature Melkam sorghum variety was used as a test crop. Sorghum was planted on the area of plot size 10m x 9m (90m²) at spacing of 75cm by 30cm. Distance between plot and block were 1m and 2m, respectively. The experiment consisted of eight treatments, seven type of soil and water conservation structure on which the sorghum crop was planted and control (without conservation structure). Test treatments are open ended tied ridge, soil bund, contour ridge, closed ended tied ridge, Broad bed and furrow, Semi-circular, mulching and control. Those physical soil and water structures were constructed based on (Critchley et al, 1991) manual and Ethiopia soil and water conservation guideline with some modification to fit the soil, slope and site of the experiment. Data Collection, Soil Sampling and Statistical Data Analysis. Treatment effect was determined using plant height, panicle length, above ground biomass and grain yield. Composite soil sample was collected from (0-20 spots) before planting in zigzag movement with the sampling depth of 0-20cm, Soil sample after harvest was collected from every plot (at 5 spots /auger points) and analyzed for soil physio-chemical properties. Soil moisture content also recorded at planting time as well as at different growth stage of sorghum.

Data Analysis.

Analysis of variance was performed using the GLM procedure of SAS Statistical Software Version 9.1. Effects were considered significant in all statistical calculations when the P-value was < 0.05. Means were separated using Least Significant Difference (LSD) test.

RESULT AND DISCUSSION.

Soil Analysis.

Table 1. Soil physico-chemical properties of Erer

P(H ₂ O)	E.C in mmhos/cm	M CF	% TN	% C	P (ppm)	Exch. K (cmol(+)/kg soil)	Exch. Na (cmol(+)/kg soil)	CEC (meq/100g soil)	Sand %	Clay %	Silt %	Classification
7.83	2.746	1.11	0.070	1.66	1.98	0.852	0.700	14.443	38	46	16	Sandy clay

The soil of Erer is sandy clay in distribution and known by its salinity nature (table 1). The EC of the sample was 2.746 mmhos/cm which was in salinity range. The organic matter which was 2.8, total nitrogen and available p (ppm) were very low when compared with the standard.

Table 2. Effect of Soil and Water conservation structure on Growth Parameter of Sorghum.

S N	Treatments	Plant height (cm)			Panicle length (cm)			
		Year 2017	Year 2018	Year 2019	Year 2017	Year 2018	Year 2019	
1	Control	125.9 ^b	100.3 ^{bc}	97.467 ^d	17.47 ^{ab}	16.33 ^{bc}	16.33 ^d	
2	Open ended	137.5 ^{ab}	118.6 ^{ab}	125.067 ^{ab}	16.27 ^b	18.73 ^{ab}	21.267 ^{ab}	
3	Soil bund	132.8 ^{ab}	130.7 ^a	121.8 ^{abc}	16.27 ^b	20.53 ^a	20.4 ^{abc}	
4	Contour ridge	136.2 ^{ab}	102.9 ^{bc}	132.867 ^a	18.27 ^{ab}	20.2 ^a	22.133 ^a	
5	Closed ended	149.2 ^{ab}	112.7 ^{abc}	110.6 ^{bcd}	18.93 ^{ab}	21.53 ^a	18.667 ^{bcd}	
6	Broad bed & furrow	153.7 ^a	101.7 ^{bc}	116.8 ^{abc}	19.67 ^a	15.87 ^{bc}	19 ^{bcd}	
7	Semi-circular	143.7 ^{ab}	108.9 ^{abc}	122.867 ^{ab}	19.6 ^a	18.93 ^{ab}	19.4 ^{abc}	
8	Mulching	139.6 ^{ab}	96.1 ^c	103.2 ^{cd}	18.93 ^{ab}	14.93 ^c	18 ^{cd}	
	LSD		22.45	22.05	19.011	2.69	3.485	2.96
	CV (%)		9.2	11.6	9.33	8.6	10.8	8.71

Plant height

The effect of physical soil and water conservation structure showed that there was high significance difference on sorghum plant height at of 5% significance level the during three growing season. In 2017 the highest plant height (153.7 cm) was recorded from the treatments with broad bed & furrow, this was in statistically parity with the rest treatments except control, while the lowest plant height (125.9 cm) was recorded from control treatment. Ramesh and Rathika (2009) that taller sorghum was observed on the ridges and furrow while the lowest height on the flat land. In 2018 the highest plant height (130.7 cm) was recorded from treatment with soil bund, but this was in statistically parity with the rest of treatment except treatment with broad bed & furrow, mulching and control, while the lowest plant height (96.1 cm) was recorded from treatment with mulching. In 2019 the highest plant height (132.8 cm) was recorded from the treatment with contour ridge, this was in statistical parity with the rest of treatment except treatment with closed ended tied ridge, mulching and control, while the lowest plant height (97.467 cm) was recorded from the control treatment. The result of the current study was in agreement with the finding that indicated a significant effect of the conservation practices in increasing the plant height of the crop at different stage and conservation structures were significantly (p<0.05) increasing all the agronomic data during the dry season (Mikias etal ,2018). The hypothesis behind this finding is that the extra moisture conserved during the dry season due to the conservation structure can prominently contribute for better uptake of nutrients by the plant for facilitating the photosynthesis, fertilization of flowers, seed setting, protein synthesis, and nitrogen metabolism activities within the plants tissues, which would in turn improve the physical stand and yield of crops (Mudalagiriyappe BK et al, 2012, Patil, 2003).

Panicle Length

The effect of physical soil and water conservation structure showed that there was high significance difference on sorghum panicle length at 5% significance level during three growing season. In 2017 the highest plant panicle length (19.67 cm) was recorded from the treatments with broad bed & furrow, but this was in statistically parity with the rest of treatments except treatment with open ended tied ridge and soil bund, while the lowest panicle length (16.27 cm) was recorded from treatment with open ended tied ridge and soil bund. In 2018 the

highest panicle length (21.53 cm) was recorded from treatment with closed ended tied ridge, this was in statistically parity with the rest treatments except treatment with broad bed & furrow, mulching and control, while the lowest panicle length (14.93 cm) was recorded from treatment with mulching. In 2019 the highest panicle length (22.133 cm) was recorded from treatment with contour ridge, this was in statistical parity with the rest treatment except treatment with Broad bed & furrow, closed ended tied ridge, mulching and control, while the lowest plant height (16.33cm) was recorded from control treatment. This observation is similar to the study by (Ramesh, et al,2009) observed that there was significant sorghum growth parameter(plant height, panicle length) in the conservation structure of rain water through land configuration methods such as compartmental bunding, ridges and tide ridging.

Table 3. Effect of soil and water conservation structure on yield and yield components of sorghum.

S N	Treatments	Biomass in kg/ha		Yield in kg/ha		
		Year 2018	Year 2019	Year 2017	Year 2018	Year 2019
1	Control	2500 ^c	3667 ^c	707.3 ^{bc}	697.8 ^c	1125 ^c
2	Open ended	6805.6 ^{ab}	9981 ^{ab}	1090.7 ^a	1244.3 ^{ab}	2000 ^{ab}
3	Soil bund	5757.6 ^b	8444 ^{bc}	557.3 ^c	874.8 ^{bc}	1398.8 ^{bc}
4	Contour furrow	7941.9 ^a	11648 ^a	695.7 ^{bc}	1324.9 ^a	2130.9 ^a
5	Closed ended	5517.7 ^{bc}	8093 ^{bc}	683.7 ^{bc}	856.3 ^{bc}	1375 ^{bc}
6	Broad bed	6224.7 ^b	9130 ^b	935.7 ^{ab}	875.6 ^{bc}	1404.8 ^{bc}
7	Semi-circular	4457.1 ^{dc}	6537 ^{cd}	869.7 ^{ab}	843.7 ^c	1351.2 ^c
8	Mulching	3055.6 ^{dc}	4481 ^{dc}	1097.3 ^a	768.1 ^c	1232.1 ^c
	LSD	1692.1	2481.7	311.2	391.7	628.1
	CV (%)	18.29	18.3	21.4	23.9	23.9

Biomass

The effect of physical soil and water conservation structure showed that there is highly significance difference on sorghum biomass at significance level of 5% during three growing season. In 2018 the highest biomass (7941.9 kg/ha) was recorded from the treatments with contour furrow, this was in statistically parity with open ended tied ridge treatments, while the lowest biomass (2500 kg/ha) was recorded from control treatment. In 2019 the highest biomass (11648 kg/ha) was recorded from treatment with contour ridge, this was in statistically parity with open ended tied ridge treatments, while the lowest biomass (3667 kg/ha) was recorded from control treatment. Ridges have been found to be very efficient in storing the rain water, which has resulted in substantial grain yield and biomass increase in some of the major dry land crops such as sorghum, maize, wheat, and mung beans in Ethiopia (Georgis and Takele 2000). Similarly reported that contour ridge and tied ridges are increase dry biomass and yield of sorghum due to improved and stored soil moisture within the root zone karrar etal (2012)

Grain Yield.

The effect of physical soil and water conservation structure showed that there is high significance difference on sorghum grain yield at significance level of 5% during three growing season. In 2017 the highest grain yield (1097.3 kg/ha) was recorded from the treatments with mulching (due to undisturbed top soil and increase soil moisture), this was in statistically parity with the rest treatments except contour ridge, closed ended tied ridge, soil bund and control, while the lowest plant height (557.3) was recorded from treatment with soil bund (Table 4). This have conformity with finding reported that different agricultural water conservation methods(mulching, ridges, supplementary irrigation...) saved limited water and improved grain yield per hectare in drought prone agro ecological zone (Uwizeyimana. D et al, 2018). In 2018 and 2019 the highest grain yield (1324.9kg/ha and 2130.9kg/ha respectively) was obtained from treatment with contour ridge, this was in statistically parity only with the open ended tied ridge treatments, while the lowest grain yield (697.8 kg/ha and 1125 kg/ha) was obtained from control (table 3). This was in line of agreement with in situ soil water conservation techniques such as contour ridge and tied ridges improved soil moisture stored within the root zone as compared to the control, resulting in higher grain yield of sorghum Karrar, et al, (2012). Similarly, reported that contour ridges and other tied ridges has resulted in above 130% higher in grain yield compared to flatbed planting (control) and also under ridges the average grain yield ranged from 50 to over 100 percent when compared with traditional practice (Mikias et al, 2018).

Table. 4 Effect of different insitu conservation measures on economic sorghum productivity.

Treatments	Yield kg/ha	TR(ETB/ha)	TVC(ETB/ha)	TFC(ETB/ha)	TC(ETB/ha)	NI(ETB/ha)	B/C
No conservation)	1125	12,375	1125	2680	3805	8,570	2.2
Open ended	2000	22,000	1350	2680	4030	17,970	4.5
Soil bund	1398.8	15,386.8	1350	2680	4030	11,356	2.8
Contour Furrow	2130.9	23,439.9	1350	2680	4030	19,409.9	4.8
Closed E	1375	15,125	1800	2680	4480	10,645	2.6
Broad B	1404.8	15,452.8	1125	2680	3805	11,647.8	3
Semi circular	1351.2	14,863.2	1125	2680	3805	11,058.2	2.9
Mulch	1232.1	13,553.1	1125	2680	3805	9748.1	2.5

Key* where, TR=total revenue, TVC =total variable cost, TC =total fixed cost, TC=total cost, NI= net income and B/C benefit cost ratio

Data concerning economic comparison was presented in table 3. The detail evaluation of the economic analysis of conservation treatments showed that, the direct impact of moisture and soil saving in generating net income (NI) was very high for a hectare of land per season which means very high value from hectare. Maximum total cost (ETB) was obtained by control treatment whereas the minimum variable cost (ETB) was obtained by semicircular structure. Benefit cost ratio (BCR) of each treatment was computed as the ratio of NI earned to the TC expended. Accordingly, maximum BCR (4.8) were obtained by contour furrow conservation measure. However, the lower BCR was recorded by no any conservation measure and mulching respectively. This implies that, minimum yield were obtained by those treatments and they were not economically more profitable. From this economic analysis, contour furrow was the most economically viable treatment with high BCR and optimum net benefit followed by open ended tied ridges (19,409.9 ETB and 17,970) respectively. Therefore, farmers in the study area were benefited when they apply contour furrow and open ended tied ridges, rather than absolute control (no conservation measures). Generally the experiment with contour furrow and open ended tied ridges treatments were economically profitable for farmers.

Conclusion

Introduction of physical soil and water conservation structure in moisture stress area improve the soil moisture at the rooting zone due to improved soil infiltration and cached runoff at time of the rain fall which increased the crop stand, biomass and grain yield of early maturing sorghum in the study area. Contour furrow, open ended tied ridges, and broad bed were significantly increase the plant height, panicle length, above ground biomass and grain yield of sorghum and reduced soil loss. This is due to extra moisture stored in the soil and root zone of the crop at dry season due to the conservation(because of used design) which prominently contribute for better uptake of nutrients by the plant, which would in turn improve the physical stand and yield of crops.

Physical soil and water conservation practices are absolutely necessary in agricultural operations for successful sorghum production and improve productivity in such Erer site of moisture stressed area. Moreover Contour furrow and open ended tied ridges are promising physical structure in the study area at improving the biomass of sorghum crop and grain yield due to improved soil moisture in the soil and root zone. Generally, it is necessary more or repeated research for validity and conformity to consider and quantify the soil loss and soil moisture at different growing stage of crop as well as to determine its adoptability analysis. Farmers in the study area were benefited when they apply contour furrow and open ended tied ridges, rather than absolute control (no conservation measures). Farmers in the study area can be benefited or obtain (17,759.9 ETB) and (16320 ETB) when they apply contour furrow and open ended tied ridges respectively, rather than absolute control (no conservation measures). Generally the experiment with contour furrow and open ended tied ridges treatments were economically profitable for farmers.

Recommendation

Farmers of Babile District should use appropriate soil and water conservation measures during the crop production season. Farmers of Erer should practice or use contour furrow and open ended tied ridges on sandy clay loam soil texture as physical soil and water conservation structure respectively. Office of agriculture and other NGO's should create awareness for farmers on use of appropriate soil and water conservation measures which could fit with the physical properties of the soil. Farmers in the study area can be benefited or obtain (17,759.9 ETB) and (16320 ETB) when they apply contour furrow and open ended tied ridges respectively,

rather than absolute control (no conservation measures).

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