International Journal of Agricultural Economics
2023; 8(3): 116-121
http://www.sciencepublishinggroup.com/j/ijae
doi: 10.11648/j.ijae.20230803.16
ISSN: 2575-3851 (Print); ISSN: 2575-3843 (Online)

Evaluation of Mulching and Tied Ridges on Soil Moisture and Yield of Maize at Daro Lebu District, Western Hararghe Zone, Oromia, Ethiopia

Gamachu Ayala*, Ayana Bulti, Bayisa Muleta

Department of Soil and Water Engineering, Oromia Agricultural Research Institute, Mechara Agricultural Research Center, Mechara, Ethiopia

Email address:

gameayele@gmail.com (Gamachu Ayala)

*Corresponding author

To cite this article:

Gamachu Ayala, Ayana Bulti, Bayisa Muleta. Evaluation of Mulching and Tied Ridges on Soil Moisture and Yield of Maize at Daro Lebu District, Western Hararghe Zone, Oromia, Ethiopia. *International Journal of Agricultural Economics*. Vol. 8, No. 3, 2023, pp. 116-121. doi: 10.11648/j.ijae.20230803.16

Received: October 31, 2022; **Accepted**: January 4, 2023; **Published**: June 27, 2023

Abstract: The study was conducted to evaluate the effect of soil moisture conservation structures on soil moisture, yield and yield components of Maize in Daro Lebu district of western Hararghe zone where highly affected by moisture stress. The soil moisture conservation structures used as treatments were tied ridges, tied ridges with vetiver 5cm thickness mulch, Tied ridges with vetiver 10cm thickness mulch, Vetiver mulching 10cm thickness only, Vetiver mulching 5cm thickness only and Farmers practice used as control. The treatments were laid out in RCBD with three replications on two locations; on-station and Milkaye FTC. The data on soil moisture content, plant height, head weight, head number per plot, Number of cobs, stand count at harvest and grain yield were collected. The moisture conservation techniques improved soil moisture stored within the root zone as compared to the farmers practice resulting in higher yield and yield components of maize. Findings from this study revealed that tied ridge only, tied ridge with 10 cm and tied ridge thickness with 5cm saved limited soil moisture and improved maize grain yield in the drought prone areas. Even though, tied ridge only, tied ridge with 10 cm and tied ridge with 5cm thickness retained surface runoff, reduce erosion and improve water holding of the soil, there was no significant difference ($p>0.05$) among them on maize grain yield and growth parameters, but when compared to farmers practice are significant ($p<0.05$) at both location. Therefore, it can be concluded that the use of the soil moisture conservation practices (tied ridge only, tied ridge with 10 cm and tied ridge with 5cm) are advisable and could be appropriate for maize production as well as improving soil moisture of root zone of maize in study area and similar moisture stress area.

Keywords: In-situ Moisture Conservation, Ridges, Soil Moisture, Yield

1. Introduction

Irregular or insufficient rainfall can be a serious limitation to agricultural production, causing low yields and even crop failure. This is particularly true in dry lands, where productivity levels are generally low. In most cases, a great deal can be done to improve the efficiency of rainwater use. Every year there is a loss of 25% crop yield globally caused by severe drought [1] and 36 million people in sub-Sahara Africa are experiencing severe food shortage because of the drought [2].

Maize crop was ranked as a third place cereal consumed in the world after wheat and rice [3], and first yield and productive cereal [4]. Maize is an important food crop in sub-Sahara Africa, 300 million people in sub-Sahara Africa are consider maize a primary source of food crop and livelihood [5]. It occupied 17% of cultivated land [4] and 21% in East Africa [6]. Cereals contributed 87.48% of the grain production in Ethiopia. Maize, teff, wheat and sorghum made up 27.43%, 17.26%, 15.17% and 16.89% of the grain production, in the same order. Maize is the one of the major crop in Ethiopia with is the top crop by the number of farming community engaged and the highest in area coverage in the country [7].

A significant cause of low production and crop failure in rain fed agriculture is lack of water in the soil. This is caused by a combination of low and erratic rainfall and poor utilization of the water that is available. Soil moisture management is, therefore, a key factor when trying to enhance agricultural production. Mulching and tied ridges were among soil moisture management that can reduce soil erosion as well as conserve soil moisture [8]. Most of sub-Saharan Africa maize production is based on rain fed systems, there is a need to find out alternative soil moisture conservation strategies to mitigate drought effects. In these regards mulching, tied ridges, terracing, bunding, rain water harvesting and supplementary irrigation method are some of the methods with high soil water conservation potential.

Mulching is the covering of the soil with different materials (e.g. grass, compost, manure) not only helps to preserve soil moisture and decrease soil temperature (reducing evapo-transpiration), but it can also increase soil fertility, suppress weeds, and improve rainfall penetration into the ground. Mulching has been used to good effect in Kenya, Tanzania and other countries in East Africa.

Mulches are ground covers that prevent the soil from being washed away, reduce evaporation, increase infiltration, and control growth of unwanted weeds [9]. Mulch can be organic crop residue, pebbles, or materials such as polythene sheets. Organic mulches add plant nutrients to the soil upon decomposition. The organic mulching is commonly method used in semi-arid to improve soil fertility and maintain soil water content. The organic mulch was applied after seed sowing. The vetiver grass (Vetiveria zizanioides L.) was spread on the bed ridges [10].

1.1. Statement of Problem

Ethiopia is one of the most vulnerable countries of the world to climate change and variability and Hararghe is one of the areas currently under influence of climate change. Rainfall variability, dry spells, soil moisture stress and drought are the main challenges for rain fed agriculture production and productivity; particularly in the midland and lowland parts of the W/Hararghe zone [9]. Extreme dry spells and recurrent drought is usual. Late start, early finish and little in amount is the main characteristics of rainfall in the study areas. In Western Hararghe as a whole, maize and sorghum are major crops used for food.

The most important methods of moisture conservation and improving agricultural production are use of integrated soil moisture conservation structures and organic mulching. It is therefore important for small scale farmers to improve maize production such as mulching to conserve soil moisture in order to optimize productivity.

1.2. Objective

1) To evaluate effect of integrated mulching and tied ridges on maize yield and yield component.
2) To analyze effect of mulching and ridges on soil moisture conservation and water use efficiency.

2. Material and Methods

2.1. Description of Study Area

The study was conducted at Daro Lebu on Mechara Agricultural Research Center on-station and Milkaye FTC, in western Hararghe zone where highly affected by moisture stress. The study area lies to the east of Addis Ababa on 434 km and south of Chiro town, the capital of the zone, at a distance of 110 km. The area has bimodal type of rain fall distribution with annual rainfall ranging from 900-1300mm (average annual rainfall of 1094mm) and ambient temperature of the district varies from 14 to 26°C with an average of 20°C (Climate data obtained from McARC, 2018 unpublished). The nature of rain fall is very erratic and unpredictable causing tremendous erosion. The major soil type of the area is sandy clay loam which is reddish in color (Report on farming system of Daro Labu districts, Mechara Agricultural Research Center, unpublished data). Generally, there are two rainy seasons: the short rainy season '*Belg*' lasts from mid- February to April whereas the long rainy season '*kiremt*' is from June to September. The rainfall is erratic; onset is unpredictable, its distribution and amount are also quite irregular.

2.2. Treatments and Experimental Design

Tied ridge with different rate of vetiver mulch (5 cm, 10 cm) and farmers practice used as control were arranged in RCBD design with three replications. Early mature Melkasa-2 maize variety with spacing of 75cm between row and 25cm in plant was used for the study. The recommended fertilizer rate of Urea 100kg/ha and NPSBZn 100kg/ha applied.

The structures were constructed on plot areas of 5.25m*6m and 1m distance between plot and blocks. The ridges were constructed by 0.3m width, 0.25m height and 0.45m distance between two tied ridges moisture conservation structure. The tied ridge constructed with small earth tie at every 2m along contours perpendicularly to the slope to conserve water from external catchments upslope and slows the flow of water over the surface. The mulch evenly applied at thickness of (5, 10 cm) for mulched treatments. The slope of the land considered was between 1-5%. Finally, continuous inspection and repair was done for all structures.

The treatment arrangements were as below:-

1) Tied ridges;
2) Tied ridges with vetiver 5cm thickness mulch;
3) Tied ridges with vetiver 10cm thickness mulch;
4) Vetiver mulching 10cm thickness only;
5) Vetiver mulching 5cm thickness only;
6) Farmers practice used as control.

2.3. Method of Data Collection and Analysis

Agronomic data, soil data and yield of maize were collected. The growth parameters such as plant height stand count at harvest, number of cobs per plot, head weight in gram per plot, number of head per plot and grain yield were collected. The grain yields were expressed at 12.5% moisture content. Soil physical properties such as soil moisture, texture and chemical properties PH, C/N, CEC and organic carbon collected and analyzed under standard procedure. The soil moisture content is determined as the weight of the wet soil samples were measured and put in an oven at 105°C for 24 hours and then the weight of dry samples was measured. The following formula was used for calculating the soil moisture content.

$$SMC = \frac{(Ww-Wd)}{(Wd)} * 100 \quad (1)$$

Where; SMC = Soil moisture content (%), Ww = Weight of the wet soil (gm), Wd= Weight of the dry soil (gm).

Finally, the collected data were subjected to analysis of variance (ANOVA) using R software 4.2 version statistical software and the means of treatment effects were separated using least significant difference (LSD) test.

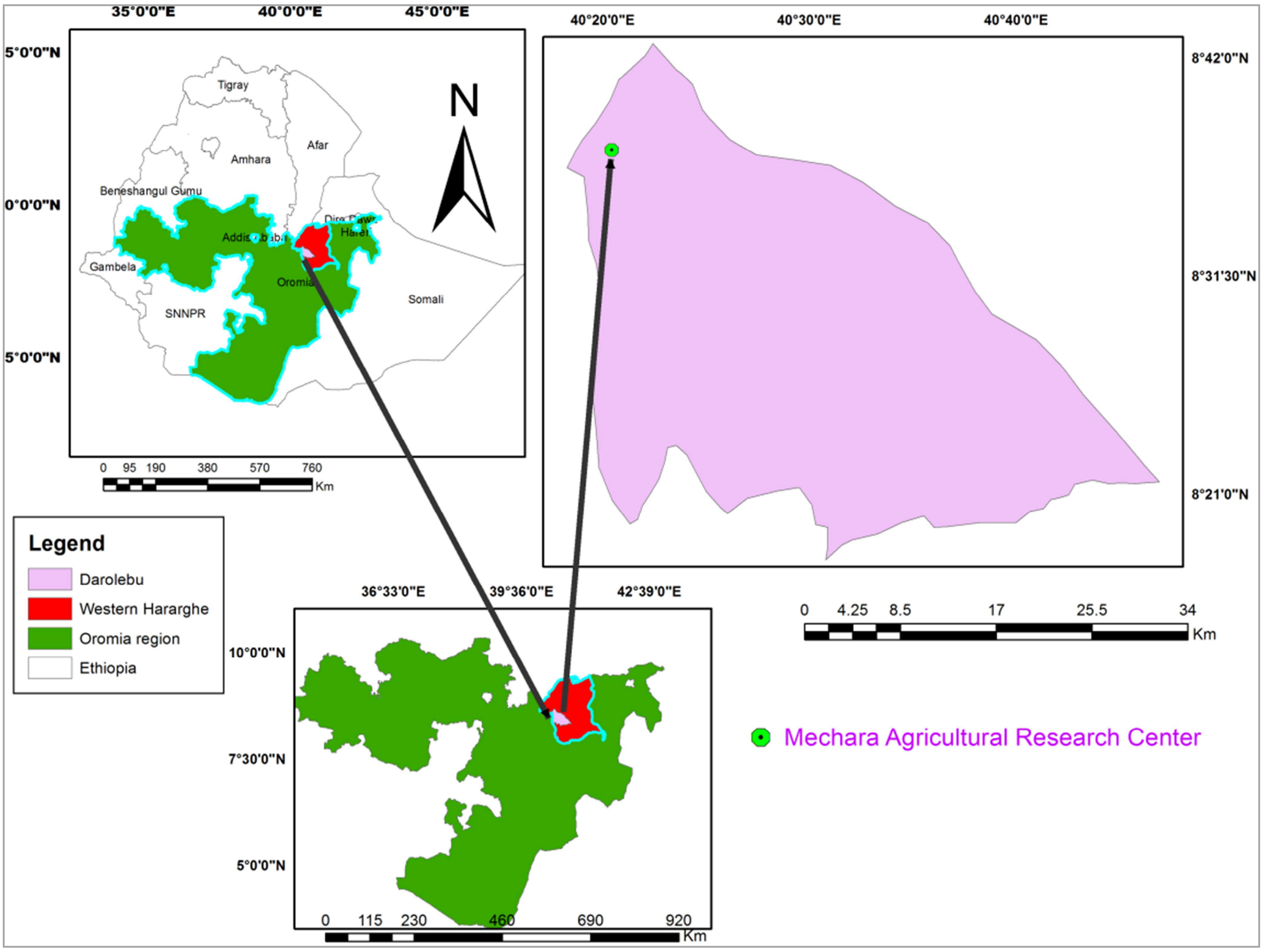

Figure 1. *Map of study area.*

3. Result and Discussion

3.1. Soil Physical and Chemical Properties of the Area

As shown on the (table 1), the soil texture of the area is sandy loam soil at both location which have a characteristics of low water holding capacity and in addition, have moderate organic carbon content of the soil. Due to these characteristics the soil, it need method of conserving soil moisture under crop root zone to improve crop production. Also, the cation exchange capacity (CEC) is a major controlling agent of stability of soil structure, nutrient availability for plant growth, soil pH and the soil's reaction to fertilizers. The carbon to nitrogen ratio measures the relative nitrogen content of organic materials and it's relevant to the breakdown of organic materials in the soil especially applicable in discussing the effects of crop residues on soil nitrogen levels and the rate of breakdown of crop residues. When the carbon to nitrogen ratio (14.56) is less 25, the decomposition proceeds at the maximum rate possible under environmental conditions which shows nutrient are readily available for crop production. Therefore, these soil physical chemical properties shows the soils of the area need intervention to improve soil moisture for crop production during drought period and even during normal rainfall. In general, when integrated soil moisture conservation structures such as tied ridges with different mulch thickness could increase maize production and become means of improving food security of smallholder farmers living in this drought prone area.

Table 1. *Soil physicochemical analysis result at Milkaye PA.*

Parameters	Result	Unit	Method	Target range	Interpretation
PH-H_2O	6.98	-	-	5.50 - 7.00	neutral
OC	1.42	%	Walkely And Black	1.00 - 3.00	moderate
TN	0.03	%	Kjeldahl Method)	0.12 - 0.25	low
C:N	14.56	-	-	-	-
Avail.P	9.70	mg/kg	Olsens Method	20 - 30	low
CEC	26.33	Meq/100g soil	Ammonium Acetate Method	25 – 40	high
Texture	Sand (53) Clay (11) Silt (36)	%	Hydrometer Method	-	Sandy loam
EC	0.03	mS/cm	-	0.40 - 0.80	low
Avail.K	75.5	mg/kg	Ammonium Acetate Method	150 - 250	high

Source: Own laboratory result

Table 2. *Soil physicochemical analysis result at McARC on-station.*

Parameters	Result	Unit	Method	Target range	Interpretation
PH-H_2O	6.58	-	-	5.50 - 7.00	neutral
OC	0.34	%	Walkely And Black	1.00 - 3.00	moderate
TN	0.03	%	Kjeldahl Method)	0.12 - 0.25	low
C:N	14.56	-	-	-	-
Avail.P	8.90	mg/kg	Olsens Method	20 - 30	low
CEC	23.96	Meq/100g soil	Ammonium Acetate Method	25 – 40	high
Texture	Sand (55) Clay (9) Silt (36)	%	Hydrometer Method	-	Sandy loam
Avail.K	21.0	mg/kg	Ammonium Acetate Method	150 - 250	high

Source: Own laboratory result

3.2. Effect of Soil Moisture Conservation Methods on Soil Moisture Content

The soil moisture parameter is the most important parameters in moisture stress areas. The effects of in-situ soil moisture conservation on soil moisture content are shown figure 2 and table 3 below. The soil moisture content of soil was taken three times; early, mid and late stage of maize growth. The highest soil moisture content is observed on tied ridge with 5 cm vetiver mulch followed by tied ridge only and vetiver mulch of 10 cm thickness during early growth stage. During mid-growth stage of maize the highest soil moisture was recorded on tied ridge with 5 cm vetiver mulch followed by tied ridge with 10 cm vetiver mulch. As reported in [10], the tie ridges has the capacity to retain surface runoff near the cropped area, reduced risk of erosion and increased water holding capacity of the soil. Soil water content control phenological, physiological and morphological properties of the crop. In addition to this, when the soil available water decrease, the number of grain per plant and yield per unit area decline.

The trend of the soil moisture content decrease from early stage to late growth stage. This shows there is recharge due to soil moisture conservation structures and related with rain fall distribution. This result agreed with [11] and [12] in-situ moisture conservation can improve soil moisture storage, prolong the period of moisture availability, and enhance the growth of crops and economic yield. During late stage the rainfall of the area ceased. Generally, the highest overall soil moisture content was recorded from tied ridge with 5 cm vetiver mulch during early and mid of crop growth stage. This was due to tied ridge has better performance in store high amount of water and high water retention capacity which available for crop than other structures. The result is in agreement with [13] and [14] as tied ridge and mulch were beneficial in increasing crop yields in seasons with below-normal rainfall in semi-arid environments. [15] Also found that tied ridge was found harvest more water than farmers practice.

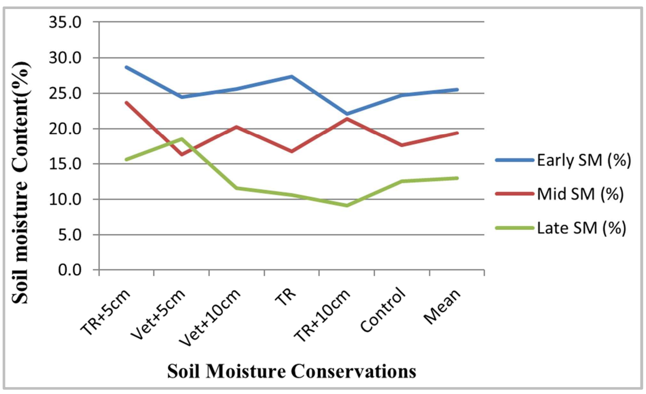

Figure 2. *Effect of soil moisture conservation structures on soil moisture content.*

Table 3. *Mean of Soil Moisture content.*

TRT	Early SM (%)	Mid SM (%)	Late SM (%)
TR+5cm	28.6	23.7	15.6
Vet+5cm	24.46	16.32	18.5
Vet+10cm	25.58	20.24	11.5
TR	27.29	16.77	10.6
TR+10cm	22.04	21.37	9.1
Control	24.74	17.59	12.5
Mean	25.5	19.3	13.0

3.3. Effect of Soil Moisture Conservation on Yield and Yield Components of Maize

The results of analysis of variance (ANOVA) reveals that there was a significant difference ($P<0.05$) among treatments on head weight (g) and yield (kg/ha) among soil moisture conservation practices during 2019 cropping season at Milkaye FTC (Table 2). Results indicated that plots treated with tied ridge gave the highest grain yield of 8593 kg/ha and head weight (610.7g) followed by tied ridge with 10 cm and 5m vetiver mulch respectively at Milkaye FTC. The analysis of variance (ANOVA) reveals that there was a significant difference ($P<0.05$) among treatments on plant height (cm) and yield (kg/ha) among soil moisture conservation practices during 2019 cropping season at on-station. The highest mean yield was observed on vetiver mulch with 10 cm thickness followed by tied ridge treatment with yield advantage of 46.8% and 27.4% respectively during 2019 at on-station. The mulching treatment with thickness of 10 cm was the first in terms of producing higher maize grain yield and yield component this may be due to the fact that mulching improved soil nutrition through incorporation of soil organic matter after mulch decomposition. This result agreed with work of [9] who reported mulching treatment which produce higher grain yield and yield component this may due to the fact that mulching resulted in addition improvement soil nutrition through incorporation of soil organic matter after mulch decomposition.

There was high variation of yield across season at on-station. The yield of maize was decreased by half during 2020 at on-station. This is related with the seasonal rainfall variation which means the early onset of rain was not normal during 2020 at on-station and it directly affected uniform germination which caused the yield reduction. The farmers practice (control) treatment showed the lower yield and yield components compared to the other soil moisture conservations method due to the low ability to retain the soil moisture at both locations and seasons. There is also, variation of maize yield across location among soil moisture conservation treatments during the same year in 2019. The maize yield at Milkaye FTC was better than that of on-station.

Table 4. *Mean growth and yield data of maize at Milkaye 2019.*

Trt	Ph	Head w/g	STCH	No of Cobs/ha	Yield (kg/ha)
TR+5 cm	223.3	570.0ab	92.7	44328.7	7465ab
TR	199.2	610.7a	91	50578.7	8593a
Control	223.3	540.0ab	78	40046.3	6227b
TR+10 cm	217.5	449.0b	93	46180.6	7697ab
Vet + 5cm	225.8	530.7ab	81.3	40046.3	6690ab
Vet+10 cm	227.5	564.3ab	80.3	40972.2	6771ab
Mean	219.4	544	86.1	43692.1	7240.4
Lsd (5%)	Ns	133.1	Ns	Ns	1966.1
Cv (%)	7.8	13.4	18.1	15.2	14.9

Table 5. *Mean growth and yield data of maize at on-station 2019.*

Treatments	PH	STCH	No of Cobs/ha	Yield (kg/ha)
TR+5 cm	222.7ab	124.3	42940	6000ab
TR	208.8c	125.3	44907	6076ab
Control	211.0c	124.7	42014	4769b
TR+10 cm	231.0a	126	43634	5394b
Vet + 5cm	214.3bc	117	43403	5648b
Vet+10 cm	219.0bc	126.7	52199	7002a
Mean	217.8	124	44850	5815
Lsd (5%)	10.8	Ns	Ns	1327.1
Cv (%)	2.7	7.3	13.8	12.5

Table 6. *Mean Growth and yield data of maize at on-station 2020.*

Trt	PH (cm)	STCH/ha	No. Cobs/ha	yield (kg/ha)
TR +5cm	183.7	44656a	41376	3186
TR	185	41905ab	41376	3643
Control	199.3	44127a	39683	3028
TR + 10cm	187.3	37989b	42011	3492
Vet +5cm	185.7	41799ab	38730	3172
Vet +10cm	182	42857ab	34815	3171
Mean	187.2	42222	39665	3282
Lsd (1%)	37.9	7806.3	14844.3	990.8
CV (%)	7.8	7.1	14.5	11.7

4. Conclusion and Recommendation

Rain fed agriculture in semi-arid areas of Ethiopia is suffering from moisture stress which is a major limiting factor for successful crop production. Rainfall variability, dry spells, soil moisture stress and drought are the main challenges for maize production and productivity; particularly in the midland and lowland parts of the Western Hararghe zone. This research work was done in western Hararghe in Daro Lebu districts to evaluate the effect of in-situ moisture conservation practice on soil moisture, yield and yield component of maize. The soil moisture conservation techniques are necessary to maintain optimum soil moisture for supplying the required quantity of water and essential nutrients to the crop plants and maintain physical, chemical and biological properties of soil. In-situ moisture conservation techniques improved soil moisture stored within the root zone as compared to the farmers practice resulting in higher yield and yield components of maize.

Findings from this study revealed that tied ridge only, tied ridge with 10 cm and tied ridge thickness with 5cm saved limited soil moisture and improved maize grain yield per hectare in the drought prone agro-ecological zone. Even though, tied ridge only, tied ridge with 10 cm and tied ridge with 5cm thickness retained surface runoff, reduce erosion and improve water holding of the soil, there was no significant difference among them on maize grain yield, but when compared to farmers practice are significant at both location. Therefore, it can be concluded that the use of the in-situ moisture conservation practices (tied ridge only, tied ridge with 10 cm and tied ridge with 5cm) are advisable and could be appropriate for maize production as well as improving soil moisture of root zone of maize in study area and similar moisture stress area. Promotion of the technology should be done to improve agricultural production similar agro ecologies. In addition, further study should be needed to prove which in-situ moisture conservation practices best from the selected technologies, but, when we see in terms of cost effectiveness for practical applicability for farmers and competition for animal feed, tied ridge only have the potential to improve soil moisture in root zone there by increase maize grain yield than treatments integrated with mulching.

Acknowledgements

We would like to express our heartfelt and deep gratitude to staff members of Mechara Soil and Water Engineering research team for their active participation in conducting this experiment. We would also like to thank Oromia agricultural research institute for they financed the project.

References

[1] Bankole, F., Menkir, A., Olaoye, G., Crossa, J., Hearne, S., Unachukwu, N., & Gedil, M. (2017). Genetic gains in yield and yield related traits under drought stress and favorable environments in a Maize population improved using marker assisted recurrent selection. Frontiers in Plant Science, 8 (808), 1–11. http://dx.doi.org/10.3389/fpls.2017.00808.

[2] Nazareth, V. (2016). Evaluating conservation agriculture and its adoption potential in developing countries (Master Dissertation). University of Florida (https://soils.ifas.ufl.edu/…/soilsifasufledu/sws…/Nazareth_Vijay_Immediate).

[3] Olaniyan, A. B. (2015). Maize: Panacea for hunger in Nigeria. African Journal of Plant Science, 9 (3), 155–174. http://dx.doi.org/10.5897/Ajps2014.1203

[4] FAO. (2015). FAO STAT statistical data base for Agriculture.

[5] Macauley., H. (2015). Feeding Africa, Cereal Crops: Rice, Maize, Millet, Sorghum, Wheat (pp1-36). (Retrieved from) (https://www.afdb.org/DakAgri2015/Cereal_ Crops).

[6] Ndlovu, E. (2013). Impact of tree species on maize productivity by small holder farmers in eastern Kenya (Master Dissertation). Kenya: Jomo Kenyatta University.

[7] CSA (2018). (Central Statistical Authority) Federal Democratic Republic of Ethiopia. Statistical Abstracts Agency. Addis Ababa.

[8] Rajkhowa, D. J., Das, Anup, Ngachan, S. V., Sikka, A. K. and Lyngdoh, M. 2015. Integrated Soil and Water Resource Management for Livelihood and Environmental Security. (Eds.) pp 1-19. ICAR Research Complex for NEH Region, Umiam – 793 103, Meghalaya, India.

[9] Deborah M Pearsall, Karol Chandler-Ezell, Alex Chandler-Ezell, (2003). Identifying maize in neotropical sediments and soilsusing cob phytoliths. Journal of Archaeological Science, Volume 30, Issue 5, Pages 611-627, ISSN 0305-4403.

[10] Uwizeyimana *et al.,* 2018. Effect of water conservation measures on soil moisture and maize yield under drought prone agro-ecological zones in Rwanda.

[11] Ayala et al., 2019; Evaluation of In-situ water harvesting Structures on Soil Moisture, Yield and Yield Components of Sorghum in Moisture Deficit Areas of Daro Lebu and Boke districts. *Oct. Jour. Env. Res. Vol. 7 (2): 064-073.*

[12] Mudatenguha, F., J. Anena, C. K. Kiptum and A. B. Mashingaidze, 2014. In situ rain water harvesting techniques increases maize growth and grain yield in a semi-arid agro-ecology of Nyagatare, Rwanda. Int. J. Agric. Biol., 16: 996–1000.

[13] Gebreyesus, B. Wortmann, C. S., Martha, M., Heluf, G. and Amare, B. (2006). Micro-basin tillage for grain sorghum production in semiarid areas of northern Ethiopia. Agronomy Journal, vol. 98: 124-128.

[14] Stroosnijder, L. and Araya, A. (2010). Effects of Tied Ridges and Mulch on Barley (Hordeum vulgare) Rainwater Use Efficiency and Production in Northern Ethiopia. Agric. Water Manag., 97: 841-847.

[15] Dagnaw, A., Bagegnehu, B,. Abiy, G. (2018). On-farm Verification of the Soil Moisture and Yield Response of Tied Ridge on Maize Production in Dry Areas of SNNPR, Ethiopia. *Journal of Environment and Earth Science, Vol. 8, No. 5, 2018.*