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Evaluating the effect of *in-situ* rainwater harvesting techniques on maize production in moisture stress areas of humbo woreda, wolaita zone, southern Ethiopia

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A B S T R A C T

The study was conducted to investigate the effect of different *in-situ* water harvesting structures as soil moisture conservation techniques under maize crop production in Abela Sippa kebele Wolaita zone, Ethiopia where rainfall variation is affecting agriculture with prolonged dry spells during critical crop growth stages. The experiment was laid out in a Randomized Complete Block Design, with three replications and four treatments. The four treatments used in the study were; Control, *Targa*, Tie-ridge and Zai pits. Findings from this study revealed that maize grain yield and yield components, such as, grain yield, dry matter biomass, and cob length were highly significant ($p<0.05$) on *Targa*. Soil-moisture content over the crop growing season at dry spell periods was significantly higher in *Targa* and *Tie ridges* than the control. Maize yield of (7150 kg ha^{-1}), (6190 kg ha^{-1}), (4500 kg ha^{-1}) and (4900 kg ha^{-1}) was obtained from *Targa,* Tie ridge, Zai pits and Control, respectively. *Targa* and *Tie ridge* treatments recorded higher net returns (29712 and 25164 kg ha^{-1}) than Control (20370 kg ha^{-1}) and *Zai* (14350 kg ha^{-1}) treatments. The results revealed that the *in-situ* rainwater harvesting techniques could play great role in improving crop yield in dry periods. However, the utilization of the technology is surrounded by various constraints. The major constraints include labour, cost, lack of knowledge and crops planted on bunds. The findings suggest that Targa structure improved water availability during the growing season, thereby protecting crops from dry periods and it needs minimum cost, less labor power ,and easily constructed by local farmers (not require complicated knowledge).

Keywords: *In-situ* Rainwater harvesting, Farmers' perception, Soil moisture, Maize yield.

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Introduction

The efficient use of water in agricultural systems is needed to improve crop production and resilience to environmental adversities that may be caused by climate change and extended droughts, especially in arid and semi-arid areas. Marginal and erratic rainfall aggravated by the loss of water by runoff and evaporation are the main causes of low crop production in these areas (Yosef and Asmamaw, 2015). Ethiopia has been dependent on subsidence rain-fed agriculture for centuries, and crop production has thus been heavily reliant on the availability of rainwater (Araya and Stroosnijder, 2010; Yosef and Asmamaw, 2015).

Out of the 13.6 million ha of cultivated land in Ethiopia, close to 97% is rain-fed implying that the nation's annual harvests depend heavily on the patterns of the seasonal rains (Awulachew *et al.,* 2005; FAO, 2005). Analysis of maize crop yield patterns since the 1970s shows that crop yields are mainly dependent on season quality (rainfall quantity and distribution) thereby making rainfall the most important crop yield determinant (MLARR, 2001) crop yield depression and crop failure due to moisture stress is thus a common phenomenon in the semi-arid areas. Studies in Ethiopia have also shown that improved crop productivity can only be achieved in the region if policies and strategies are adopted by regional governments to improve agricultural water management (Mahoo *et at*., 2007).

Farmers in the semi-arid zones have therefore developed strategies, including RWH, to cope with this uncertain and erratic rainfall patterns. RWH practices refer to all practices whereby rainwater is collected artificially to make it available for cropping or domestic purposes (Ngigi *et al.*, 2005). Water harvesting techniques (WHTs) have played a key role in improving the efficient use of rainwater and have increased the sustainability and reliability of rain-fed agriculture (Biazin *et al.*, 2012). Rain Water Harvesting (RWH) has been promoted as an approach to integrate land and water management, which could contribute to recovery of agriculture production in rain fed systems and the general water resources (Rockström *et al.*, 2002). *In-situ* WHTs improve the availability of water in the soil profile to decrease the effects of dry periods caused by the seasonal variation of rainfall. Soils contemporarily hold water, so *in-situ* water harvesting prolongs the availability of water in the root zone by reducing runoff and evaporation losses (Vohland and Barry, 2009). Accordingly, *in-situ* RWH, using different soil and water conservation (SWC) activities, has gained renewed interest; as part of the world wide effort to combat climate change and currently the scheme is in progress at an even larger scale (Mintesinot and Mitiku, 2002). The study area under consideration, Humbo Woreda, is characterized by, risk of meteorological droughts/rainfall inadequate and poorly distributed over the cropping season to produce acceptable crop yield and erratic occurrence of rainfall with spatial and temporal variability and uncertainty (Ahmed and Naggar, 2003). During the '*Belg*' season, the rains are very rare; Farmers usually delay planting until a substantial amount of rainfall has occurred, to avoid the risk of crop failure in early stages of crop growth. Such delay often results in inadequate moisture supplies during the flowering stage of the cereal crops and hence minimum grain yield (Abiye *et al.*, 2002). Therefore, this research was required to fill the gaps to enable the farmers use *in-situ* water harvesting techniques in order to boost the production of maize crop. Therefore, the objective of the research was to evaluate the contribution of selected *in-situ* rainwater harvesting techniques for crop production under rain-fed farming in moisture stress areas of Humbo woreda, Wolaita zone.

Materials and Methods

Description of the study area

The field experiment was conducted at Humbo woreda which is one of the 12 woreda of Wolaita Zone and it is far from the capital city of Ethiopia 380 km and 18 km south of Soddo town on the main road to Arba Minch. The woreda is located 1420 meter above sea level, 6°43'44"N latitude and 37°45'51"E longitude in South Nation Nationalities and People Regional State (SNNPRS) shown in Fig. 1 below.

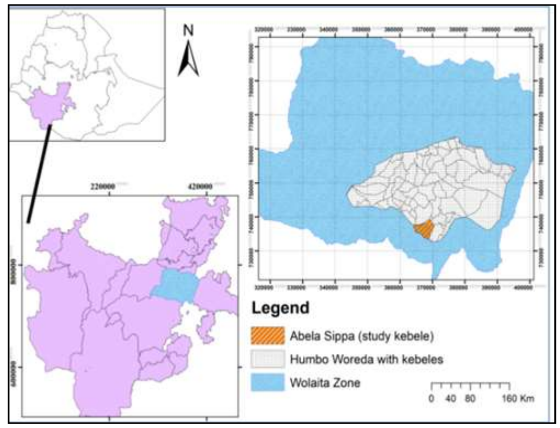

Fig. 1. Map of the study location.

The climatic condition of the study area, average daily temperature is 18.3ºC-21.0ºC, the annual rainfall varies between 710 mm and 1337 mm (CV = 16%) with a mean of 1148 mm for the past 11 years. The rainy season can further be divided into 2 periods: the "Belg" or small rains that take place from, February, March and April but high (peak) rainfall on May and low rainfall on June (flowering stage) these indicated that during the 'Belg' season, the rains are very rare and the 'Kiremt' or big rains that take place from July to September (Fig. 2). The erratic and unreliable nature of the rainfall in the woreda affects the rain fed crop production, which is the main economic stay for the dwellers of the area (Fitsum *et al.*, 1999).

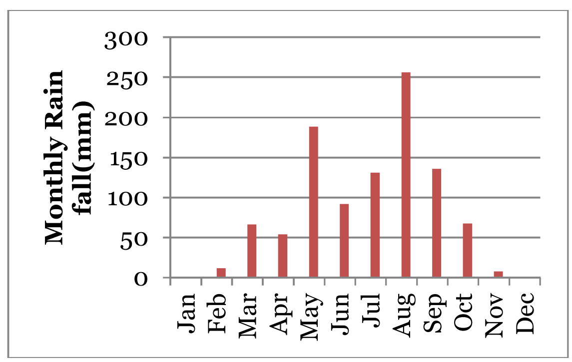

Fig. 2. Average monthly rainfall of the study area.

Soil physical characteristics such as bulk density (1.55 g/cm^{3}) and soil texture (clay 75%, sand 9%, silt 16%) which shows soil type of the area was sandy loam were determined in the laboratory. Woreda is sub divided into 2 urban and 41 rural Kebeles, with total area of 86,646 ha, which is 70% of lowland and 30% midland (WZFED, 2005). Mixed agriculture is the main economic activities, which accounts 92% of the total population in the study area. The major crops grown in the study area are cereals such as teff, maize, sorghum, cotton, cowpea and root crops like sweet potatoes, and fruits like mango, avocado and banana according to Humbo District Agricultural Office (HDoA).

Experimental design

A field experiment was conducted on the effect of different *in-situ* soil moisture conservation structures for maize production under rain fed farming situations during cropping season of 2018 at Abela Sippa kebele. The experiment consisted of four different *in-situ* soil moisture conservation techniques (Targa, Zai, Tie ridge and Control) with maize planting at spacing of 40 cm x 75 cm between plant and between rows. The experiment have a completely randomized block design (RCBD) used because; there is fertility gradient on experimental field.

A layout of completely randomized block design with four treatments and three replicates, for a total of 12 plots. Each plot was 6 m x 10 m area with slope range of 3-5%. Plots were separated by 0.5 m to facilitate crop management operations and 1 m space between blocks.

Based on previous recommendations of fertilizer application on maize by Debelle and Friessen (2001), 100 kg ha^{-1} Urea in two applications (50 kg ha^{-1} during sowing and another 50 kg ha^{-1} was applied 40 days after sowing) and 100 kg ha^{-1} of DAP in one application (only during sowing) were applied on the plots. A local maize cultivar (Awassa BH540) was planted with density of 40,000 plants per hectare with spacing of 40 cm and 75 cm between plants and between rows, respectively.

Tied ridge: When the ridges or furrows are blocked with earth ties with intervals, they are known as 'tied ridges' or furrow disking. In Tied-ridges, the earth ties are spaced at fixed distances to form a series of micro-catchment basins in the field. Tie spacing for tied-ridge was 5 m interval made by manually with 75 cm spacing between consecutive ridges constructed along contour line. One plot of tie-ridge was 6 m x 10 m.

Planting pit/Zai: Is pitting cultivation, which takes place in the form of Zai which is dug with distance between pit 40 cm and between row 75 cm to a depth of 16 cm. crop residue (4.5 mg ha^{-1}) was incorporated and decomposed in the soil before sowing on the Zai pits to keep the fertility level of the soil at optimum condition and 100 kg ha^{-1} DAP and 100 kg ha^{-1} urea.

Targa: Is a rectangular basin built from soil or crop residue before rain season constructed along contour lines spaced 1.5 m apart, which are tied approximately at 1.43 m interval by ridges made in horizontal 7 and vertical 4 number of Targa with a total 28 Targa constructed in each plot at staggered position across the contour. Within each, the Targa two rows prepared by 75 cm space with a total of 8 numbers of rows and 24 planting pits in each row. The bund ridges of Targa rise about 0.2 m above the ground and the embankment thickness 0.2 m.

Methods of data collection

Determining soil moisture content

The state of water in the soil can be described in two ways: quantity present and energy status. The quantity present is expressed as gravimetric (mass) or volumetric. The gravimetric water content is the mass of water in a unit mass of dry soil (g of water/g of dry soil). The wet weight of soil sample is determined; the sample is dried at 105°C to constant weight and reweighed (Gardner, 1986). The volumetric water content is expressed in terms of the volume of water per volume of soil (cm^3 of water/cm^3 of soil). Measuring soil moisture measurements was conducted at three periods (initial, development and mid stage) to evaluate the amount of soil water during just after the rainfall and after 10 days of without rainfall during crop growing seasons.

An auger was used for soil sampling from the depth of 0-20 cm and 20-40 cm because 70% of moisture extraction was taken from the rooting depth (0.4 m). From each of the two depths collect sub samples of the auger sample and mix well in a plastic bucket. The weight of the wet soil samples was measured and put in an oven at 105°C for 24 hours and then the weight of dry samples was measured. The soil water stored (%) in each 0.4 m incremental depth down was determined gravimetrically.

It was then converted to water depth (mm) by multiplying by the specific bulk density values measured by the core sampler methods as described by Blake (1965).

Volumetric water content can be calculated from gravimetric water using the following equation:

$$SMC = \frac{Ww - Wd}{Wd} * 100$$

Where,

SMC = Soil moisture content dry base (%)
Ww = Weight of the wet soil (g)
W_d= Weight of the dry soil (g)

Volumetric soil water content (cm^3/cm^3) is determined as:

$$\theta = w * \rho d$$

Where,
w = gravimetric water content
ρd = bulk density (g/cm^3)

Agronomic data parameters

Agronomic parameters including grain yield, above ground biomass, plant height and cob length data were collected .To measure cob length and plant height six stands from each plot were randomly selected and measured. Above ground biomass was weighted from each plot at the end of the growing season; the plants were cut, tied in bundles and left to dry for 10 days under the sun. To get grain yield in each plot at the end of the growing season; the heads were cut and the grains were threshed and weighed and yield per plot was recorded.

Statistical analysis of data

All the agronomic data were recorded and being subjected to analysis. Analysis of variance was performed using the GLM procedure of SAS Statistical Software Version 9.1 (SAS Institute, 2007). Effects were tested under (P=0.05). Means were separated using Fisher's Least Significant Difference (LSD) test, Crop Watt 8.0 and survey data was analyzed and presented qualitatively using different statistical methods (SPSS) of descriptive statistics; Means as well as percentages and frequencies were calculated.

Results and Discussion

Effect of treatments on volumetric soil-moisture content

Table 1. Treatments means for SMC (%) of the root zone during just after one day RF and after 10 days of rainfall.

Treatment	Initial period SMC (%)		Development period SMC (%)		Mid period SMC (%)	
	Just after one day of RF	After 10 days of rainfall	Just after one days of RF	After 10 days of rainfall	Just after one day of RF	After 10 days of rainfall
Targa	54.09a	51.15a	58.90a	55.80a	54.00a	46.50a
Tie ridge	45.50a	43.00ab	54.20a	52.00a	50.00a	42.60ab
Zai	42.32a	35.60ab	51.15a	23.20b	48.00a	31.93ab
Control	40.80a	35.18b	44.00a	26.30b	45.00a	30.50b
CV (%)	16	16	19	16	19	18
LSD (0.05)	14	8	30	8	12	9

Table 2. Comparing each structure for soil moisture content and maize water requirement in growth stages.

Treatment	After one day of RF				After 10 days of RF				
Initial	Total SMC mm/m rz	Available SMC mm/m rd	Available SMC at 0.3m rz	ETc/day	Total SMC mm/m rz	Available SMC mm/m rz	Available SMC at 0.3m rz	ETc/dek	% of crop water need satisfaction at dry spell period
Targa	54.10	29.80	8.92	1.04	51.20	28.13	8.43	10.40	87
Tie-ridge	45.50	25.00	7.50	1.04	43.00	23.65	7.00	10.40	72
Zai	42.30	23.20	6.90	1.04	35.60	19.50	5.87	10.40	56
Control	40.80	22.40	6.70	1.04	35.20	19.30	5.80	10.40	55
Development			0.86 m				0.86 m		
Targa	58.90	32.30	27.70	2.63	55.80	30.70	26.30	26.30	100
Tie ridge	54.20	29.80	25.60	2.63	52.00	28.60	24.50	26.30	93
Zai	51.20	28.20	24.10	2.63	23.20	12.76	11.00	26.30	42
Control	44.00	24.20	20.80	2.63	26.30	14.46	12.40	26.30	47
Mid stage			1 m				1 m		
Targa	54.20	29.80	29.80	3.00	46.50	25.60	25.60	30.00	85
Tie ridge	50.15	27.58	27.58	3.00	42.60	23.40	23.40	30.00	78
Zai	48.00	26.40	26.40	3.00	31.90	17.50	17.50	30.00	58
Control	45.00	24.75	24.75	3.00	30.50	16.70	16.70	30.00	55

*NB: TAW (total available water), RAW (readily available water), SMC (soil moisture content), rz (root zone) RAW=TAW*P; Where, p is critical depletion (p= 0.5 for maize).*

The effects of the treatments on soil moisture content (SMC) just after one day of rainfall and after 10 days of rainfall at different growing season were shown in Table 1 and 2. The results obtained showed non-significant differences in SMC between all treatments ($p>0.05$) at initial period just after one day of rainfall.

There was significant difference between treatments Targa and Control ($p<0.05$) after 10 days of rainfall at initial period but no significant difference ($p>0.05$) between Tie ridge, Control and Zai shown in Table 1. In Table 2, treatments Targa (82%), Tie ridge (72%), Zai (56%) and Control (55%) satisfy crop water requirement during dry spell periods (after 10 days of rain rainfall). Similarly, there was no significant differences between treatments ($p>0.05$) at development period just after one day of rainfall. In Table 2, percent of crop water need satisfaction after 10 days of rainfall was 100%, 93%, 42% and 47% for Targa, Tie ridge, Zai and Control, respectively. These results showed that the treatment Zai and Control were not satisfying crop water requirements during dry spell period when more water lost from these structures. The result also showed the superiority of the tested techniques (Targa and Tie ridges) over the Control method by reducing run off and evaporation loss. This result was in agreement with McHugh *et al.* (2007).

Although there was no significant differences between the tested techniques at mid period during just after one day of rainfall on SMC can be put in a descending order as Targa> Tie ridge >Zai> Control. But, significant differences was observed between Targa and Control ($p<0.05$) during mid period after 10 days of rainfall and no significant difference ($P>0.05$) between Tie ridge, Zai and Control in Table 1 shown. In Table 2, after 10 days of rainfall at mid period treatment Targa, Tie ridge, Zai and Control satisfied 85%, 78%, 58% and 55% crop water requirement during dry spell periods, respectively. The results obtained showed at all the growing season significant difference in SMC ($P<0.05$) between *in-situ* water harvesting structures and control on 10 days after rainfall (at dry season).

Next to Targa higher soil moisture content stored on Tie ridge structure. The present findings was agreed with (Botha, 2006) who stated that RWH techniques reduce unproductive water losses, particularly evaporation (E) and run off (R) and optimize rainwater productivity. The results indicated that the efficiency of Targa in retaining water was better, because the ridges were made up of maize residue and soil are able to improve soil water content in the soil root zone during cropping period compared with control. According to studies from Northern Ethiopia on *in-situ* water harvesting systems, tied-ridging, open ridging and sub-soiling improved soil water content at the root zone during cropping period compared to the Traditional tillage by 24%, 15% and 3%, respectively (McHugh *et al.*, 2007).

Effect of water conservation methods on growth of maize

Table 3. Mean growth parameters of maize under moisture conservation structures.

Treatment	GY(tha^{-1})	DMB (tha^{-1})	Ph(cm)	CL(cm)
Targa	7.15a	8.23a	208a	39.36a
Tie ridge	6.19a	7.8ab	202a	35.26b
Zai	4.50b	5.76c	201a	37.30ab
Control	4.90b	6.15bc	196a	35.50b
CV %	9.40	13.00	3.90	2.96
LSD (0.05)	1.00	1.90	15.80	2.18

NB: GY (grain yield), DMB (dry matter biomass), Ph (plant height), CL (cob length). Treatments with the same letters have no significant difference.

Plant Parameters

Grain yield

As shown in Table 3 above and Fig. 3 below, the grain yield of maize was increased significantly ($p<0.05$) in targa (7.15 t ha^{-1}) followed by Tie ridge (6.19 t ha^{-1}), and there was no significant difference ($p>0.05$) between Zai (4.50 t ha^{-1}) and Control (4.90 t ha^{-1}) treatment. However, the treatment Targa (7.15 t ha^{-1}) and Tie-ridge (6.19 t ha^{-1}) has significant ($P<0.05$) differences in grain yield than the Control (4.90 t ha^{-1}). According to Agriculture and Natural Resource office of Humbo woreda (study area), the average grain yield production of maize in the area on irrigated and without irrigation was reported to be 3.67 t ha^{-1} and 2.25 t ha^{-1}, respectively. Which indicates that, practicing of *in-situ* moisture conservation structures particularly Targa can produce more crop yield than Control. Control treatment in the present study showed the lower yield compared with Targa and Tie ridge, Control treatments may attributed to the low ability to retain the soil moisture as in Table 3 and 4 above shown. This result is also in conformity with the findings of Solomon (2015) and Yoseph (2014) who reported that maize grain yield was significantly affected by moisture conservation practices. When soil available water content decrease, the number of grain per plant and yield per unit area declines (Mansouri and Saberali, 2010). Through RWH (rainwater harvesting) structures determining the production increases through the efficiency of the techniques in conserving rainwater when compared with control. The current results agree with the findings of Botha, (2006) who reported that RWH was found to be the most appropriate measure of determining the efficiency of the techniques to improve dry land crop yields. Similarly, Barron and Okwach (2005) showed that, rainwater harvesting technique increased yield by about 70% in semi-arid Kenya.

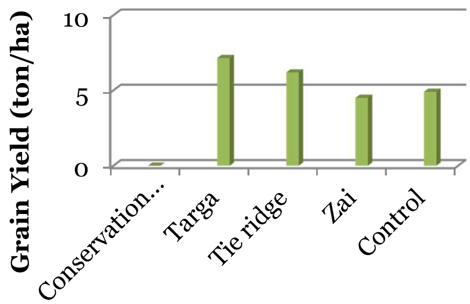

Fig. 3. Effect of treatments on grain yield.

Dry matter biomass

Biomass yields for different treatments were summarized in Table 3 and Fig. 4. There was significant difference (P<0.05) between all treatments on the maize dry matter biomass. There was significant different (p<0.05) between Targa, Zai and Control, however, Targa do not differ significantly from Tie ridge and Tie ridge do not significantly different (p>0.05) between control and significant difference (p<0.05) between Zai and Tie ridge treatments. Values can be arranged in descending order as Targa, Tie-ridge, Control, and Zai. The treatments Targa and Tie ridge had the highest biomass production of 8.23 t ha^{-1} and 7.80 t ha^{-1} biomass yield for the maize growing seasons, respectively than the treatment Control (6.15 t ha^{-1}) and Zai (5.76 t ha^{-1}). The lower biomass production was obtained under treatment Zai and control due to in efficiency to conserve moisture during dry spell periods as shown in Table 3.

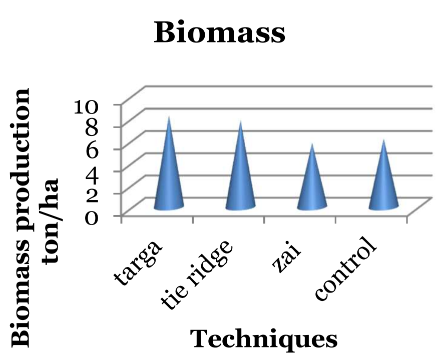

Fig. 4. Effects of treatments on dry matter biomass production.

Plant height

As can be seen from the Table 4 and Fig. 5 there was no significant (p>0.05) difference between among all the treatments in plant height during the maize growing season. However, water harvesting technique was superior in plant height, the values of the tested techniques can be put in a descending order as Targa, Tie-ridge, Zai and Control in the maize growing season. The results showed that the water harvesting increased the plant height because it led to increase the rate of leakage of water into the soil and which led to increased soil moisture content as shown in Table 3. The results agreed with the findings of Ahmed *et al.*, (2018) who reported that *in-situ* water harvesting techniques increased the yields of maize and accompanied with increase of plant height.

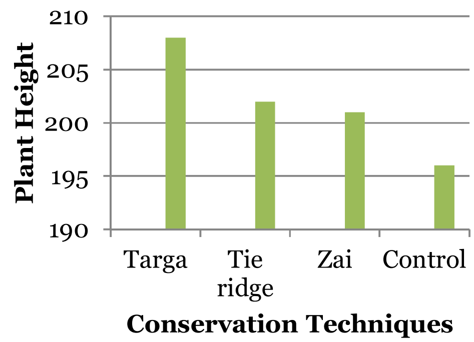

Fig. 5. Effects of treatments on plant height.

Cob length

As shown in above Table 3 and Fig. 6 there was significant (p<0.05) difference between treatments Targa, Zai, Tie-ridge and Control. There is no significant (p>0.05) difference between Tie ridge, Zai and Control. The result showed that cob length of maize increased by Targa treatments compared to Control. This was also in conformity with the findings of Solomon (2015) and Yoseph (2014) who reported that maize grain yield and yield components were affected significantly by moisture conservation practices.

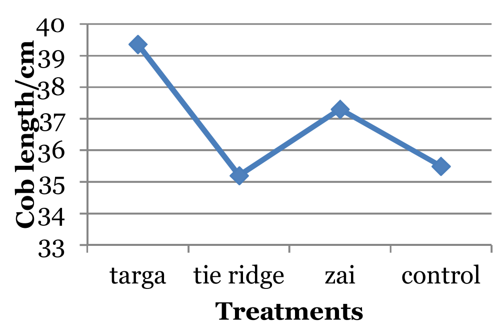

Fig. 6. The effects of treatments on cob length.

Gross returns

As shown in Table 4 below, among the different rainwater harvesting techniques, Targa recorded highest gross returns (45045 ETB ha^{-1}) compared to other conservation methods. The next best was conservation measures Tie ridge by recording higher gross returns (38997 ETB ha^{-1}) than Control. Control recorded gross returns (30870 ETB ha^{-1}) and Zai water conservation measures recorded lowest gross return (28350 ETB ha^{-1}) compared to all other treatments.

Economic costs and benefit analysis of treatments

Table 4. Estimated economic costs per hectare of treatments.

Treatments	Average yield (t ha^{-1})	Adjusted yield (t ha^{-1})	Unit price ETB kg^{-1}	Gross field benefit (ha)	Cost of labor	Cost of agro-chemicals	Cost of maize seed	Cost of fertilizer	Total costs that vary (ha)	Net benefits ha^{-1}	Benefit cost ratio
Targa	7.15	6.435	7	45045	8833	1000	500	5000	15333	29712	1.93
Tie-ridge	6.19	5.571	7	38997	7333	1000	500	5000	13833	25164	1.81
Zai	4.50	4.050	7	28350	7500	1000	500	5000	14000	14350	1.02
Control	4.90	4.410	7	30870	5500	1000	500	5000	12000	20370	1.69

NB: ETB: Ethopian Birr

Net returns

Table 4 shows the expenditure on materials and operations incurred by farmers for production of maize. Net revenue computed as total revenue minus total variable costs was presented in Table 4. As in above Table shown among the different rainwater harvesting techniques, Targa and Tie ridge recorded higher net returns (29712 ETB ha^{-1} and 25164 ETB ha^{-1}) than Control (20370 ETB ha^{-1}) and Zai (14350 ETB ha^{-1}). It means rainwater harvesting system with Targa and Tie ridge has direct effects on crop production and economic benefits over control due to better moisture holding capacity.

An average of 29712 ETB constituting 193% of the total revenue was earned as net revenue per hectare in Targa techniques. An average of 25164 ETB constituting 181% of the total revenue was earned as net revenue per hectare in Tie ridge techniques. An average of 20370 ETB, constituting 169 % of the total revenue was earned as net revenue per hectare in conventional. This result indicated that Targa *in-situ* rainwater harvesting techniques by 24% of the total revenue was earned as net revenue per hectare and Tie ridge *in-situ* rainwater harvesting techniques by 12% of the total revenue was earned as net revenue per hectare increased over conventional. Which was consistent with findings from the study conducted by Vohland and Barry (2009) rainwater-harvesting systems and the adoption of the rainwater harvesting practices have positive effect on incomes, measured in return to labour. In the case of soil and water conservation measures (*in-situ* rainwater harvesting structures), it usually involves significant initial and on-going investment in both cash and labour with benefits being realized in the long term (Ellis-Jones and Tengberg, 2000).

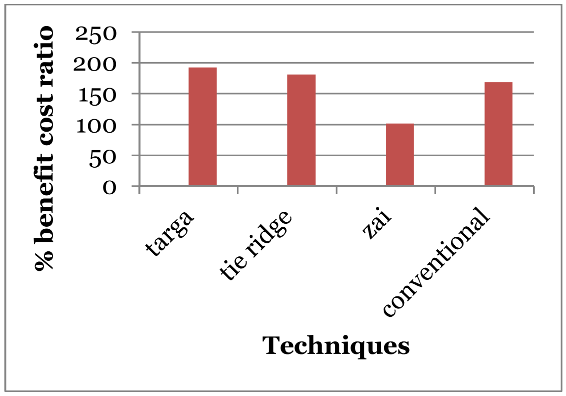

Fig. 7. Percent of the treatments benefit cost ratio.

Conclusion

The characteristics of agriculture in Humbworeda is predominantly rain-fed farming. This farming system resulted in fluctuating food crop productivity mainly due to moisture stress during mid and developmental season emanated from rainfall variability in the This study was conducted to know the potential of *in-situ* water harvesting techniques on maize yield, yield components and soil moisture. The comparative study between the Control, Zai, Targa and Tie-ridge showed that the soil moisture, grain yield and biomass for the Targa were consistently higher when compared to the control. Accordingly, out of IRWH technologies Targa is observed to be a climate smart technique, which contributes to conservation of natural resources (conserve soil moisture and reduces surface runoff water) and increase yield at dry land condition. These water harvesting structures on farmers' fields have minimum cost, less labor power required, do not leave much space as well as simple to construct. This study clearly demonstrated that *in-situ* rainwater harvesting techniques could play an important role in improving soil water storage, crop yields and extending the growing seasons in dry periods. The implementation and adoption of these techniques will however require careful planning, community participation and to better understanding of the choices in making decision.

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