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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, SNNPRS, ETHIOPIA

MSC THESIS
BY
WUDNESH NABA YAYA

HAWASSA UNIVERSITY
FACULTY OF BIOSYSTEMS AND WATER RESOURCE ENGINEERING

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN SOIL AND WATER CONSERVATION ENGINEERING

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I hereby certify that I have read this thesis prepared under my direction and recommended that it be accepted as fulfilling the thesis requirement.

Name of major Advisor	Signature	Date
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As member of the Examining Board of the Final MSc. Open Defense, we certify that we have read and evaluated the thesis prepared by Wudnesh Naba entitled **Evaluating The Effect Of *In Situ* Rainwater Harvesting Techniques On Maize Production In Moisture Stress Areas Of Humbo Woreda, Wolaita Zone, SNNPR, Ethiopia .** We recommend that it has to be accepted as fulfilling the thesis requirement for the degree of Master of Science in **Soil and Water Conservation Engineering.**

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Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the SGS through the DGC/SGC of the candidate’s department/School.

Thesis approved by

DGC/SGC	Signature	Date

DEDICATION

Firstly, I would like to thank my Almighty God (Comforter) for giving me strength, ability and patience in completing this work.

This valuable work is dedicated to my late father Mr. Naba Yaya and my mother Mrs. Dinkinesh Bekele, for their encouragement, support and understanding, which laid down the foundation of my education which made me who I am today. This work is also dedicated to my husband; I express my deepest thanks and appreciation to my husband Mr. Tamirat Anjulo for his encouragement, love, and patience to withstand situations during my absence. I also express my special thanks to my husband for his Praying Starting from the beginning up to the final thesis. Lastly, my sons Nahum and Biltasor who did not understand what I was doing, but having them there was enough.

DECLARATION

I declare that this thesis is my bona fide work and all sources of materials used for this thesis have been duly acknowledged. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

Name: **Wudnesh Naba** **Signature**______________________

Place: College of Bio System and Water Resource Engineering, Hawassa University, Hawassa.

Date of Submission:______________________________

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LIST OF ABBREVIATION

BD	Bulk Density (g. cm-3)
Co	Control
DAs	Development Agents
Dec	Decade
DMB	Dry Matter Biomass (ton/ha-1)
E	Evaporation
E.C	Ethiopian Calendars
Eff	Effective
Es	Evaporation from the soil surface (mm)
Ex	Field Run off
FAO	Food and Agriculture organization of the United Nations
FTC	Farmers Training Center
Gy	Grain Yield (ton/ha-1)
Ha	Hectares
Irr.req	Irrigation requirement
IRWH	In situ Rain Water Harvesting
Kc	Crop factor
P	Rain fall
Ph	Plant height(m)
R	Run off
RWHT	Rain Water Harvesting Techniques

RWP	Rain water productivity
SMC	Soil moisture content
SNNP	Southern Nations and Nationalities and people
SPSS	Statistical Package for Social Science
Ta	Targa
Tr	Tie ridge
UNEP	United Nation Environmental Protection
UNFCC	United Nations Frame Work Convention on Climate Change
Wd	Weight of the dry soil (g)
Ww	Weight of the wet soil (g)
Za	Zai pits

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ABSTRACT

Rainfall fluctuations, dry spells and drought are the main constraints for rain fed agriculture. In recent years the yield and productivity of maize have been declining drastically. This is mainly attributed due to the lack of appropriate soil and rainfall management practices. This situation is envisaged can be improved under the prevailing conditions by adopting simple water harvesting techniques with the intention of raising and sustaining maize productivity. Accordingly a study was conducted to investigate the effect of some In situ water harvesting techniques on performance of maize crop with respect to soil moisture content, yield and yield components and to assess farmers' perception of water conservation techniques. To achieve the objectives of the study data and information collected through house hold survey and field experiment. The experiment was conducted in Wolaita Zone Humbo Woreda at Abela Sippa kebele, which has an irregular rain fall distribution and a prolonged dry season which leads low soil moisture availability during critical crop growth stages. The study was conducted over a period of one growing season (2010/11) using maize as indicator crop at the farmers training center of the Abela Sippa kebele. 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 ($p<0.05$) by Targa treatments, but plant height was not significant different. Soil-moisture content over the crop growing season at dry spell periods was significantly higher in Targa and Tie ridges than the control. Targa treatments increased maize yield production to (7.15 ton/ha), Tie ridge increased significantly maize production to (6.19ton/ha), Zai pits yielded (4.5ton/ha) and Control treatment yielded (4.9 ton/ha). Targa and Tie ridge treatments recorded higher net returns (29712, and 25164 ha-1) than Control (20370ha-1) and Zai (14350 ha-1) treatments. The results revealed that the rainwater harvesting technology by the community members to be a good initiative in improving agricultural practices in periods of water scarcity. But, 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 labour power ,and easily constructed by local farmers(not require complicated knowledge).

Key words: *In situ rain water harvesting, farmers' perception, soil moisture, Maize yield*

1. INTRODUCTION

1.1 Background

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 rain-fall 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). Given that Ethiopia's national GDP is mainly based on agriculture, the annual GDP growth during1983–2000 showed strong correlation with rainfall variation (WWAP, 2009).

Seasonal rainfalls are highly unpredictable and variable in Ethiopia (Gissila et al., 2004) contributing to higher risk of production in arid and semi-arid regions due to less crop water availability during the growing seasons (Araya and Stroosnijder, 2011; Tesfaye and Walker, 2004). Hence, smallholder- based agricultural production varies noticeably from year-to-year.

If rainfall is less than crop water requirements, then clearly actual yields will be less than Potential; moreover the impact of variable rainfall is strongly affected by the nature of the soil and the stage of the growing period (Critchley and Scheierling, 2012).

Rain fed agriculture is practiced in almost all the agro ecological / hydro-climatic zones of the world. But in dry lands, which cover approximately 40 percent of the global land area yields of the major crops tend to be relatively low; between a quarter and half of their potential (Rockström et al., 2007; Wani et al., 2009; Scheierling et al., 2013).

Semi-arid areas face climatic variability at different temporal scales. High natural inter-annual climatic variability is expressed as droughts and floods; a high seasonal variability leads to dry spells (Usman and Reason, 2004). In addition climate change was affect dry land region, where livelihoods are largely rain fed, and cereal or livestock farming system based. Recent climate change scenarios project that between 2000 and 2050, and for warming levels of 1.8°C to 2.8°C (2.2°C to 3.2°C compared to preindustrial temperatures), decreases in yields of 14 to 25 percent for wheat, 19 to 34 percent for maize, and 15 to 30 percent for soybean (Deryng et al., 2011).

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, 2003).

Rainwater is collected from fields, house roofs and streets, and can be stored in underground tanks or open ponds. *In situ* RWH practices mainly help to overcome dry spells, as the soil, which is the main storage site of *in situ* RHW practices, serves only some days to weeks as a storage system (Falkenmark et al., 2001). By manipulating the soil surface structure and vegetation cover and density, evaporation from the soil surface and surface runoff can be potentially reduced, infiltration is enhanced and thereby the availability of water in the root zone increased. *In situ* RWH practices need low technical efforts compared to larger scale water harvesting schemes but show only comparatively short-term effects on soil water availability compared to temporally storage extended systems (Falkenmark et al., 2001).

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 (Humphreys et al., 2008, Rockström et al., 2010).

Water harvesting techniques (WHTs) have played a key role in improving the efficient use of rain water and have increased the sustainability and reliability of rain-fed agriculture (Biazin et al., 2012).

Ethiopia increasing rain water storage capacity and improving water control and rain water management techniques ,especially rain water harvesting are critical to ensure that Ethiopia gets maximum use of its rain fall(Awulachewu,2010).

It is considered as the most single most important means to increase agricultural productivity and provide a source of domestic water supply in drought prone area (Getaneh and Tsigae, 2013).

Several adaptation measures are being promoted to cope with a changing climate, such as the use of different crops or crop varieties, soil conservation, changing planting dates, and irrigation (Bryan *et al*., 2009), but these may not all be viable choices for smallholder farming either due to their high costs, technical restrictions, or even cultural limitations (Adger *et al.*, 2012).

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).

Therefore *In situ* RWH, along with other 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).

1.2 Problem Statement

Rainfall variability is an inherent challenge for farming in tropical and sub-tropical agricultural systems. These area practices subsistence farming systems, with high incidence of poverty and limited opportunities to cope with ecosystem changes. The variable rainfall also result in poor crop water availability, reducing rain fed yields to 25-50% of potential yields, often less than 1 tone cereal per hectare in South Asia and Sub-Sahara Africa (Nuguse, 2008).

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 phenomena in the semi-arid areas.

To mitigate the effects of these drought impacts there should be the need for farmers to use water conserving technologies so as to increase the time period required for crop moisture stress to set in. 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 (IMAWESA, 2007).

Techniques to improve soil moisture retention or water harvesting is not known to most farmers or not commonly practiced in Ethiopia. Much of the earlier studies related to land and water management practices concentrated on adoption and socio-economic impact assessment on single practices (soil and water conservation, water harvesting ponds, tanks, shallow wells or supplementary irrigation),which could ignore the complementarities and/or substitutability of the different practices (Kassie *et al.*, 2013).

Water harvesting techniques are postulated in this study to improve the management of the water status, either in the form of surface water (run off) or as soil moisture. It is unfortunate that water harvesting techniques are often overlooked as attractive options to increase crop yield and to help people to alleviate poverty, attain some degree of food security.

Some farmers have still mixed feelings about this technology and all its advantages, the adoption rate of the technologies by all farmers is still low and this is due to the fact that the technology is surrounded with a lot of constraints such as poor capital and human resource endowments, lack of access to credit, involvement in off-farm activities, negative Perceptions, gender issues, sedimentation, inaccessibility of the construction materials, lack of technical know-how are among the factors negatively influence the adoption of RWH technologies (Nigussie, 2008).

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 (Mohammed *et al.,* 2003; Ahmed and Naggar, 2003; Omer *et al.,* 2003).

The other characteristic problem of Humbo Woreda is that livelihood is dependent on subsistence crop production. 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).Such factors and many others have raised growing interest for remedies and improvements of the existing situation.

Therefore, this study has a significant role in filling the research gaps so as to enable the farmers use *in-situ* water harvesting techniques in order to boost the production of maize crop.

1.3. Objectives of the Study

General objective

To evaluate the contribution of selected in-situ rainwater harvesting techniques for crop production under rain-fed farming /rainfall stress areas.

1.3.1 Specific objectives

- To evaluate the effectiveness of selected In situ moisture holding structures at field condition.
- To determine the effect of *In situ* rain water harvesting structures on selected maize yield and components.
- To assess the current status of RWH practice and farmers perception of water conservation techniques.

1.3.2 Hypotheses

- There are no differences between RWH control practices in Plant available water for maize production.
- There are no differences in yield of maize under different RWHT compared with control practices.

1.3.3 Significance of the study

The changes in climate, especially poor rainfall patterns and distributions are key issues posing major agricultural challenges for food security and threaten the rural livelihoods of many communities in the study area. Rainfall (P) is low and limited. These limited P is mostly lost through runoff and evaporation, which result in low soil moisture availability and possible crop failure. Therefore these study to identify the best water harvesting techniques.

2. LITERATURE REVIEW

2.1 Principle and definition of rainwater harvesting

Rainwater harvesting is a simple and low cost water supply technique that involves the capturing and storing of rainwater from roof and ground catchments for domestic, agricultural, industrial and environmental purposes (Oduor & Gadain, 2007).

Rain water harvesting is the collective term for a wide variety of interventions to use rainfall through collection and storage, either in soil or in man-made dams, tanks or containers bridging dry spells and droughts. The effect is increased retention of water in the landscape, enabling management and use of water for multiple purposes. In agriculture, rainwater harvesting has demonstrated the potential of doubling food production by 100% compared to the 10% increase from irrigation. Rain fed agriculture is practiced on 80% of the world agricultural land area, and generates 65-70% of the world staple foods. For instance in Africa more than 95% of the farmland is rain fed, and almost 90% in Latin America (UNEP/SEI, 2009).

Rainwater harvesting techniques can be applicable in all agro-climatic zones. However, it is more suitable in arid and semi arid areas. These are areas of mean annual rainfall of 200mm-800mm (rarely exceeding 800mm); the average temperature is above 18c^{o}. The rainfall may come in one or two seasons. In such environment, rain-fed crop production is usually difficult without some form of RWH (Rebeka, 2006).

2.2 Classification of Rainwater Harvesting Technology Systems

Water harvesting pertains to any practice that collects runoff for productive purposes.

A distinction is often made between *In situ* water harvesting, i.e., the capture of local rainfall on farmland, and ex-situ water harvesting, i.e., the capture of rainfall that falls outside the farmland (Oweis et al, 1999).

RWH systems for crop production are divided into different categories basically determined by the distance between catchments area & cropped basin as follows (Bores & Ben Asher, 1982).

A*) In Situ* Rainwater Harvesting

In situ rainwater conservation is a system that conserving the rainfall where it falls in the cropped area or pasture. Under this category, the most common technology is conservation tillage that maximizes the amount of soil moisture within the root zone. Conservation tillage is defined as any tillage sequence having the objective to maximize the loss of soil, and water and having an operational threshold of leaving at least 30% mulch or crop residue cover on the surface throughout the year (Rockstrom, 2000 cited in Ngigi, 2003). However for small scale farmers' conservation tillage is any tillage system that conserves water and soil while saving labor and traction needs.

In addition to conservation tillage, a number of cultural moisture practices such as ridging, mulching, addition of manure, etc could fall under *in situ* rainwater harvesting conservation system. The other positive effect of *in situ* water conservation technique is to concentrate with in-field rainfall to cropped area. On the other hand, although soil improvements such as addition of manure would enhance realization of better yield, the technique may offer little or no protection against poor rainfall distribution (Ngigi, 2003).

B) Run off farming

The run off farming systems, which entail run off generation either within field or from external catchments and subsequent application either directly in the soil profile or periodic storage for supplemental irrigation, are further classified according to two criteria as storage rainwater harvesting systems and direct run off application system (Ngigi, 2003).

Storage RWH systems are aim at storing rainwater in various types of storage dams. These systems are implemented in Ethiopia in various parts of Amhara, Oromia and Tigray regions (Daniel, 2006). This system, although it is simple to design, has challenges such as high cost of lifting water, cracking and hence abandoned, and loss of water through seepage has been identified as drawbacks. In contrary, since the system enables to store large quantities of water in ponds at the times of abundance rainfall, has advantages like conserving water for livestock watering small scale irrigation.

According to the size of catchments, run off generation rainwater conservation system is further divided in to macro-catchment system which large external catchments providing massive run off (floods) that is diverted from gullies and ephemeral streams and spread in to crop land, i.e, spate irrigation; small external catchments in which run off is diverted to crop lands from adjacent roads, fields, etc and small external catchments normally with in crop land that generate small quantities of run off for single crop, group of crops or row crops (Ngigi, 2003).

2 .3 Rainwater Harvesting in Africa

As to Falkenmark et al., (2005) 70% of the world's poor live in rural areas and are often at the mercy of rainfall based sources of income (rain-fed agriculture). In developing countries there is an increasing competition for limited water resources. As a result, food production is water constrained and the degree of freedom is constantly shrinking. Therefore, water is increasingly understood as a key factor in socio-economic development.

The planting pit system is a Micro catchment technique which is holes dug to catch runoff and allow time for infiltration and they are usually fertilized with organic matter in the form of plant debris or compost.

Pits of 30 cm diameter are dug, 90cm apart and 15-20cm deep. An experiment Niger showed a doubling yield of maize from 6000kg/ha on a manure field without Zay to 12000kg/ha on fields with Zay pits (Fatondjj et al.,).

Farmers in the Yatenga province in Burkina Fasso provide an example where water harvesting is used to improve production and increase income.

As early as 1989, farmers in 8,000kg/ha in 400 Yatenga villages were using an improved version of their traditional water harvesting techniques that involved building simple stone bund across the slopes of their fields (Postel, 1992; Tiffen et al., 1994, cited in IWMI, 2003).

2.4 Rainwater Harvesting Technologies in Ethiopia

In Ethiopia, rainwater harvesting dates back to the pre- Axumite period (560 BC) (Fattovich, 990: cited in Daniel, 2006). However, it has not been filtered through modernization.

While direct diversion of overland surface water on to the field has been commonly practiced in many parts of Ethiopia, digging holes to collect water is rather a new practice in highland parts (Getachew, 1999).

The food security strategy of Ethiopia, RWH is aimed to meet two goals: to cultivate horticulture during dry period and to provide water as supplementary irrigation in wet season (Hurne ,2004).

In South of the country, Konso have had a long and well established tradition of building level terraces to harvest rain water to produce sorghum successfully under extremely harsh environment ;low ,erratic and unreliable rain fall conditions (Hailemichael,2011).

Introduction of RWH structures in the drought prone Wukro district of Tigray Region was found to be important both in terms of harvesting enough water needed to meet both the domestic and the irrigation needs. A significant number of farmers of the *Woreda* started to obtain higher yields after they adopted the technologies and their annual income had become higher (Nigussie, 2008).

In Ethiopia, though it has long history in the country, it is only recently that rainwater Harvesting has started to receive significant attention from Ethiopian government. It has been regarded as one of the crucial tools to achieve food self-sufficiency, and is being implemented on a large scale particularly in water scarce areas of the country. A study conducted by Rami, (2003) emphasized mainly on rainwater harvesting implementation related problems and the prospects of using it for the stated objective of attaining food self-sufficiency. It has been found that RWH is top of the agenda in different regions of the country, as is the case at national level. The success in attaining the planned amounts of tanks and ponds to be constructed and the perceptions of the beneficiaries are found mixed.

Shortages of required construction of raw materials, lack of timely dispersal of finance and shortage of skilled labor have been among the factors inhibiting the attainments of the stated goals. This is evident from Amhara region where it once was planned to construct 29,005 tanks made of cement and plastic and 27,955 wells were excavated for the purpose but only 12,614 tanks were constructed. Furthermore, the tanks constructed so far are found to be substandard, many collapsed and majority leak and seep water, the main factor being lack of experienced masons and supervisors and mismatch between the type of soil in the area and the tank construction method. The tanks were first tested in Adama area and implemented in the two regions, with basically different soil structures from Adama area, without taking into account the specificities of the two regions (Rami, 2003).

In addition, most of the construction was assigned to each Woreda as a quota resulting in less attention being paid to quality as compared to number. Moreover, the implementation tended to be in top-down approach, particularly in Amhara region, and this has also contributed its share to the problems.

2. 5The role of in situ rain water harvesting structures in Northern Ethiopia

In the Tigray highlands of Northern Ethiopia, the role of *in situ* rainwater harvesting (RWH) in water resources conservation is well recognized. Soil and water conservation (SWC) activities have long been in practice in Tigray, but the large scale and well organized program started over three decades ago (Esser et al., 2002). Since its large scale initiation, millions of hectares of sloppy areas have been treated by different SWC measures and tree seedlings planted in different parts of the region (BoANR, 2002). Initially, physical structures were mainly introduced (Chadhokar and Solomon Abate, 1988), such as the widespread stone bunds constructed along contour lines. Lately, particularly following the devastating drought and famine of the 1980s (Getachew Alem, 1999), these were supplemented by different RWH structures [e.g., semicircular micro catchments (half-moon ponds (HMPs), ditches, trenches, etc.], aimed at intercepting runoff water and improving infiltration and ground water recharge, thereby ensuring availability of water in springs and shallow wells.

Farmers also cultivated their crops behind earthen barriers and ditches to increase their crop yield (Desta et al., 2005; Mintesinot and Mitiku , 2002; Nyssen et al., 2004). Where rainfall is unevenly distributed and soils have high water-holding capacity, this system may store water for a prolonged period of time, impacting positively on the surrounding ecology and increased crop yield (Girmay Gebresamuel et al., 2004).

In the semi-arid areas of Ethiopia the use of tied-ridges in yield of the major crops including maize, sorghum and wheat was obtained regardless the different planting patterns used, i.e. planting in the furrow or top of the ridge compared to the flat seed-bed (farmers practice) particularly in drier seasons .The average grain yield increase ranges from 50 to > 100% compared to the traditional practice depending on soil type, slope, rainfall and the crop grown in some of the dry land areas, Kobbo and Melkassa (*Kidane and Rezene 1989*).

2.6. Studies on rainwater-harvesting systems for enhancing food security, agriculture and its adoption.

Biazin *et al.,* (2012) did a review on rainwater harvesting and management in rain-fed agricultural systems in Sub-Saharan Africa. The study indicates that micro-catchment and *In Situ* rainwater harvesting techniques are more common than rainwater irrigation techniques from macro-catchment systems. The rainwater harvesting techniques could improve the soil water content of the rooting zone, nearly six fold of crop yields have been obtained, reduces risk of crop failure due to dry spells but also improving water and crop productivity Biazin *et al.,* (2012).

Vohland & Barry (2009), did a review of *In-Situ* rainwater harvesting practices modifying landscape functions in African dry lands. The results were based on impacts of different aspects of sustainability on *In Situ* rainwater harvesting systems that improve hydrological indicators such as, infiltration and ground water recharge, soil nutrients are enriched, and biomass production increases with subsequent higher yields leading to food security. Farmers especially those with least resources usually expect to see benefits with a cropping season from such technological investment.

The experience of Zambia shows that crop yields have on the minimum doubled. Maize yield rose from under 0.5t/ha to above 2t/ha and cotton from 1.5t/ha to 3t/ha under conventional as compared to conservation agriculture respectively. This has been attributed to improved rainwater harvesting.

Using RWH technology, a farm household could increase its agricultural yield, by improving the availability of water during the dry spell period at times, where rainfall stops earlier than the usual rainy season period.

An study made by (Yitebitu , 2004), farmers were able to increase their average crop yield From0.3 ton to 0.8 ton in nearly one hectare of land and others got a bumper harvest using RWH technology, yield increased from 0.8 to 2 tons of sorghum from approximately the same size of holding. The crop stable remains green for longer period with new shots due to residual moisture and provide pasture for livestock.

2.7 Effects of rain water harvesting structures on soil moisture

Globally, the total volumes of water stored with in soil are huge, but any given locality they are relatively small and quickly depleted through evaporation. Because of this in recent decades there has been increased interest in various in situ rain water harvesting management techniques that enhance infiltration and water retention in the soil profile (World Bank, 2006).

It is important to note that RWH can be used to rehabilitate degraded land and retain moisture (FAO, 2001).

Water harvesting retains moisture *in situ* through structures that reduces run off from fields and hold water long enough to allow infiltration (Rockstrom, 2002).

Improved in-field water harvesting can increase the time required for crop moisture stress to set in and thus can result in improved crop yields and have resulted in positive effects on soil fertility ,moisture conservation and agricultural productivity (Alemu and Kidane ,2014,Kidane, 2014,Kidane etal.,2012).

3. MATERIALS AND METHODS

3.1 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 and18 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" 510'E longitude in South Nation Nationalities and People Regional Government (SNNPR).

The climatic condition of the study area, average daily temperature is 18.3°C-21°C, the annual rainfall varies between 710 mm and 1337 mm (CV = 16%) with a mean of 1148mm for the past 11years. 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) rain fall on May and low rain fall 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 (Fig1). 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).

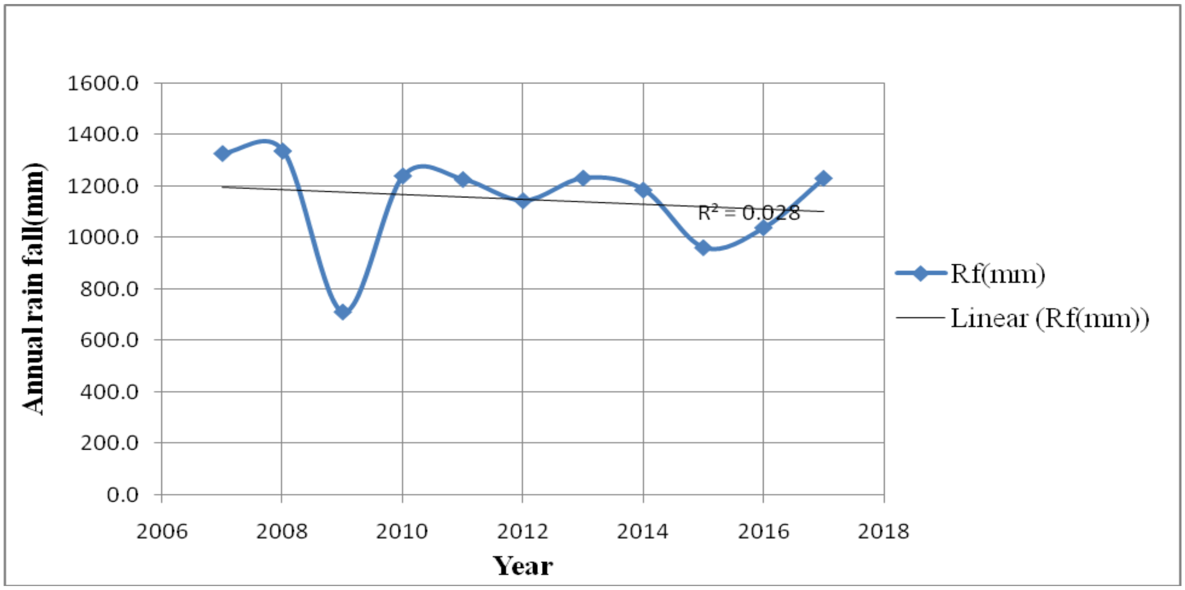


Figure 1: Shows that yearly rainfall profile of the study area shows rain fall variability among the years for a period of 11 years (2007 –2017).(Source NMA of SNNPR)

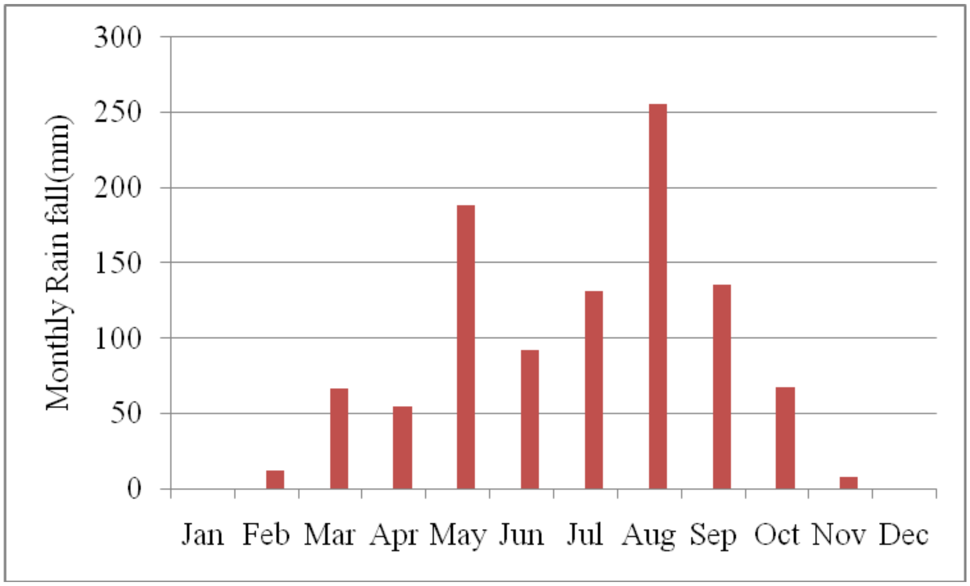


Figure 2: Shows that monthly rain fall of the study area (2018)

Soil physical characteristics such as bulk density (1.55g/cm$^{3)}$ and soil texture (clay75%, sand 9%, silt16%) which shown 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 hectare (ha) which is 70% of lowland and 30% midland (WBSEDP, 2005) . It is bordered on the South by West Abaya woreda, North by Sodo Zuria woreda, East by Damote Woyde woreda, and West by Ofa woredas. The human population in the area is a total of 172484 peoples (as per data from woreda Agricultural bureau).

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, cow pea and root crops like sweet potatoes, and fruits like mango, avocado and banana according to Humbo District Agricultural Bureau(HDAB, 2011).

In Humbo Woreda there are about 43 water schemes and currently 38 of them are functional. There are about 16 HDWs/shallow, 3 springs with distribution, 14 boreholes and 172 water points.

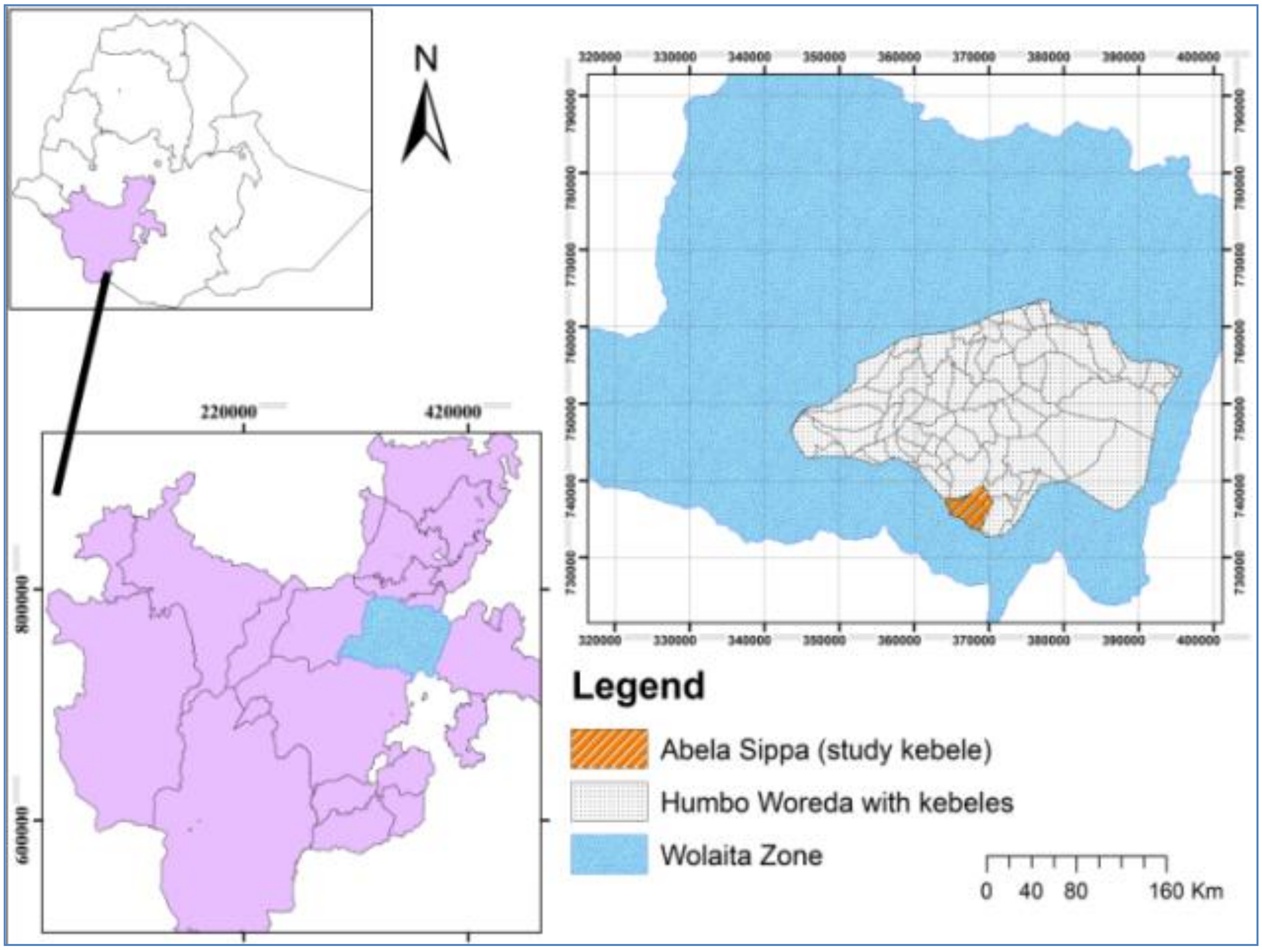


Figure 3: Map of the study area

3.2 Materials

To conduct the research activities materials used were auger, improved maize seed, human power, fertilizer (Urea and Dap) ,meter and soil digging materials.

3.3 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 2010 E.C 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 40cm by 75cm 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 × 10 m area with slope range of 3-5%. Plots were separated by 0.5m to facilitate crop management operations and 1m space between blocks.

Based on previous recommendations of fertilizer applications on maize _ (Debelle et al., 2001; Demeke et al., 1997), 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 Targa , Tie ridge, Zai and Control plots .

A local maize cultivar (Awassa BH540) was planted with density of 40,000 plants ha^{1} spacing of 40cm and 75cm with in rows and between rows respectively.

The Description of in situ soil moisture conservation structures used in this study was described with their design procedures under the following way:

Tied ridge*:* Ridging, which creates furrows by opening the soil in between, is widely applied in different areas (Jones and Stewart, 1990; Lal,1990, 1991). In areas of low and erratic rainfall, the furrows created by ridging can be left open, or closed at regular intervals for holding water and facilitating infiltration. 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 (Lal, 1990; Nyamudeza and Jones, 1994; Wiyo et al., 1999).

There has been a long experience of ridge tillage in Eastern Africa (Dagg and MacCartney, 1968; Gebreegziabher et al., 2009; Pereira et al., 1958, 1967).

Tie spacing for Tied-ridge was 5 m interval made by manually with 75cm spacing between consecutive ridges was constructed along contour line.

One plot of Tie-ridge was 6m X 10m so eight number of Tie ridge required within one plot and 24 a number of seeds planted with in each row, so totally 192 seeds planted in the furrow on the one plot.

Planting pit/*Zai* : Is pitting cultivation,which takes place in the form of Zai by applying biomass production(4.5 Mg ha^1) was improved in the pit before planting in Burkina Faso (Kabore, 1995; Kassogue et al., 1996; Ouedraogo and Kabore´ , 1996; Fatondji et al., 2001; Kabore and Reij, 2004), Tassa in Niger (Hassan, 1996), or the Chololo pits and Ngoro pits of the Matengo people in East Africa (Mutunga and Critchley, 2001; Kato, 2001; Mati and Lange, 2003; Malley et al., 2004).

The Zai form are dug with distance between pit 40cm and between row 75 cm to a depth of 16 cm, within one row 24 Zai pits was dig having a total 192 number of Zai pits required with a diameter of between 20 cm they are usually fertilized with organic matter in the form of 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 100kg ha^1 DAP with 50 kg ha^1 urea was applied during sowing and 50kgha^1 urea also applied after 40 days after sowing).

Targa *:* A traditional in situ water harvesting technique indigenous to the Derashe peoples, 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 1.43m 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 75cm space total of 8 numbers of rows and 24 planting pits in each row. The bunds ridges of *Targa* rise about 0.2m above the ground and the embankment thickness 0.2m.

The Derashe farmers have been successfully harvesting optimum yield of sorghum and maize from rain fed farming which would have been hardly possible under low amount and uneven distribution of the rainfall in the area had it not been for the sake of their *Targa* an effective water conservation measure (Personal communication and observation).

Control: farmers practice in Humbo area that means simply plowing the fields without any conservation structures**.** The plots were ploughed three times that was twice before sowing (before the onset of rain, and after first rain) .

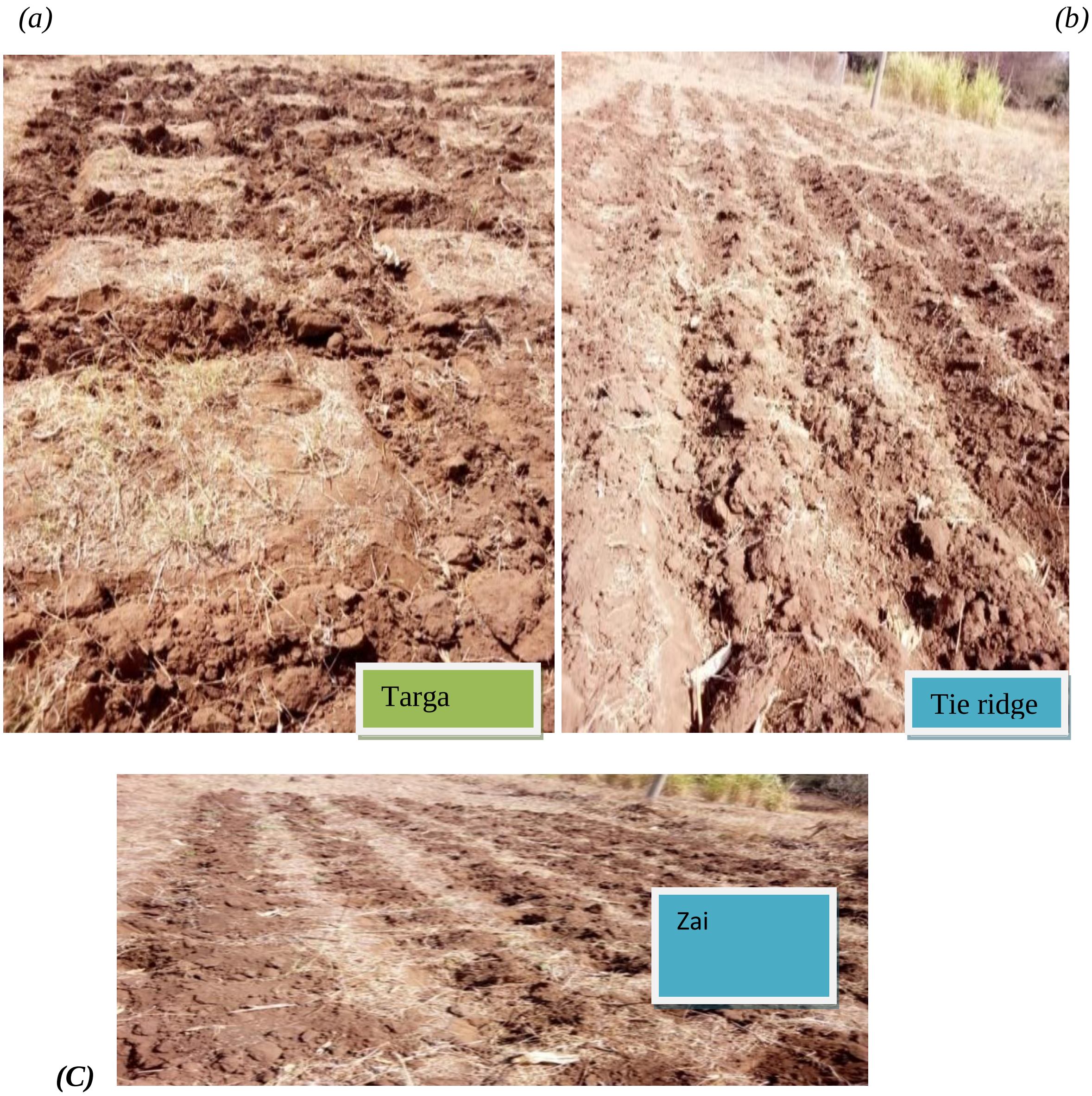


Figure 4*:* Design of the structures photos on the field before planting

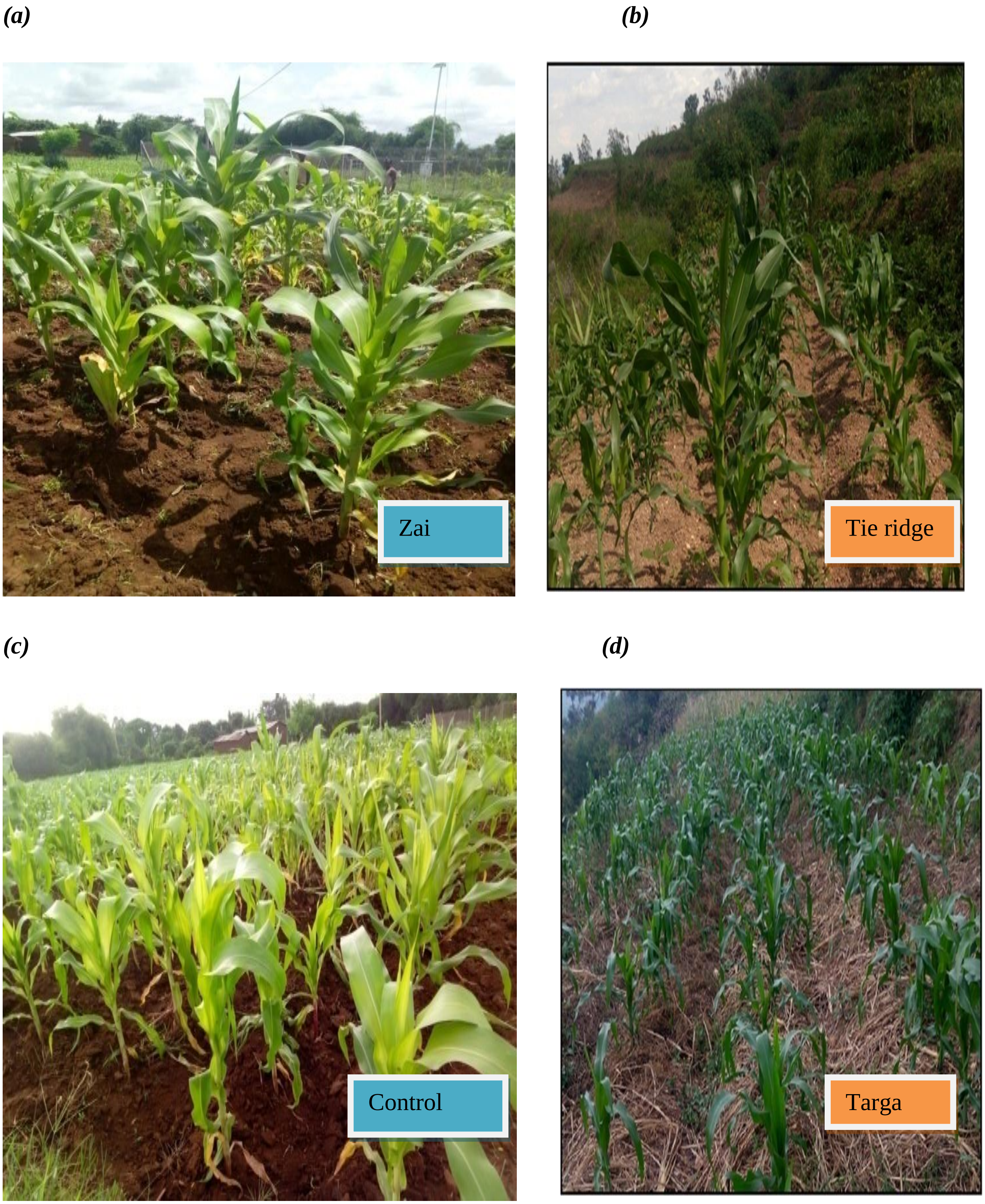


Figure 5: Design of the structures photos on the field after planting

Table 1: Experimental layout for the maize on the study area

B1	**T**	**0.5m**	**Ti**	**0.5m**	**Z**	**0.5m**	**C**	**10m**
1m								
B2	**Ti**	**0.5m**	**Z**	**0.5m**	**C**	**0.5m**	**T**	
1m								
B3	**Z**	**0.5m**	**C**	**0.5m**	**T**	**0.5m**	**Ti**	**6m**
41.5m								

Total area of 20mx41.5m=830m^2 fertility gradient

3.4 Methods of data collection

3.4.1 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^{0}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 (cm3 of water/cm3 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 rain fall and after 10 days of without rain fall during crop growing seasons.

To taken soli composite method used "x" around the field to collect soil from various places on the field.

An auger was used for soil sampling from the depth of 0-20cm and 20- 40 cm because70% of moisture extraction was taken from the rooting depth (0.4m). 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 0.4m 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 (gm)

W_d = Weight of the dry soil (gm)

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)

3.4.2 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.

3.5 Assessing farmers’ perception and current status of RWH practices

3.5.1 Survey Data Collection Methods

Survey was conducted on Humbo Woreda at Abela Sippa kebele to understand the perceptions of the farmers on the moisture conservation techniques and the current status of the water conservation in the area. To gather adequate information that meets the stated specific objectives of the research, qualitative data collection methods were employed in this study.

The sources of data for this research were primary household data collected with close and open ended structured survey questionnaire.

In-depth discussion was conducted which was led by the researcher to have the understanding, perceptions, current uses and a constraint over the utilization of RWH was carried out.

3.5.2 Sampling Procedures

The samples were selected through probability sampling methods and the technique was simple random sampling which was used to represent the study area. Simple random sampling was a procedure that provides equal opportunity of selection for each element in the population. The lottery techniques were used where a symbol of each unit of the population was placed in a container, mixed and lucky numbers were drawn to constitute the sample. Simple random was the most convenient method because every element or number of the population had equal chances of being selected Babbie (1973). This eliminates the bias inherent in non-probability sampling procedures because the probability sampling process is random; every farmer had an equal opportunity of selection in the population. The sample size was determined using proportional probability to population Yamane (1967) provides a simplified formula to calculate sample sizes stated below:

$$n = \frac{N}{1 + N(e)^2}$$

Where n is the sample size, N is an estimate of the population size and e is the absolute size of the error in estimating N that the researcher is willing to permit. The study used 95 percent level of confidence with an allowable error of 0.05.

Using the above stated formula the sample size of **183** households farmers were selected from out of **340** farmers population.

3.6 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, 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) using descriptive statistics; Means as well as percentages and frequencies were calculated.

4. RESULT AND DISCUSSION

4.1 Effect of treatments on Volumetric Soil-moisture content

Soil moisture content (SMC) of the soil profile was measured at three periods, i.e. at initial, development and mid period. The effects of the treatments on soil moisture content (SMC) during just after one day of rain fall and after 10 days of rain fall at different growing season were shown in Table (2 and 3).

The results obtained showed not significant differences in SMC between all treatments ($p>0.05$) at initial period just after one day of rain fall. The detailed statistical analysis for initial period just after one of rain fall was presented in Appendix1.

There was significant difference between treatments Targa and Control ($p<0.05$) after 10 days of rain fall at initial period but no significant difference ($p>0.05$) between Tie ridge, Control and Zai shown in Table (2). In Table (3) shown after 10 days of rain rainfall treatments Targa 82%,Tie ridge 72%,Zai 56 % and Control 55% satisfy crop water requirement during dry spell periods. Similarly there was no significant differences between treatments ($p>0.05$) at development period just after one day of rain fall.

But,there was significant difference between all treatments ($p<0.05$) in the development period during after 10 days of the rain fall in Table (2).

In Table (3) shown after 10 days of rain fall treatment Targa 100%,Tie ridge 93%,Zai 42% and Control 47%.When the treatments conserved water with crop water requirements at dry spell period. These results shown that the treatment Zai and Control were not satisfying crop water requirements during dry spell period 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 Ibrahim (2008), Mohammed (2009), Li *et al*., (2000); Tian *et al*., (2003); and McHugh *et al*., (2007) Stated that RWHT conserving their good effect on soil moisture throughout the growing season.

Although there was no significant differences between the tested techniques at mid period during just after one day of rain fall on SMC they can be put in a descending order as Ta>Tr>Za>Co .But significant differences was between Targa and Control ($p<0.05$) during mid period after 10days of rain fall and no significant ($P>0.05$) difference between Tie ridge, Zai and Control in Table (2) shown.

In Table (3) after 10 days of rain fall at mid period treatment Targa 85%, Tie ridge 78%, Zai 58% and Control 55% satisfy crop water requirement during dry spell periods.

The results obtained showed at all the growing season significant difference in SMC ($P<0.05$) between *in situ* water harvesting treatments and Control on 10 days after rain fall (at dry season).

As Table (3) shown above the higher soil-water storage was obtained on the Targa ridges compared with other tested technique which satisfy crop water requirement at all crop growing seasons. Next to Targa higher soil moisture content stored on Tie ridge structure. This indicated the rain water harvesting (RWH) techniques collect surface run off and concentrate it into the root zone areas of crops. The present findings was agreed with (Nhlabatsi,2010) who stated that RWH techniques reduce un productive water losses, particularly evaporation(E) and run off(R)and optimize rain water productivity. The results, indicated that the efficiency of Targa in retaining water was enhanced , because the ridges were made up of maize residue and soil are able to improved soil water contenting in the soil root zone during cropping period compared with control .(Our studies was agreed with field studies from Northern Ethiopia on *in situ* water harvesting systems such as Tied-ridging, Open ridging and Sub-soiling improved soil water contenting the root zone during cropping period compared to the Traditional tillage by 24%, 15% and 3% respectively (McHugh et al., 2007), WHTs ensures high-level and reliable crop production, benefiting from enhanced soil-water storage and decreased net runoff (Li et al., 2000).

Table 2: **Treatments means for SMC (%) of the root zone during just after one day RF and after 10 days of rain fall.**

Treatment	Initial period SMC (%)		Development period SMC (%)		Mid period SMC (%)	
	Just after one day of RF	After 10 days of rain fall	Just after one days of RF	After 10 days of rain fall	Just after one day of RF	After 10 days of rain fall
Targa	54.097a	51.15a	58.9a	55.8a	54.2a	46.5a
Tie ridge	45.5a	43ab	54.2a	52a	50.15a	42.6ab
Zai	42.32a	35.6ab	51.15a	23.2b	48a	31.93ab
Control	40.8a	35.18b	44a	26.3b	45a	30.5b
CV	16	16	19	16	19	18
SE	4	2.5	8	2.4	3	2.6
GT	45	41	51	39	49	37
LSD	14	8	30	8	12	9

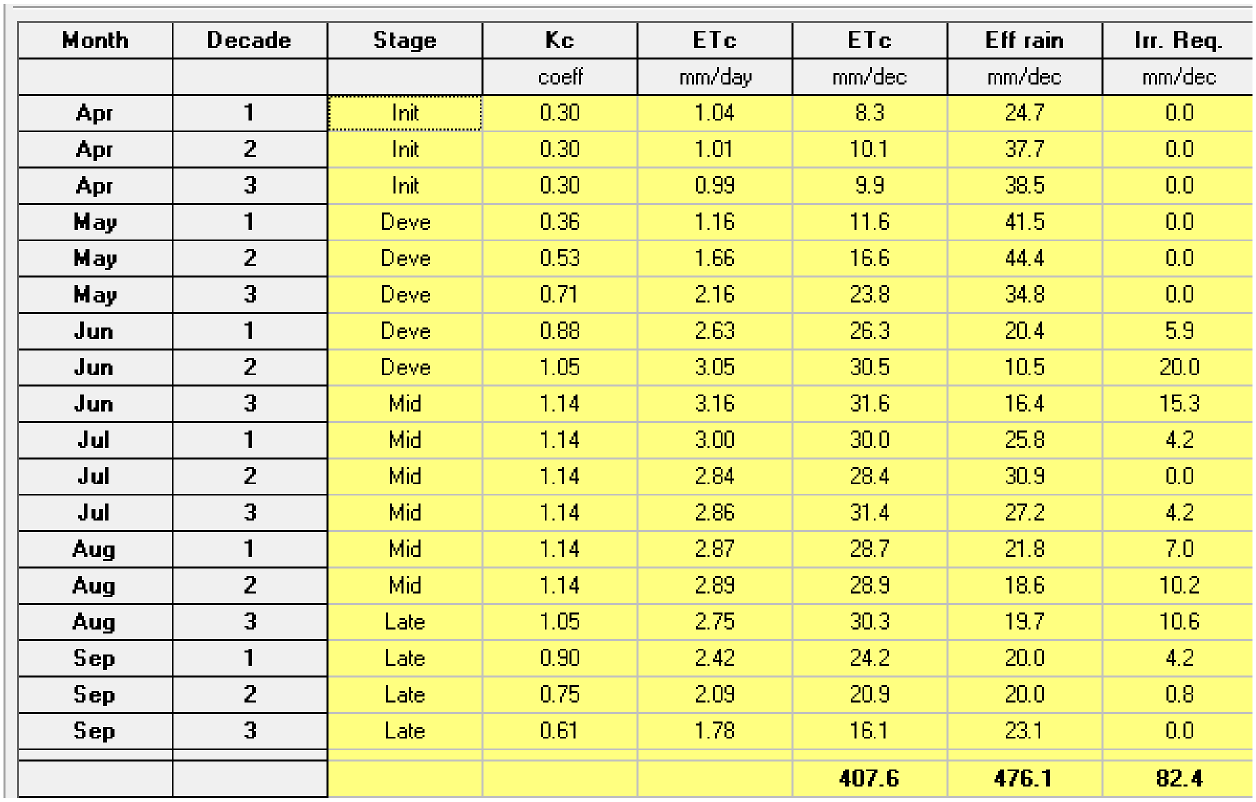
NB:Ta(targa),Tr(tie ridge),Co(control),Za(zai)

Table 3: To compare each structure conserved soil moisture content with maize water requirement in growth stages

Treatment									
	After one day of RF				**After 10 days of RF**				
	Total SMC mm/m rz **Initial**	Readily SMC mm/m rd	Readily SMC at **0.3m** rz	ETc/day	Total SMC mm/m rz	Readily SMC mm/m rz	Readily SMC at **0.3m** rz	ETc/dec	% of crop water need satisfaction at dry spell period
Targa	54.097	29.75	8.92	1.04	51.15	28.13	8.43	10.4	87
Tie ridge	45.5	25	7.5	1.04	43	23.65	7	10.4	72
Zai	42.32	23.2	6.9	1.04	35.6	19.5	5.87	10.4	56
Control	40.8	22.4	6.7	1.04	35.18	19.3	5.8	10.4	55
	Development		**0.86m**				**0.86m**		
Targa	58.9	32.3	27.7	2.63	55.8	30.7	26.3	26.3	100
Tie ridge	54.2	29.8	25.6	2.63	52	28.6	24.5	26.3	93
Zai	51.15	28.13	24.1	2.63	23.2	12.76	11	26.3	42
Control	44	24.2	20.8	2.63	26.3	14.46	12.4	26.3	47
	Mid stage		**1m**				**1m**		
Targa	54.2	29.8	29.8	3.00	46.5	25.6	25.6	30	85
Tie ridge	50.15	27.58	27.58	3.00	42.6	23.4	23.4	30	78
Zai	48	26.4	26.4	3.00	31.9	17.5	17.5	30	58
Control	45	24.75	24.75	3.00	30.5	16.7	16.7	30	55

N:B TAW(total available water),RAW(readily available water),SMC(soil moisture content) ,rz(root zone)
RAW=TAWXP
Where, p is critical depletion /p value of maize is 0.5

Table 4: Maize water requirement and Effective rain fall of the study area



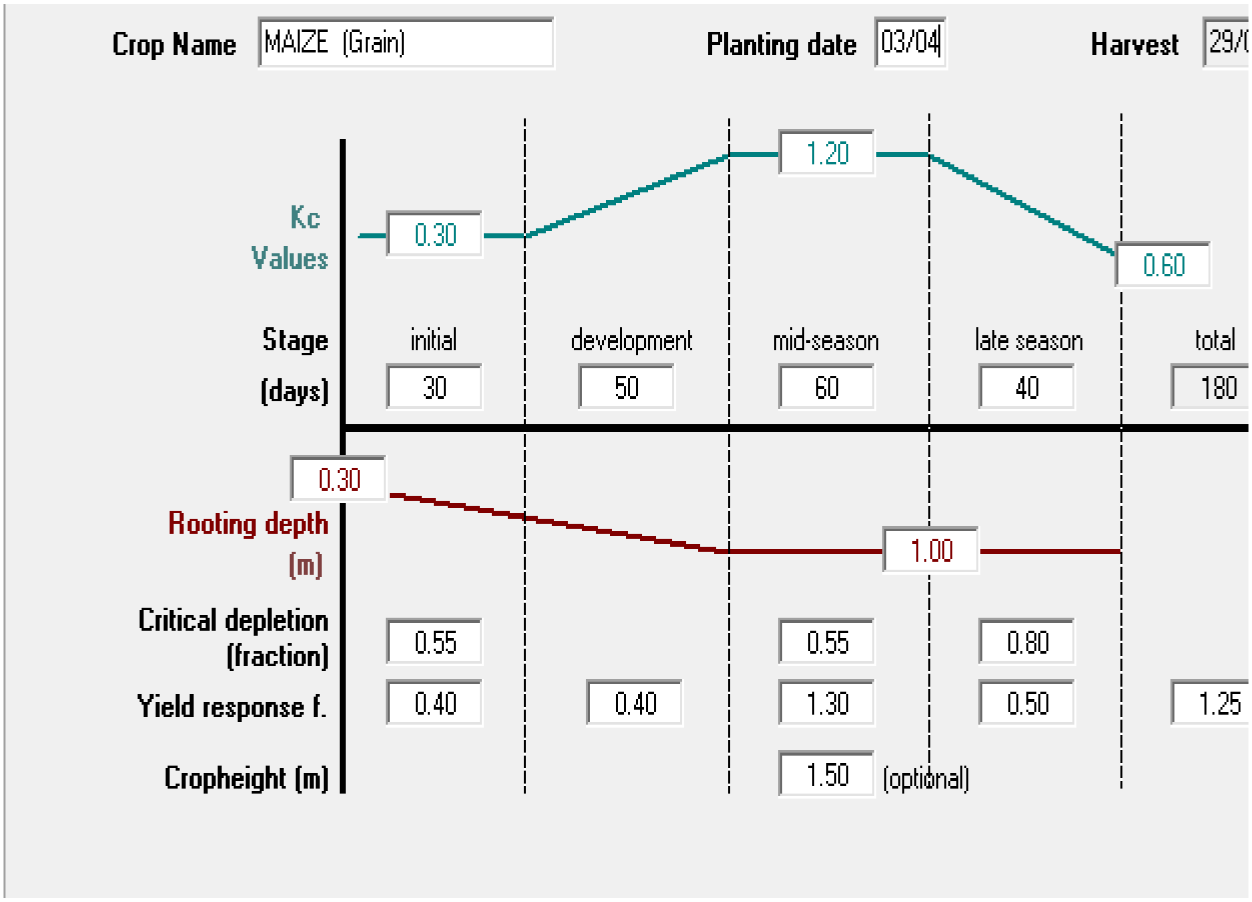
Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	1	Init	0.30	1.04	8.3	24.7	0.0
Apr	2	Init	0.30	1.01	10.1	37.7	0.0
Apr	3	Init	0.30	0.99	9.9	38.5	0.0
May	1	Deve	0.36	1.16	11.6	41.5	0.0
May	2	Deve	0.53	1.66	16.6	44.4	0.0
May	3	Deve	0.71	2.16	23.8	34.8	0.0
Jun	1	Deve	0.88	2.63	26.3	20.4	5.9
Jun	2	Deve	1.05	3.05	30.5	10.5	20.0
Jun	3	Mid	1.14	3.16	31.6	16.4	15.3
Jul	1	Mid	1.14	3.00	30.0	25.8	4.2
Jul	2	Mid	1.14	2.84	28.4	30.9	0.0
Jul	3	Mid	1.14	2.86	31.4	27.2	4.2
Aug	1	Mid	1.14	2.87	28.7	21.8	7.0
Aug	2	Mid	1.14	2.89	28.9	18.6	10.2
Aug	3	Late	1.05	2.75	30.3	19.7	10.6
Sep	1	Late	0.90	2.42	24.2	20.0	4.2
Sep	2	Late	0.75	2.09	20.9	20.0	0.8
Sep	3	Late	0.61	1.78	16.1	23.1	0.0
					407.6	**476.1**	**82.4**

N:B Decade(10days),Kc(crop factor),ETc/mm/day(crop water requirement per day),ETc/mm/dec(crop water requirement per 10 days),Eff. rain mm/dec(effective rain fall per 10 days, Irr.req mm/dec(irrigation requirement per 10 days).

Table above was shown that long term rain fall data of the study area which shown total water requirement of maize throughout growth stage (407.6mm) but ,there was water scarcity during maize growth stages (only rain fall was not satisfy crop water requirement) at mid, development and late stages which requires some of additional water from irrigation

At initial period SMC data taken April one crop water requirement 1.04mm/day after 10days 10.4mm and structures hold Tie ridge(7mm), control(5.8mm),Targa (8.43mm) and Zai (5.87mm). At development period SMC data taken June 1 maize water requirement 2.63mm/day after 10 days 26.3mm and structures hold Targa (26.3mm),Tie ridge(24.5mm) Zai(11mm),Control(12.4mm).

At mid period July 1 maize water requirement 3mm/day after 10 days 30mm but structures hold Targa (25.6mm), Tie ridge (23.4),Zai (17.5mm) and Control (16.7mm).



Crop Name MAIZE (Grain)

Planting date 03/04

Harvest 29/

	initial	development	mid-season	late season	total
Kc Values	0.30		1.20	0.60	
Stage (days)	30	50	60	40	180
Rooting depth (m)	0.30		1.00		
Critical depletion (fraction)	0.55		0.55	0.80	
Yield response f.	0.40	0.40	1.30	0.50	1.25
Cropheight (m)			1.50 (optional)		

Figure 6: Maize crop calendar of the study area

Above figure (4) shown that there was low crop water requirement at initial stage then it become high (peak) at mid stage and down ward (low water requirement) at late stage .

4.2 Effect of water conservation methods on growth rate of maize

Table 5: Mean performance of maize growth parameters under moisture conservation structures

Treatment	GY (Ton/ha)	DMB (Ton/ha)	PH (Cm)	CL (Cm)
Targa	7.15a	8.23a	208a	39.36a
Tie ridge	6.19a	7.8ab	202a	35.26b
Zai	4.5b	5.76c	201a	37.3ab
Control	4.9b	6.15bc	196a	35.5b
CV%	9.4	13	3.9	2.96
SE	0.3	0.54	4.5	0.632
GT	5.68	6.9	201	36.8
LSD(0.05)	1	1.9	15.8	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.

4.3 Plant Parameters

4.3.1 Grain yield

As shown in above Table 5 that grain yield of maize was increased significantly ($p<0.05$) in Targa treatment (7.15ton/ha) followed by Tie ridge (6.19ton/ha), and there Was not significant difference ($p>0.05$) between Zai (4.5ton/ha) and Control (4.9ton/ha) treatment.

However, the treatments of Targa has (7.15ton/ha) and Tie ridge (6.19ton/ha) significant ($P<0.05$) differences in grain yield than the Control (4.9ton/ha). 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 3.67ton/ha and 2.25ton/ha 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

Table (3and 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. Water is very important for crop from germination to maturity ,deficit of water decrease cell division and cell proliferation which generate lower grain yield and fail crop(Duplessis,2003;Mohammad etal.,2015).When soil available water content decrease, number of grain per plant and yield per unit area decline (Mansouri, Modarres, and Saberali,2010).

Through RWH (rain water harvesting) structures determining the production increases through the efficiency of the techniques in conserving rain water 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 Hillel, 1967; Tabor, 1995; Gupta, 1995; Ojasvi et al., 1999;Oweis et al., 1999; Prinz, 2001) stated that micro catchment water harvesting (MCWH) and moisture conservation techniques (e.g., tillage and mulching) are such practices to be used to increase yield of crops (millet, sorghum, corn, wheat, etc.) and tree. Similarly, Barron and Okwach (2005) showed rain water harvesting technique 70% average yield increase from 1100 to1900 kg/ha in semi-arid Kenya. Several studies have shown that on many cases, crop yields are higher when RWH practices are applied (e.g Ellis Jones and Tengberg, 2000), other studies showed that RWH structures such as Tera (Van Disk and Ahmed, 1993) mainly serve to reduce crop failure during dry spells and droughts and thus help to enhanced food security.

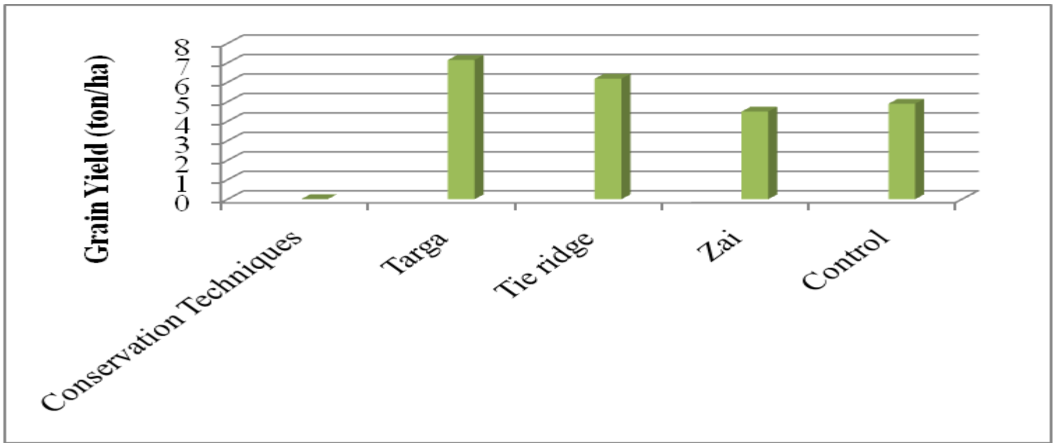


Figure 7: Effect of treatments on grain yield

4.3.2 Dry matter biomass

Biomass yields for different treatments were summarized in Tables (5).Biomass production plays an important role in the grain yield of maize. The detailed statistical analysis for plant biomass yield during the maize growing season is presented in appendix 8. There was significant difference ($P<0.05$) between all treatments on the maize dry matter biomass.

There was significant different ($p<0.05$) Targa, Zai and Control, however, Targa do not differ significantly from Tie ridge and Tie ridge do not significant 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 (Ta), (Tr), (Cr), and (Za). The treatments Targa and Tie ridge had the highest biomass production of 8.23 ton/ha and 7.8ton/ha biomass yield for the maize growing seasons, respectively, than the treatment Control (6.15 ton/ha) and Zai (5.76). The lower biomass production obtained under treatment Zai and control due to in efficiency to conserve moisture during dry spell periods at maize growing seasons as Table above shown .The increase in biomass production of the Targa and Tie ridge treatments would be as a result of high soil moisture available on plant root zone through conserve moisture (reduce runoff and evaporation) during the critical periods like mid period, initial and developmental periods as above Table (4)shown during dry spell periods. The highest biomass production obtained under treatment Targa and the second higher biomass production under Tie ridge treatments. So, these studies agreed with biomass production enhanced by RWH structures studies have mainly been conducted on cereal crops (Singh etal.,1998 such as sorghum(Tabor,1995;Ellis Jones and Tengberg,2000;Kabore and Reij,2004) and maize (Kayombo etal.,2004;Wakindiki and Ben Hur,2004;pretorius etal.,2005).

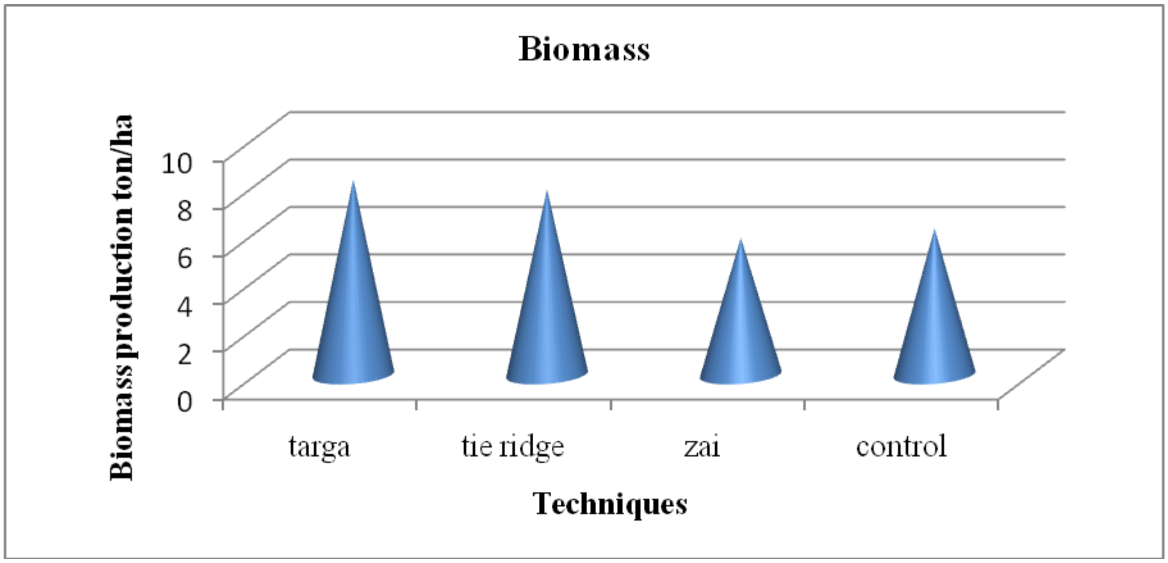


Figure 8: Effects of treatments on dry matter biomass production

4.3.3 Plant height

As can be seen from the Table (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 (Ta), (Tr),(Za) and (Co) 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 (4) .The results agreed with the findings of Elramlawi *et al*. ,(2018) *who* reported that *In situ* water harvesting techniques increased the yields of maize and accompanied with increase of plant height.

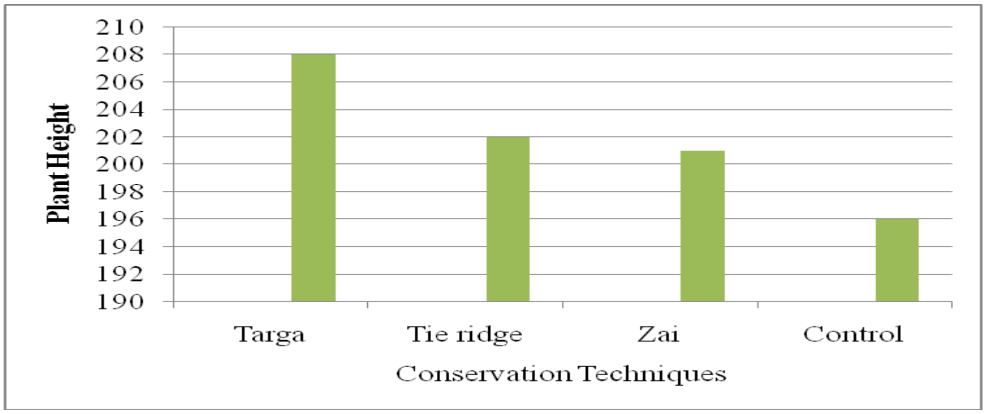


Figure 9: Effects of treatments on plant height

4.3.5 Cob length

As shown in above Table (5) there was significant (p<0.05) difference between treatments Targa , Zai ,Tie ridge and Control. The detailed statistical analysis for cob length during the maize growing season is presented in Appendix 10.

There is no significant (p>0.05) different 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 and (2015) and Yoseph (2014) who reported that maize grain yield and yield components was significantly by moisture conservation practices.

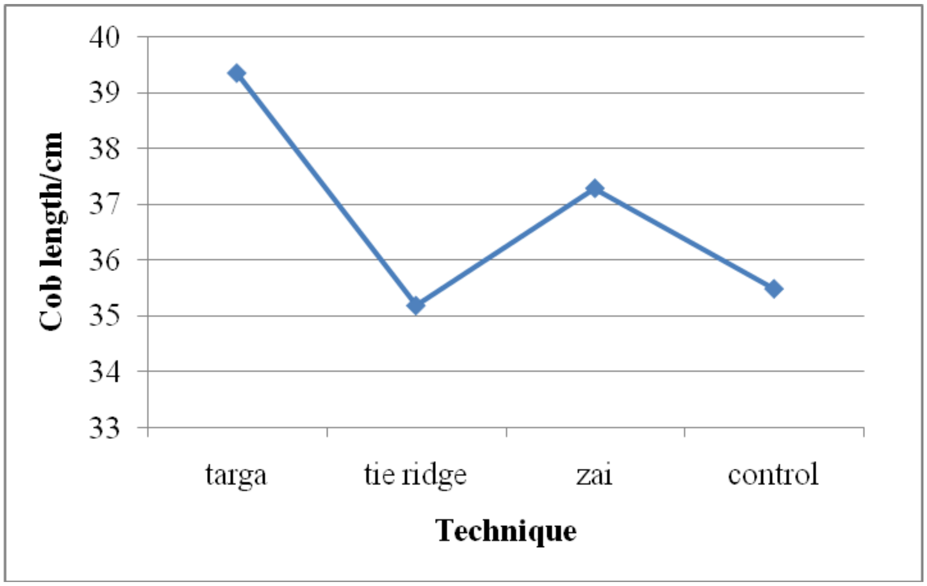


Figure 10: The effects of treatments on cob length

4.4 Economic costs and benefit analysis of treatments

Table 6: Estimated Economic costs per hectare of Treatments

Treatments	Average yield(ton/ ha)	Adjusted yield (ton/ha)	Unit price /kg	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	Benefit cost ratio
Targa	7.15	6.435	7 birr	45045	8833	1000	500	5000	15333	29712	1.93
Tie ridge	6.19	5.571	7 birr	38997	7333	1000	500	5000	13833	25164	1.81
Zai	4.5	4.05	7 birr	28350	7500	1000	500	5000	14000	14350	1.02
Control	4.9	4.41	7 birr	30870	5500	1000	500	5000	12000	20370	1.69

4.4.1 Gross returns

As in above Table (6) shown among the different rain water harvesting techniques, Targa recorded highest gross returns (45045birr ha-1) compared to other conservation methods. The next best was conservation measures Tie ridge by recording higher gross returns (38997birr ha-1) than Control .Control recorded gross returns (30870birr ha-1) and Zai water conservation measures recorded lowest gross return (28350birrha-1) compared to all other treatments.

4.4.2 Net returns

Table 6 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 6. As in above Table shown among the different rain water harvesting techniques, Targa and Tie ridge recorded higher net returns (29712birr/ha-1 and 25164 birr /ha-1) than Control (20370birr/ ha-1) and Zai (14350birr/ ha-1). It means rainwater harvesting system with Targa and Tie ridge has direct effects on crop production and economical benefits over control due to better moisture holding capacity .Which was agreed with the findings Mahapatra *et al.,* (1973) reported that improved water management practices recorded consistently higher net returns over control, due to better moisture conservation measures.

An average of 29712 birr constituting 193% of the total revenue was earned as net revenue per hectare in Targa techniques. An average of 25164 birr constituting 181% of the total revenue was earned as net revenue per hectare in Tie ridge techniques. An average of 20370 birr, constituting 169 % of the total revenue was earned as net revenue per hectare in conventional. This result indicated that Targa *in situ* rain water harvesting techniques by 24% of the total revenue was earned as net revenue per hectare and Tie ridge *in situ* rain water 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 & Barry (2009) rainwater-harvesting systems and the adoption of the rainwater harvesting practices have positive effect on incomes, measured in return to lab our. 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 & Tengberg, 2000).

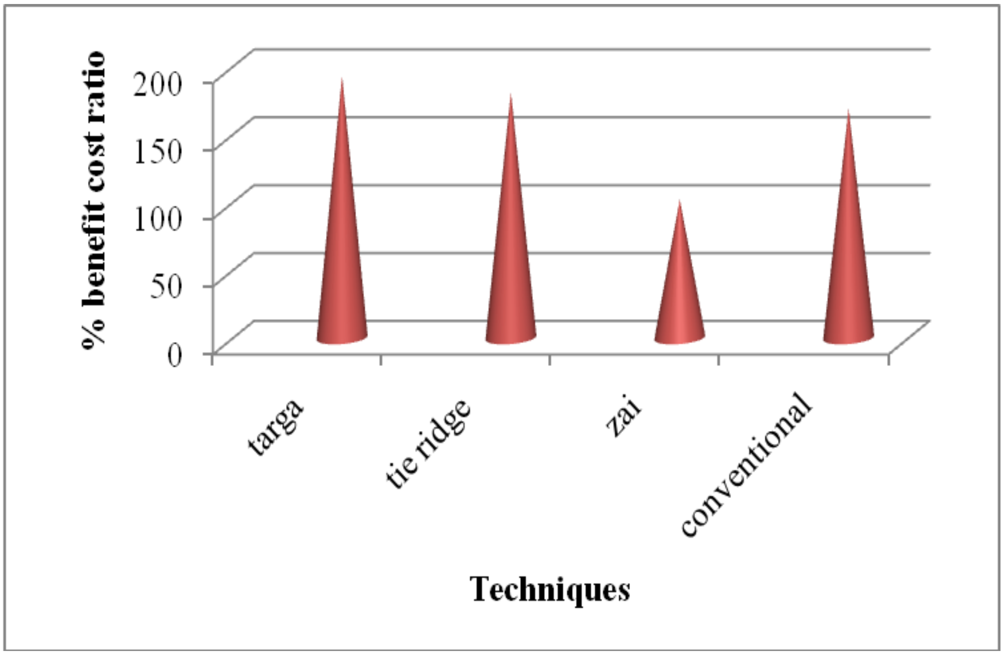


Figure 11: Percent of the treatments benefit cost ratio

4.5 Community perception and its adoption process of rain water harvesting

In order for the rainwater harvesting (soil and water conservation interventions) to succeed in enhancing food security, it was depend mainly on the level of acceptance of the technology and its adoption by the farmers.

Table 7 : Farmers information about water scarcity for crop production of the area

Do you have water shortage for agricultural production	Frequency	Percent
Yes	179	96.7
No	4	2.2
I don't know	2	1.1
Which month(s) of the year is water shortage usually severe in this area in crop production season		
May	37	20.2
June	108	59
July	14	7.7
August	13	7.5
September	11	5.6

Table 7 Indicates that majority of farmers (96.7%) reported that there was shortage of water during crop growing periods. They said that shortage of rain fall during crop growing months were June (59%), July (7.7) , August (7.5%) ,September(5.6%) and May (20.2).

From these months 86.9 % farmers said that May, June and July were the most severe months in water shortage at mid and development period and 13.1% farmers said that at late stage(September and August) . All the farmers argued that the moisture stress presently limiting agricultural production. This situation force farmers to use less water leading to a reduction in agricultural production and the other purposes during these serve months. Majority of the farmers explain the reasons for shortage of rain fall in the area because of forest degradation ,climate change and removal of long indigenous tree which receive rain fall.

In these cause there was shortage of rain fall at crop growing period that cause failure of crop and excess rain fall which lead run off. These findings are agreement with UNFCCC (2002), reported that smallholders‟ farmers who live in the arid and semi-arid lands have long experienced water shortages and drought due to unreliable and poorly distributed rains, which damage crops and livestock.

Table 8: What changes did you see on the water sources of your area as the result of climate change

Farmers perception	Frequency	Percent
Inadequate water	84	46.9
Some water availability	15	8.2
Greater difference in water availability b/n years	83	44.9
Don't know	-	-

Table (8) shows that majority of farmers (44.9%) stated that the effect of climate change on water sources was greater difference in water availability between years,(8.2%)some water availability and (46.9%) stated that less adequate water availability. Climate change disasters can thus negatively affect water resources which are the most important for sustainable development. As a farmer's explanation the changes on water resources were due to climate change leads to long term droughts which make people suffer and spend a lot of energies and time as well as walk long distances to collect water during water scarcity and unavailability. That was associated with more frequent extreme events, with great influence on water supplies, food production and peoples‟ livelihoods .These findings were in consistent with Ngigi (2009) ,who stated that Climate change, population growth, increasing water demand, overexploitation of natural resources and environmental degradation has significantly degraded the worlds freshwater resources. According to UNFCCC (2002), the rains have become more unpredictable since the 1980‟s. This pattern is consistent with arid and semiarid lands was experienced an increase in the frequency and severity of droughts and significant declines in rainfall and river flows due to climate change. Farmers explained climate changes effects most of the areas were characterized by low and erratic rainfall, concentrated in one or two short rainy seasons. This results in high risk of droughts, intra- and off-seasonal dry spells, and frequent food insecurity.

Table 9: Farmers practiced rain water harvesting techniques

Type of water conservation techniques they practiced	Frequency	Percent
Roof water harvesting	—	—
Trapezoidal	—	—
Mulching	33	18
Bund	27	14.8
Inter cropping	58	31.7
None	65	35.5

As presented in the Table 9 (31.7%) of sample households informed that most of the time they practice inter cropping (maize + cowpea) while 18% of households use mulch and (14.8%) bund. The remaining 35.5% of the households were not use any type water conservation techniques. As shown in table large number of the farmers practice inter cropping during dry periods rather than practicing water harvesting techniques because cowpea resist dry periods. The other's who were not practice any type of water conservation activity said that because of lab our shortage and cost problems but they are fully understand about the benefits of the water harvesting techniques.

Table 10: Sources of information about water harvesting techniques

Information sources	Frequency	Percent
Extension officers	120	65.6
Demonstration sites	46	25.1
Newsletters	7	3.8
One-to–one consultation	10	5.5

Results of Table 10 shows that most farmers reported getting information about water harvesting techniques from Extension Officers (65.6%) followed by demonstration sites (25.1%)**,** while minority of the farmers (3.8%) from newsletters and (5.5%) one to one consultation. This result reflects that farmers are more receptive to information passed on Extension Officers and are ready to adopt the technologies, compared to other sources of information. NSIAH (2003), stated that the Extension Officers were the most preferred source of information to the respondents. Moreover, the respondents when asked to indicate one choice of how they would like to receive agricultural information, they overwhelmingly indicated that the Extension Officers were their most preferred source of information NSIAH (2003). This is because in most cases the Extension officers‟ operate as facilitators and communicators helping farmers in decision making and ensuring that appropriate knowledge is implemented to obtain the best results.

Table 11: Constraints that affecting the adoption of rain water harvesting practices

Constraints	Frequency	Percent
Lack of knowledge	44	24
Cost	43	23.5
Crops planted on bunds	31	16.9
Lab our	53	29
Land owner ship	12	6.6

Table (11) Results shown that most of farmers (29%) said that the adoption of rain water harvesting practices affected by labour ,(23.5%) by lack of cost,(24%) by lack of knowledge (6.6%) land ownership and (16.9%) crops planted on bund . Labour was an important factor in rainwater harvesting activities. In construction of structures, utilizing the stored water and making use of the products, labour is necessary. In farm household, labour was highly depending on family size. Family size was an important factor in determining the extent to which labour was available for agricultural work in rainwater harvesting. It is identified that the larger the size of the household, the more availability of lab our for peak period rainwater harvesting activities.

Table 11 the study found that most farmers (29%) lack of labour that influence to implement and subsequent adoption of the water harvesting techniques. This means households with large family size are more likely to utilize the technology since they can compensate costs that the technology demands. This implies that households with large family size have more chance of getting enough labour for rainwater harvesting activities. Some interviewed RWH non-user farmers also stated that they did not use the technology due to the labor shortage in their family to utilize the stored water.

Lab our availability is a factor that is likely to influence the adoption of innovations (Foti *et al*, 2008). From the findings, majority of participants considered the rainwater harvesting technology to be a tedious task and lab our demanding on the construction part especially if they do not receive any form assistant. According to the views of the participants, the labour requirement for the construction was mainly emphasized as a challenge that would affect its adoption. Based on Semgalawe (1998), farmers were reject newly introduced soil and water conservation technologies even when they were aware that adoption of the measures protects and improves productivity of their lands depending on several socioeconomic and institutional factors that can be barriers to technology adoption (Bewet, 2007).

Cost was the second influence (23.5%) on the adoption rate of water harvesting techniques. According to Pachpute et al.,(2009) who stated that lack of resources, including finances, skills, lab our and land, was acknowledged within the literature to be a key constraint to the adoption of RWH by the poorest farmers.

Low-wealth farmers are often reluctant to adopt technologies because they need stable income especially when the returns to adopt are unclear or will only bear fruits in the future (Drechsel *et al.*, 2005).

Among other factors that influence adoption of the techniques, (24%) lack of technical knowledge and skills. Rain water harvesting techniques are more complex in their implementation and need funds as well as the inadequate technical knowledge and skills that the community have about such the techniques.

Hobart (1993) points out that, development projects often fail to succeed in achieving their goals or purpose, due to the fact that indigenous knowledge is diminished by the western scientific knowledge on development (developers knowledge). The issue of acknowledging local knowledge, has been emphasized by development critics because it has potential in contributing to peoples' material intellectual and general welfare. The same applies the same to the principal of participatory development in incorporating people's knowledge in program planning (Cooke& Kothari, 2001). If the local knowledge was included by the development organization it can encourage participation of the people in a particular program or the local people can take control of their own development (Watson, 2009). This was evident based on the findings from the study that during the mobilization and sensitization period the people were not consulted about their views or knowledge when it comes to issues related to water or food security in the location, and how they have been initially coping with water shortage.

It was crucial to the farmers in the community to receive technical and institutional support from the project initiators for them to develop their indigenous practices (Biazin *etal.*, 2012). The lack of support and application methodologies was considered to be one of the negative factors that influence the adoption of rainwater harvesting technologies. Based on Baidu-Forson's study (1999) he indicates that methods to improve adoption of improved soil and water management by the community was to include demonstration of short-term benefits and risk reduction characteristics of the technology and support for dissemination of knowledge on gains from adoption.

Land ownership taken (6.6%) that affect adoption rate of rain water harvesting techniques that indicated that direct willingness to participate and make it effective. This corroborates that issues of ownership and control (land), and as pointed out in FAO (1991) land tenure issues can have a variety of influence on water harvesting practices. Lack of tenure may make people to be reluctant to invest in water harvesting structures on land that they don't formally own. Foti *et al.,* (2008) also pointed out that land ownership is likely to influence adoption if the investments are tied to the land and the benefits of the investment are long term. Feder *et al.*, (1985) indicates that given the uncertainty, the fixed transactions, and information costs associated with innovations, there may be a critical lower limit of farm size, which prevents smaller farms from adopting (Foti *et al.,* 2008).

The other major factors that discourages or slows down the adoption process were crops planted on bund (16.9%) community was that the rainwater harvesting technology was not tailored to meet the community's requirements or needs in the area. FAO (1991) points out that before a specific technique is selected, there should be considerations given to the social and cultural aspects prevailing in the area of concern, as they are vital and will affect the success or failure of so many projects that did not take into account people's priorities. This could be clearly seen from the findings of the case study area, where the community members were not consulted about their priorities on what sort of community development projects they required the most. According to the findings and suggestions made, most of the community participants would have preferred high valued crops like 'maize and beans' to be planted in the bunds, rather than the drought tolerant crops (sorghum, millet and cow peas) as they usually plant them in their normal rain-fed farms. Based on Foti *et al.,* (2008) high valued crops are likely to encourage farmers to invest in soil fertility and water management technologies as they are seen to offer attractive returns to such investments. The growing of drought tolerant crops is likely to have a negative influence on the adoption of techniques due to the low marginal production of such investments.

5. SUMMARY AND CONCLUSION

5.1 Conclusion

The characteristics of agriculture in Humb woreda is predominantly small scale 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 many parts of the woreda that led to food insecurity at household level.

This study revealed that the potential advantages of *In situ* water harvesting techniques on maize yield, yield components, soil moisture and farmers' perception towards rain water harvesting techniques.

The comparative study between the Control, Zai, Targa and Tie ridge showed that the soil moisture, grain yield and biomass for the Targa was consistently higher when compared to the control.

This study has clearly demonstrated that in situ rain water harvesting techniques can play an important role in improving the sustainability of food production by improving soil water storage, crop yields and extending the growing dry seasons. The implementation and adoption of these techniques will, however, require careful planning, community perception about it and to better understanding their choices in making decision to adopt it these indicating that it is important to know how farmers perceive technologies for better understanding of their choices of adoption or not.

5.2 Recommendation

- From IRWH technologies Targa is climate smart technique which contributes to conservation of natural resources (conserve soil moisture, reduces surface runoff water) and increase yield of dry land condition. These water harvesting structures on farmers’ fields have minimum cost , less lab our power required, do not leave much space and simple(no technical knowledge) required at first it was constructed then only maintains required in house hold member provided if small-holder farmers are to adopt them.

- Hence, there is need to disseminate the results of the present study to the end users even though, further research should be carried out to put the recommendation on strong basis. In this regard, Targa structure is recommended as a better solution to solve the problem in water stress and drought prone area to produce maize. It is better to test and scale up this indigenous knowledge of Derashe peoples, found in southern Ethiopia to the areas with a similar agro-ecology.

- By investigating the perceptions of the community towards the rain water harvesting particular focusing the level of adoption and the extent to which socio-economic (such as cost, lab our availability, farmers indigenous knowledge), institutional (such as extension service, etc), physical (such as soil type), and other factors that affect the adoption.

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APPENDIXES

Appendix 1 : Soil moisture content percent at initial period just after one day of rain fall

Source	Df	Ss	Ms	F	P
Treatment	3	317.91	105.97	1.37	0.22
Block	2	59.33	29.6		
Error	6	331.5	55.26		
Total	11	708.74			

Appendix 2: Soil moisture content percent at initial period after 10 days of rain fall

Source	Df	Ss	Ms	F	P
Treatment	3	187	62	2.9	0.011
Block	2	95	47		
Error	6	115	19		
Total	11	397			

Appendix 3: Soil moisture content percent at development period just after one day of rain fall

Source	Df	Ss	Ms	F	P
Treatment	3	148	49	1.87	0.23
Block	2	2004	1002		
Error	6	1382	230		
Total	11	3534			

Appendix 4: Soil moisture content percent at development period after 10 days of rain fall

Source	Df	Ss	Ms	F	P
Treatment	3	1106	368	13.2	0.0035
Block	2	79	39		
Error	6	107	17		
Total	11	1294			

Appendix 5: Soil moisture content percent at mid period just after one day of rain fall

Source	Df	Ss	Ms	F	P
Treatment	3	38	12	0.42	0.82
Block	2	48	24		
Error	6	247	41		
Total	11	333			

Appendix 6: Soil moisture content percent at mid period after 10 days of rain fall

Source	Df	Ss	Ms	F	P
Treatment	3	221	73	18.16	0.015
Block	2	1636	818		
Error	6	22	420.45		
Total	11	1980			

Appendix 7 : The result of maize yield during 2010 crop growing season

Source	DF	Ss	Ms	F	P
Treatment	3	13.26	4.42	9.95	0.0072
Block	2	0.97	0.48		
Error	6	1.71	0.28		
Total	11	15.95			

Appendix 8: The result of maize biomass during 2010 crop growing season

Source	DF	Ss	Ms	F	P
Treatment	3	13.29	4.43	5.84	0.026
Block	2	13.04	6.5		
Error	6	5.4	0.9		
Total	11	31.74			

Appendix 9: The result of maize plant height during 2010 crop growing season

Source	DF	Ss	Ms	F	P
Treatment	3	205	68	2.18	0.18
Block	2	481	240		
Error	6	378	63		
Total	11	1064			

Appendix 10: The result of maize cob length weight during 2010 crop growing season

Source	DF	Ss	Ms	F	P
Treatment	3	32.41	10.8	5.73	0.02
Block	2	1.93	0.96		
Error	6	7.19	1.19		
Total	11	41.53			

Appendix 11: Explanation of rainfall data for the study area of 2007-2017

Year	Jan	Feb	March	April	May	June	July	August	Sep	Oct	Nov	Dec
2007	44.7	44.1	46.7	75.7	210.5	142.9	205.0	289.6	241.1	19.0	8.6	0.0
2008	14.5	19.2	0.0	85.6	139.7	93.3	221.6	179.2	209.8	198.9	169.0	6.7
2009	19.5	5.6	41.3	63.9	199.1	40.4	55.7	43.1	57.5	78.3	19.1	86.8
2010	45.6	56.6	163.3	165.7	285.9	152.7	102.5	150.7	49.8	53.0	11.5	3.3
2011	0.0	9.6	86.8	17.7	247.6	93.3	156.3	177.0	211.6	78.7	147.8	0.0
2012	0.0	0.0	19.3	148.4	77.9	172.0	281.4	230.8	117.5	8.4	73.9	14.1
2013	15.0	0.0	84.7	176.4	241.1	103.0	233.9	111.9	87.8	122.0	56.3	0.0
2014	4.7	19.2	143.0	40.9	71.4	166.6	157.5	135.0	259.1	114.4	50.2	23.2
2015	12.2	0.0	99.7	0.0	158.0	99.1	99.2	49.5	177.1	75.1	114.7	76.4
2016	19.6	51.5	68.9	178.6	210.5	160.7	61.6	61.0	95.1	46.0	35.4	49.8
2017	0.0	2.6	38.1	42.4	163.9	43.5	228.5	189.8	169.2	222.9	52.1	36.6

Appendix 12: The questionnaire

Section 1 Respondent information's

Zone---------------------------Woreda------------------------Kebele--------------------

Name---

Sex: Male------------ Female-------------Age------------------------------

Marital status: ____(1) Single (2) Married (3) Divorced (4)Widowed

Member of household: -------------Male----------------Female ----------------Total-----------

Religion----------Protestant -------Muslim ----------Orthodox-----------

Speaking language---------English ---------Amahric -----------Wolaitgna-----------

Section 2: Farmers perception and current status of water conservation structures survey questions

1. **Do you have water shortage for agricultural production? Yes (   ) no (   ) I don't know (   )**

(A) If the answer is yes**,** when is the shortage season /in the crop growth stage/ planting, mid, late**, ---**

(B) Which month(s) of the year is water shortage usually severe in this area?

Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec

(C) What do you think the reason for shortage---
----

2. Do you believe it is possible to overcome the problem?yes(   ) no (   )

If yes what methods do you know/practice?---

3**. Describe the land preparation:**

A) Methods of cultivation ---

B) Timing of cultivation---

C) Cultivation materials---

D) Crop type--

What are the constraints of practices they are applying?---

What land preparation methods do you know well, but not applying?--------------------------

----

What are the reasons for not applying?---

What are opportunity of practices they are applying?--

-

4. (A) Are you aware of any water harvesting techniques? yes ( ) no ( )

(B) If the answer to 4 (a) above is yes, which water harvesting techniques are you aware of?

Water dams [ ], Water tanks [ ], roof water harvesting [ ], earth dams [ ],

Runoff water harvesting [ ], others (Please specify) [ ]

(C) Of the techniques mentioned in 4 (B) above, which one are you practicing on your farm land and why?

Technique	**Why practiced**

5. What types of options you are used during dry periods for crop production?

A) Rain water harvesting structures

B) Drought tolerant crops

C) Irrigation

D) None

6**. Farmers perception about the result of climate change on water sources**

A) Less adequate water availability

B) Same water availability

C) More water availability

D) Greater difference in water availability between years

E) Don't know

7. **Barriers to you implementing water conservation measures in your farm land**?

A) Lack of knowledge

B) Cost

C) Time commitment

D) Not personally interested

E) No barriers

9. **Ways you prefer to learn about water conservation technique on your farm lands**

A) Extension officers

B) Demonstration sites

C) Educational courses

D) Newsletters

E) One-to–one consultation

10. **What is farmer perceived priority production problem, preferred area for water conservation structure and which factor affect the preferences for alternatives?**

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11. **Is moisture stress presently limiting agricultural production?**

A) Yes

B) No

C) I don't know

D) If there is limitation how do know about it

E) What methods do you know to overcome the problem?

12. **Is the present agricultural water sources are enough for crop production**

    A) Yes

    B) No

    C) I don't know

    D) If the answer is yes how many sources do you have?

13. **What are factors affecting adoption of water conservation practices**

    A) Personal factors/education, family size

    B) Socioeconomic (farm land and livestock holding)

    C) Institutional (visits by development agents, support, training, land tenure

    D) Bio physical (flat, steeper and very steep)

15. **Effect of rain water harvesting techniques on crop yield in response to different Rain fall patterns**

    A) High

    B) Low

    C) No response

    D) I don't know