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MAXIMIZING MAIZE HARVESTS: ASSESSING THE IMPACT OF IN-SITU MOISTURE CONSERVATION TECHNIQUES IN DUGDA WOREDA, ETHIOPIA

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Abstract: Agriculture in Ethiopia, predominantly reliant on rainfed practices, faces significant challenges characterized by low productivity levels. The country's average annual grain production, standing at 7 million tons, falls below the threshold required to meet the demands of the growing population (Eyasu, 2005). This inadequacy in productivity is exacerbated by the seasonal and erratic nature of rainfall in the dry lands of Ethiopia, leading to moisture stress and hindering the potential of rainfed agriculture in these areas (Haregeweyn et al., 2005).The persistent moisture stress poses a critical limitation to agricultural productivity, particularly in regions where rainfed farming is the primary mode of cultivation. As a consequence, the nation grapples with the challenge of meeting its food demands, leading to increased food deficits. Addressing these challenges requires a comprehensive understanding of the dynamics of moisture stress and the implementation of effective strategies to enhance rainfed agriculture's resilience in moisture stress-prone regions.This research aims to delve into the multifaceted impacts of moisture stress on rainfed agriculture in the dry lands of Ethiopia. By synthesizing insights from existing studies (Eyasu, 2005; Haregeweyn et al., 2005), the study seeks to identify and propose viable solutions to mitigate the adverse effects of moisture stress. The overarching goal is to contribute knowledge that can inform the development of strategies and interventions aimed at bolstering the productivity of rainfed agriculture, fostering food security, and promoting sustainable practices in Ethiopia.
Keywords: Agriculture, Rainfed Farming, Moisture Stress, Food Deficit,Sustainable Practices

INTRODUCTION

Agriculture in Ethiopia is dominated by rain fed farming with low productivity. The average annual grain production of 7 million tons is too low to support national food demands (Eyasu, 2005). Since rainfall is seasonal and erratic in dry lands of Ethiopia, there is moisture stress limiting the productivity of rain fed agriculture in the moisture stress areas (Haregeweyn et al., 2005). Food deficit in the whole of the country, dry land areas in particular is increasing mainly due to drought and moisture deficit (Kidane and Abuhay, 2000). Maize was ranked as the third place cereal consumed in the world after wheat and rice (Olaniyan, 2015), and the first yielded and productive cereal (FAOSTAT, 2015). It is an important food crop in sub-saharan Africa, 300 million people in sub-Sahara Africa consider maize as a primary source of food and livelihood (Macauley, 2015). It occupied 17% of cultivated land (FAOSTAT, 2015) and 21% in East Africa (Ndlovu, 2013). While most of sub Saharan Africa; maize production is based on rain fed systems (Gebrehiwot and Gebrewahid, 2016), there is a need to find out the alternative soil moisture conservation strategies to mitigate moisture deficit effect. Moisture stress is a prolonged period of short precipitation resulting in water deficiencies and lack of soil moisture to support crop production (Solh and van Ginkel, 2014). It is a great hazard in the world which frustrate the productivity of agricultural crops (Aslam et al., 2015). Every year there is a loss of 25% crop yield globally caused by severe drought (Bankole et al., 2017) and 36 million people in sub Sahara Africa are experiencing severe food shortage because of the drought and shortage of moisture in soil profile (Nazareth, 2016; Water Aid, 2017). Low agricultural productivity in semi-arid region is not only due to land degradation, but also due to moisture deficit (Gebreegziabher et al., 2009). A study by Mekuria and Waddington (2004) noted the moisture stress being the major limitation to crops yield in cereal based cropping systems in Eastern and Southern Africa. Moisture retention structures plays a vital role for successful and sustainable crop production. Therefore, planting crops using in situ moisture conservation reduces problems of soil moisture stress by reducing runoff through increased infiltration and storage of water in the soil profile, the onset and occurrence of severe water stress is delayed thereby buffering the crop against damage caused by water deficits during dry periods (Nyamadzawo et al., 2013). In these regards using tied ridge and furrow closed at both end are some of the methods that contribute to mitigate soil moisture deficit and enhance maize productivity in semi-arid and arid areas. In East Shewa of Ethiopia, high moisture deficit is the primary problem which highly constrain the productivity of small holders' farmers of the Woreda (priority problems raised by farmers). In moisture scarce environments like Central Rift valley in general, particularly Dugda Woreda crop would face shortage of moisture available in the soil throughout the growing season. The major problem in this study area is unavailability of in situ moisture conservation techniques (Agricultural Production Constrain Analysis in East and North Shewa Zone, Oromia, Ethiopia, unpublished, 2017). Also the distribution of rainfall is not sufficient to sustain crop growth and development in the study area. Accordingly, crop frequently suffers from moisture stress at some stage during its growth period with the ultimate result of reduced yield from their farmland because of shortage or uneven distribution of rainfall and absence conserving surface runoff within the catchment. There is currently no sufficient research works on evaluating the effectiveness of in situ moisture conservation techniques on improving maize yield in Dugda Woreda. Hence, the utilization of in situ moisture conservation structure is critically important to increase crop yield and improve food security.

General objectives

The general objective is to investigate the effects of *in situ* moisture conserving techniques on maize yield and relevant treatments in improving production in the study area.

Specific objectives

The specific objectives are to evaluate the impacts of *in situ* moisture conserving techniques on maize yield and to recommend relevant treatments with a view to improve the yield of maize.

MATERIALS AND METHODS

Description of study area

The field experiment was conducted at Dugda Woreda which is found in East Shewa zone of Oromia regional state. It is located at a distance of 140 and 95 km from Addis Ababa and Adama, respectively. Geographically, it is situated in the central rift valley between 8 ⁰02'59" North latitude longitude respectively. Its elevation is 1600 meters above sea level (masl). The total annual rainfall and minimum and maximum temperature of the study area for 2018 cropping season is 795 mm, 13.6 and 29.2°C respectively. The dominant soil type of the study area is sandy loam soil (Figure 1).

Experimental design and treatments

The experiment was conducted for a period of one year (2018) at the three selected kebeles of Duda Woreda under rain fed condition on farmers' farmland, to investigate the effects of in situ moisture conservation on maize yield and yield components. The three kebeles of study area were selected purposively on the basis of its maize production and moisture deficit. The two farmers for each kebele were selected purposively based on their willingness and recommendation by woreda agricultural expert and Development agent (DA) for conducting experiment. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Three levels of treatments (Farmer practice(control), Furrow Closed at both End and Tied ridge) were used and conducted on similar slope. Each treatment was applied on a plot size of 10 m x 10 m (100 m^2) separated by a distance of 1 m between blocks and 1 m within plots. The height of ridge and tie was 30 cm and 20 cm, respectively. Maize was planted at spacing of 25 cm between plant and 75 cm between plots. The BH-540 maize variety was used as testing crop.

Preparation of *in situ* moisture conservation structures

All experimental plots were ploughed three times by oxen plough using the local maresha before imposing any of the treatments. In tied ridging, ridge furrows are blocked with earth ties at 3.3 m distance apart from one another to form a series of micro catchment basins in the field. The furrow was closed at both end at spacing of 10 m. The tied ridge was prepared by hand hoe. The tied ridge was prepared after planting maize crop. The structure preparation and status of maize crop was illustrated in Figure 2.

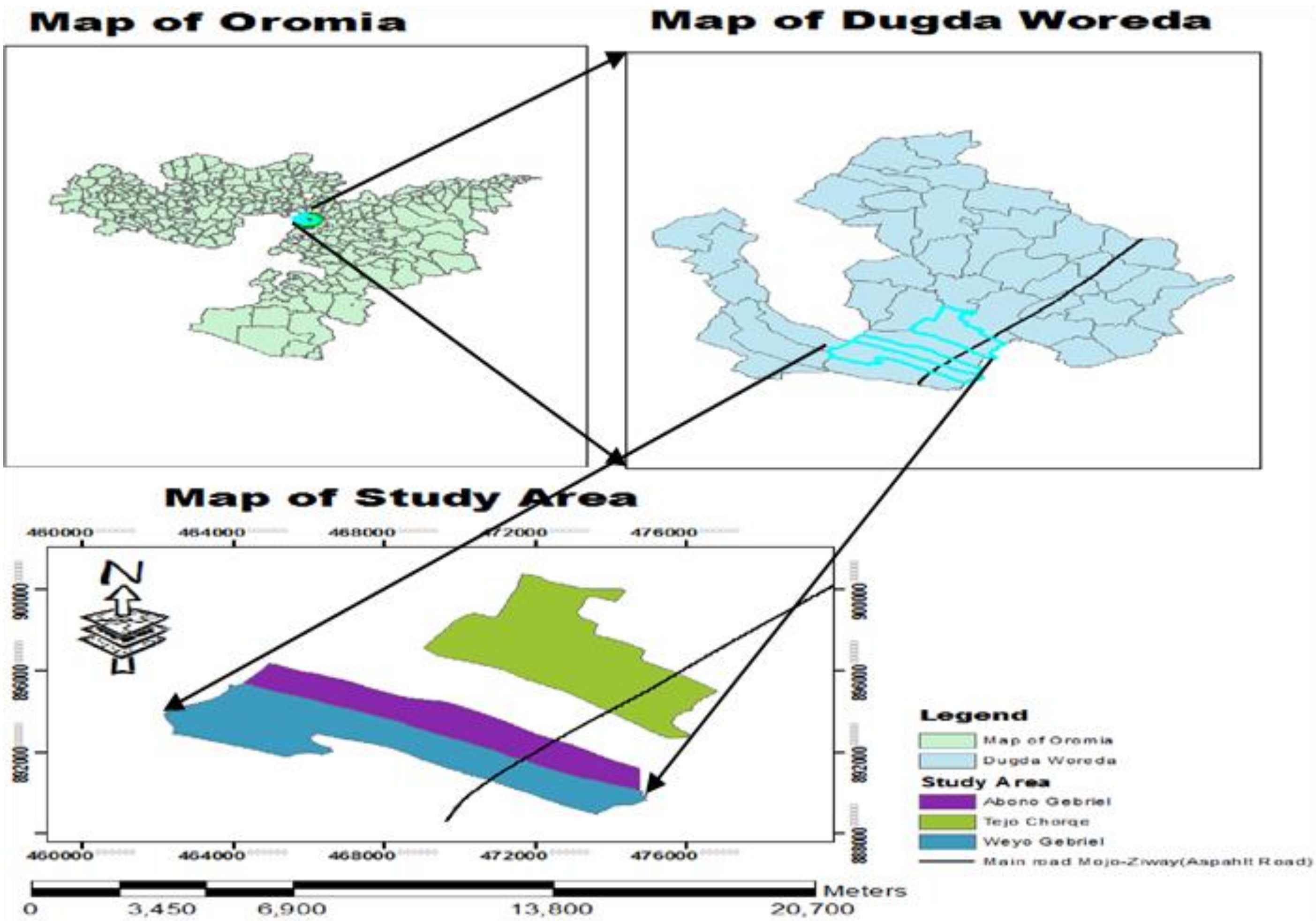

Figure 1. Map of study area.

Farmer Research Extension Group (FREG) establishment and min field day

The selected farmers were organized under Farmers Research Extension Group (FREG) to increase farmers awareness on in situ moisture conservation structures in view of improve maize yield in moisture deficit area. Three Farmers Research Extension Group (FREG) members were established one at each kebele's. Each FREG members were held; 15 farmers and a total of 45 farmers participated in the project; from this, 40% of them were women and 60% of them were men; household farmers participated on min field day and became aware of the importance's of in situ moisture conservation structure. Two (2) subject matter specialist (SMS) from Woreda Agriculture and Natural Resource Bureau and six (6) Development Agents (DAs) participated in min field day (Figure 3). The directly benefited farmers played the role of information sharing to other farmers, recording and providing information and taking an active participation in all the way from site selection, construction of *in situ* moisture conservation to harvesting. The researchers explained the whole process and discussions were made in response to the queries raised from the farmers and experts. The raised issues during min field day were uneven distributions of rainfall and crop in the study area deteriorate due to moisture stress problems and also the importance of using *in situ* moisture conservation structures in improving crop yield in the study area. In general, the farmers were convinced by the technology and some of them made a decision to construct *in situ* moisture conservation structures on their own land in the future. Moreover, field day were organized for further demonstration purpose.

Data collection

Measured parameters includes plant height, yield per hectare, plant stand counts at harvest per hectare, number of cobs per hectare, thousand weight of seeds and yield advantage. The plant height was recorded by taking the random five plants from the central three rows of the net plot area (2.25 m × 10 m) of each plot. Yield was recorded from the central three rows of the net area of 2.25 m × 10 m by excluding the border rows. Yield per plot was recorded from air-dry weight of seeds of the net plot area (2.25 m × 10 m) and expressed as ton ha-1. The plant stand counts and number of cobs (heads) per hectare were determined by counting the number of plants in the net area for the three rows (2.25 m × 10 m). Thousand weight of seeds was determined by counting thousands seed dry seeds and their weight are recorded in grams. The yield advantage (%) of using moisture conservation structure is calculated using the following equation and analyzed using descriptive statistics

Figure 2. Preparation of in situ moisture conservation structure (a) and status of maize crop (b).

$$\text{Yield advantages } (\%) = \frac{\text{Yield with structure} - \text{Yield without structure}}{\text{Yield without structure}} * 100 \quad (1)$$

Data analysis

The R analytical software version 3.5.2 was used to analyze the data. Analysis of Variance (ANOVA) was used to determine effect of the in situ moisture conservation structure method on yield and yield components parameters of the maize. Mean separation least significant difference (LSD) was used to compare and separate treatment means at 5% probability level.

RESULTS AND DISCUSSION

Grain yield

The grain yield was highly significant (P < 0.001) to *in situ* moisture conservation (tied ridge and furrow closed at both end) techniques. The mean yield indicated in Table 1 revealed that grain yield was significantly increased on tied ridge as compared to farmer practice. And the mean yield of maize significantly increased on furrow closed

Figure 3. Min-Field day at Dugda woreda,2018 crop season.

Table 1. Mean yield and yield components of maize as affected by tied ridge and furrow closed at both end.

Treatment	Plant height (cm)	Stand count at harvest/ha	Number of cobs/ha	Yield (tonha^{-1})	1000 seed weight(g)	Yield advantage (%)
TR	214.51[a]	74,675[a]	74,675[a]	8.922[a]	410.83[a]	**45.5**
FCE	213.79[a]	71,500[a]	71,500[a]	8.013[a]	370.73[a]	**30.68**
FP	211.05[a]	62,750[a]	62,500[a]	6.132[b]	290.47[b]	
Mean	213.12	69,641.67	69,558.33	7.689	357.34	
CV (%)	8.4	20	19.99	17.5	13.61	
LSD	>0.8556[ns]	>0.0618[ns]	>0.0565[ns]	3.211e-08***	1.85e-09***	

Treatment values within a column followed by the same letter are not significantly different at 0.1%. TR: Tied Ridge; FCE: Furrow closed at both End; FP: Farmer Practies; CV: Coefficient of variation; LSD: Least of significance Difference; * and *** level of significance at P<0.05 and P<0.001 respectively and ns = not significant difference.

at both end as compare to farmer practice. The higher grain yield of maize obtained from the structure of tied ridge is attributed to the greater infiltration and storage of water in soil; which gives plants ample time to take up the stored water as compared to the farmer practice. This finding agrees with many researchers Heluf (2003), Gebreyesus (2004) and Taye and Yifru (2010) had also reported the importance of tied ridge is increasing crop yield by increasing the time for the water to penetrate into the soil. Similarly, Solomon (2015) reported that the grain yield of early maturing maize varieties was significantly affected by in situ moisture conservation practices. The recorded maximum yield from the tied ridge might be attributed to the efficiency of tied ridge to conserve and retain moisture when compared to the other moisture conservation practices. This result is also in conformity with the findings of Mudalagiriyappa et al. (2012) who reported that the increased yield of maize could be attributed to the reduced surface runoff and reduced risk of erosion and soil nutrients and to increased water holding capacity of the soil in *insitu* moisture conservation structure. But, there was no significant differences ($p > 0.05$) in yield between the tied ridge and furrow closed both end techniques (Table 1).

Plant height, stand count and number of cobs per hectare

There were no statistically significant differences ($p > 0.05$) between treatments concerning plant height (cm) and stand count and number of cobs per hectare (Table 1).

Thousand seed weight

The thousand seed weight were highly significantly ($p < 0.001$) difference on tied ridge and furrow closed at both end as compared to farmer practices (Table 1). This implied that *in situ* moisture conservation structures improve thousands seed weight by retaining surface runoff and increase infiltration within the catchment. In fact, the seeds which were supplied with adequate moisture did mature well to have heavier seed weight than farmer practice. This could be attributed to the fact that the relatively higher soil moisture accumulated in the furrows and ridges of the tied ridging system permitted late maturity of the crop and as a result giving enough time for the maize plant to develop their seeds properly with adequate and continued moisture supply. A result reported by Gebreyesus (2004) on the effects of *in situ* soil moisture conservation on thousand seed weight was similar with the findings of this study. But, there was no significant difference ($p > 0.05$) in thousands seed weight between the tied ridge and furrow closed both end techniques (Table 1).

Plant height

The highest and least plant heights of 214.51 and 211.05 cm were obtained from tied ridge and farmers' practice, respectively (Table 1). The furrow closed at both end had better plant height than farmer practices. But statistically, there was no statistically significant difference between the treatments regarding plant height. The mean of plant height on tied ridge and furrow closed at both end were better than farmer practice; this could probably be as a result of the merits of these structures (tied ridge and furrow closed at both end). Within this study; tied ridge and furrow closed at both end relatively gave high plant height as compare to farmer practices due to high efficiency in moisture retention capacity.

Yield advantages over farmer fractice

The grain yield and thousand seed weight advantage of 45.5% (2.79 ton ha^{-1}) and 41.43% were obtained from tied ridge over the farmers' practice, respectively. Also the yield and thousand seed weight advantages of 30.68% (1.88 ton ha^{-1}) and 27.63% were obtained from furrow closed at both end respectively (Table 1). This implies that the two structures have a capacity to retain more surface runoff within catchment and infiltrate in soil than farmer practice. This could be attributed to increase grain yield and thousand seed weight in study area; and this result agrees with the previous findings of Heluf and Yohannes (2002) who reported that, tied ridge, has resulted in yield increments of 15 to 50% on maize and yield increment of 15 to 38% was recorded for sorghum on different soil types of eastern Ethiopia. Similarly, Jensen et al. (2003) stated that maize grain yield with tied ridging in year with dry to near normal rainfall was improved by 42% even without any nutrient inputs while the seasonal average runoff was between 5 to 9% in the plots with water conservation and 16 to 30% in the plots without water conservation. Also Araya and Stroosnijder (2010) and Walker et al. (2005) have stated that single interventions through water conservation could improve crop yield by up to 50% in arid and semi-arid regions of sub-Saharan Africa. Thus, practicing *in situ* moisture conservation structures is imperative and positively increase significance difference in grain yield and thousand seed weight in moisture deficit area.

Summary

In situ moisture conservation techniques at farm level are essential options for the moisture deficit area of Dugda woreda for improving yield through better soil water storage. Tied ridge and furrow closed at both ends were the paramount practice because of its high mean grain yield and thousand weight seed response. From all treatments, tied ridge gave higher mean yield and thousand seed weight advantages than farmers practices in study area. Similarily, furrow closed at both end gave high mean yield and thousand seed weight advantages than farmer's practices in study area. The grain yield and thousand seed weight were highly significantly ($p < 0.001$) difference on tied ridge and furrow closed at both ends as compared to farmer practices. This implies that the grain yield and thousand seed weight increased significantly according to the availability of water in the treatments. Thus, practicing in situ moisture conservation structures is imperative, and positively increase significance difference in grain yield and thousand seed weight in the study area. Therefore, it could be concluded that ensured soil moisture availability through the use of in situ moisture conservation structures can increase maize production in the study area and similar agro-ecology.

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings obtained from one cropping season, the farmers were advised to use tied ridge first recommendation and furrow closed at both end as the second options to increase maize productivity in the study area. Therefore, *in situ* moisture conservation (tied ridge and furrow closed at both end) structures should scale up on wider areas of similar agro ecology to assure food security of the country, particularly in Dugda woreda. There is need to disseminate the results of the present study to the end users (Farmers, subject matter specialist, DAs and others stakeholder). The future study should focused on integration of *in situ* moisture conservation with mulching on yield and yield components in the study area and similar agro ecology.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Aslam M, Maqbool MA, Cengiz R (2015). Drought stress in maize (*Zea mays* L.): effects, resistance mechanisms, global achievements and biological strategies for improvement. Springer.

Araya A, Stroosnijder L (2010). Effects of tied ridges and mulch on barley (Hordeum vulgare) rainwater use efficiency and production in Northern Ethiopia. Agricultural Water Management 97:841847.

Agricultural Production Constrain Analysis in East and North Shewa Zone Oromia, Ethiopia, Unpublished, 2017.

Bankole F, Menkir A, Olaoye G, Crossa J, Hearne S, Unachukwu N, Gedil M (2017). Genetic gains in yield and yield related traits under drought stress and favorable environments in a Maize population improved using marker assisted recurrent selection. Frontiers in Plant Science 8(808).

Eyasu Y (2005). Development and Management of Irrigated lands in Tigray, Ethiopia. PhD Thesis, Department of Water Engineering, UNESCO-IHE Institute for water Education Delft, The Netherlands. FAOSTAT (2015). Food and Agriculture Organization of the United Nations Statistical Database. Rome Italy: Pocketbook.

Heluf G, Yohannes U (2002). Soil and water conservation (tied ridgesand planting methods) on cultivated lands: The case of eastern Ethiopian; Soil and Water Management Research Program, Alemaya University (AU) 154 p.

Heluf G (2003). Grain Yield Response of Sorghum (*Sorghum bicolor*) to Tied Ridges and Planting Methods on Entisols and Vertisols of Alemaya Area, Eastern Ethiopian Highlands Journal of Agriculture and Rural Development in the Tropics and Subtropics 104(2):113-128.

Gebreegziabher *T*, Nyssen J, Govaerts B, Fekadu G, Mintesinot B, Mitiku H, Deckers J (2009). Contour furrows for *in situ* soil and water conservation, Tigray, Northern Ethiopia. Soil and Tillage Research, 103:257-264.

Gebrehiwot KA, Gebrewahid MG (2016). The need for agricultural watermanagement in sub-Saharan Africa Journal Water Resources and Protection 8(1):835-843.

Gebreyesus BT (2004). Tied Ridging as In-situ Rainwater Harvesting Methods for Improving Sorghum Yield at Abergelle Area, Tigray Regional State. An M.sc. Thesis submitted to Haremaya University.

Haregeweyn N, Poesen J, Verstraeten G, De Vente J, Govers G, Deckers S, Moeyersons J (2005). Specific sediment yield in Tigray-Northern Ethiopia: Assessment and semi-quantitative modelling. Geomorphology 69, 315-331.

Jensen JR, Berhard RH, Hasen S, MulchingDonagh J, Moberg JP, Nielsen NE, Nordbo E (2003). Productivity in maize based cropping systems under various soil water management strategies in a semi-arid, alfisol environment in East Africa. Agricultural Water Management 59:217-237.

Kidane G, Abuhay T (2000). A Manual for Semi-arid Areas of Ethiopia: Resource Base, Constraints and Improved Technologies for Sustainable Agricultural Production, mimeo. EARO, Addis Ababa, Ethiopia

Macauley H (2015). Feeding Africa, Cereal Crops: Rice, Maize, Millet, Sorghum, Wheat pp. 1-36.

Mekuria M, Waddington S (2004). Institutional and Policy Support Is Essential to Promote the Adoption of Soil Fertility Technologies on Maize-Based Smallholder Farms in Southern Africa. Proceedings of the 4th International Crop Science Congress, Brisbane.

Nazareth V (2016). Evaluating conservation agriculture and its adoption potential in developing countries (Master Dissertation). University of Florida

Ndlovu E (2013). Impact of tree species on maize productivity by smallholder farmers in eastern Kenya (Master Dissertation). Kenya: Jomo Kenyatta University.

Nyamadzawo G, Wuta M, Nyamangara J, Gumbo D (2013).

Opportunities for optimizing in field water harvesting to cope with changing climate in semiarid smallholder farming areas of Zimbabwe. Springer plus 2:1-9

Olaniyan AB (2015). Maize: Panacea for hunger in Nigeria.African Journal of Plant Science 9(3):155-174.http://dx.doi.org/10.5897/Ajps2014.1203.

Solh M, van Ginkel M (2014). Drought preparedness and drought mitigation in the developing world's drylands.Weather and Climate Extremes 3(1):62–66.

Solomon T (2015). On-farm verification of the effects of selected soil moisture conservation techniques on yield and yield components of early maturing maize varieties at Bako, western Ethiopia. International Journal of Advanced Earth Science and Engineering 4(1):254-264.

Taye B, Yifru A (2010). Response of maize (*Zea mays* L.) to tied ridges and planting methods at Goro, Southeastern Ethiopia. American-Eurasian Journals if Agronomy 3(1):21-24.

Walker S, Tsubo M, Hensley M (2005). Quantifying risk for water harvesting under semiarid conditions. Part II. Crop yield simulation. Agricultural water management *76*:94-107. Water Aid (2017). Wild water: The state of the world's water 1(24):1-24.