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Soil Fertility Management Research

Quality Analysis and Ranking of Vermicompost Obtained From Different Plant Materials and Animal Wastes in Terms of Their Major Plant Nutrient Contents

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Abstract

The study was conducted at Bako Agricultural Research Centre (BARC) during 2015 – 2016 E.C.The experiment was designed to characterize vermicomposts prepared from residue of main crops in the area and animal wastes in terms of major plant nutrient composition in order to identify the best quality compost. Fourteen types of bedding and feed materials combination were used as a treatment which was transformed in to vermicompost after 3 months to give uniform humus like loamy material. Laboratory analysis of the vermicompost for its chemical property and nutrient composition revealed that unlike the pH value of conventional compost which falls in alkaline array detrimental to growth of plants, the pH values of all type of vermicompost were found in suitable range for plant growth. In terms of organic carbon, CN ratio and total nitrogen content, all types of vermicompost has out smarted the conventional compost significantly. The vermicompost obtained from the combination of Maize Stover, Niger seed residue and sheep manure as well as that produced from combination of Soybean residue, Niger seed straw and Sheep Manure have shown higher value of 2.42%.. However, these types of vermicomposts were found to be very poor in other primary and secondary plant nutrient elements. With regard to other plant growth limiting nutrients the vermicompost produced from soybean residue and cattle manure scored a higher value in total phosphorus, total potassium and total magnesium. The result of this study indicated that in spite of supplying other macro and micro nutrients needed for plant growth, 4.64 tons of this vermicompost can replace the recommended amount of urea(200kg) in terms of nitrogen which at the same time supply 139 kg of DAP(64.49 kg P_20_5), an amount which exceeds the blanket recommended dose of phosphorus for maize. Thus, by virtue of the accessibility of raw materials, simplicity of its production and better availability of the nutrient contained in it to the plant, utilizing the vermicompost of soybean straw and cattle manure has a paramount importance in enhancing crop productivity and improving soil fertility.

Keywords: Soil fertility, Vermicompost. Feed stock, *Eisenia foetida*, Nutrient content, Agro chemicals

Introduction

Tropical soils are deficient in all necessary plant nutrients on the one hand and large quantities of such nutrients contained in domestic wastes and agricultural byproducts are wasted on the other hand. It is estimated that in cities and rural areas of developing countries million organic wastes are generated annually which is either burned or land filled (Gandhi*et al*,1997)

The extensive use of chemical fertilizers leads to loss of soil fertility due to imbalanced use of fertilizers that has adversely impacted agricultural productivity and causes soil degradation. Now there is a growing realization that the adoption of ecological and sustainable farming practices can only reverse the declining trend in the global productivity and environment protection (Aveyard 1988, Wani and Lee 1992, Wani*et al*. 1995).

In maintaining soil fertility through natural nutrient cycle, composting of organic materials and returning it back to the soil is a common activity in developed nations (Peter*etal*., 2000). Composting is a technology for recycling organic materials in order to achieve enhanced agricultural production.

Vermicompositing appears to be the most promising as high value bio-fertilizer which not only increases the plant growth and productivity by nutrient supply but also is cost effective and pollution free. Vermicompost can be described as a complex mixture of earthworm feces, humified organic matter and microorganisms, which promotes soil aggregation and stabilizes soil structure improving the air- water relationship of soil, when added to the soil or plant growing media, increases germination, growth, flowering, fruit production and accelerates the development of a wide range of plant species (Ndegwa, *et al*, 2001)..

Vermicomposting is faster and less labor intensive than traditional composting methods, requires less space, and creates little odor. It is a promising biotechnology for many waste management applications and is an easy way to make a positive environmental impact by reducing the amount of green-waste that finds its way into landfills, incinerators, and sometimes the ocean. The resulting nutrient-rich compost end product is an environmentally sound amendment to enrich soil for plant growth that contributes in counteracting the deterioration of the environment due to rampant use of chemical fertilizers (Inbar*et al*,1993)

Composting worms are small mesophillic, red purple worms that prefer an environment of decaying organic matter rather than soil (Piper,2005). They reproduce quickly, consume large amounts of organic material, and tolerate the environment of a worm bin. Earthworms consume various organic wastes and reduce the volume by 40–60 (Dominguez 2004). Earthworms and its excreta (vermicast), promises to usher in the ‘Second Green Revolution’ by completely replacing the destructive agro chemicals which did more harm than good to both the farmers and their farmland. Earthworms excreta (vermicast) is a nutritive ‘organic fertilizer’ rich in humus, NKP, micronutrients, beneficial soil microbes—‘nitrogen fixing & phosphate solubilizing bacteria’ & ‘actinomycets’ and growth hormones ‘auxins’, ‘gibberlins’ & ‘cytokinins’. Both earthworms and its vermicast & body liquid (vermiwash) are scientifically proving as both ‘growth promoters & protectors’ for crop plants (Rajiv et al,2010).

Extensive research on inorganic fertilization and plant breeding, carried out within the framework of conventional agriculture, has allowed agricultural producers to fine-tune nutrient inputs and plant needs in order to maximize yields. However, such detailed knowledge has not yet been attained as regards the nutrient composition of organic fertilizers as vermicompost in sustainable agriculture. Given the complex and variable composition of vermicompost in comparison with inorganic fertilizers and the myriad of effects that it can have on soil functioning, a clear and objective concept of vermicompost is required, and the complex interactions between vermicompost-soil-plant must be unraveled in order to maintain consumer confidence in this type of organic *fertilizer (Cristina and Domínguez, 2010).*

In Ethiopian context, vermicomposting is a recently adopted biotechnology in which the effort of on farm verification and demonstrating its utilization was made by Haromaya University, Ambo Plant Protection Research Center and Holeta Agricultural Research Center. However, there were very limited attempt of characterizing vermicompost and identifying it by the nutrient content and other quality parameters considered in enhancement of crop productivity and soil fertility due to lack of experience in analyzing this fertilizer by domestic laboratories. Among few individual efforts domestically made, Gezahegn et al. (2012) have vermicomposted coffee husk, enset waste, Chat waste and vegetable waste using the epigamic earthworm *Eisenia foetida* and found to be as a good option for improving solid waste management in Ethiopia and production of excellent bio-fertilizers for agronomic purposes.

Among the wettest parts of Ethiopia western Oromia receives rainfall from April to December, that allow the growth of considerable amounts of decomposable materials needed to prepare compost. However, due to lack of awareness and technical know-how, these materials are usually wasted without proper use despite the fact that soil fertility in the region is declining rapidly from time to time. The sub optimal level of NP fertilizers currently being used for crop production under farmers' conditions have aggravated the situation of soil fertility degradation and reduction of crop productivity (Heluf et al,2004). These and other facts have sparked the idea of looking for alternative sources of fertilizers other than the commercial one. To this effect, vermiculture station was established and Vermicompost preparation was launched at Bako Agricultural Research Center in the last cropping season. Therefore, this study was conducted subsequently to characterize vermicomposts prepared from residue of main crops in the area and animal wastes in terms of major plant nutrient composition in order to identify the best quality vermicompost

Materials and Methods

Description of the Study Area

The study was conducted at Bako Agricultural Research Centre (BARC) during 2015 - 2016. The centre is located in the western part of Ethiopia at a distance of 250 km away from Addis Ababa. It lies at latitude of 9^0 6' 00''N and longitude 37^0 9' 00''E and at an altitude of 1650 m above sea level. It has a warm humid climate with annual mean minimum and maximum temperature of 13.5 and 23.7 ^{0}C respectively. The area receives an annual rainfall of 1237 mm from May to October with maximum precipitation in the month of June to August (Metrological station of the centre)

Establishment of Vermiculture Station

Vermiculture station which comprises three rooms namely raw material preparation vermicomposting and drying & storage rooms was constructed in shady and ventilated area in the compound of the center. The station is a simple prototype of un elevated barn like housing with corrugated iron roof and netted strips of bamboo walls with meshed wire extension on its upper part designed to ventilate the rooms and to avoid the entrance of flying predators. A protective structure was also laid out at the basement and around the walls of the room to prevent the composting worms from the attacks of ants and other crawling enemies of the worms.

Fig.1. Front view of the vermiculture/vermicomposting/ room

Experimental Materials and Procedure

The materials used in this experiment were crop residue; maize Stover, Soybean straw and niger seed refuse that are obtained from experimental fields of the center as a bedding material and animal wastes; cattle manure sheep dropping and poultry manure collected from animal farms of the center as a feedstock for composting worms.

The earth worms employed are the red burrowing type of specious known as Esinea Fatida, which are 10 to 15 cm long with life span of only 28 months, collected from Ambo Crop Protection Research Center

Fig.3.Worms ready to be conveyed to the partially composted raw materials

In this study, fourteen types of bedding and feed materials combination were used as a treatment which undergone partial fermentation for 20 days with the combination ratio of crop residue (DOW) to animal manure 1: 2 on weight basis

Treatments

1. Maize Stover + cattle manure
2. Soybean straw + cattle manure
3. Niger seed straw + cattle manure
4. Maize Stover + soybean straw + cattle manure
5. Maize Stover + Niger seed straw + cattle manure
6. Maize Stover + soybean straw + sheep waste
7. Maize Stover + Niger seed straw + sheep waste
8. Maize Stover + soybean straw + poultry manure
9. Maize Stover + Niger seed straw + poultry manure
10. Soybean straw + Niger seed straw + cattle manure
11. Soybean straw + Niger seed straw + sheep waste
12. Soybean straw + Niger seed straw + poultry manure
13. Maize st.+ Soybean st. + Niger seed st. + cattle man. + sheep wst. + poultrywst.
14. Cattle manure only

Fig. 2.Plastic dishes containing composting materials representing each experimental unit.

The vermicomposting process was started by releasing worms in to the partially decomposed medium in condition where the three most important environmental factors (Temperature, Adequate moisture and Ventilation) were maintained (Glenn, 2009). However, during the composting process it was observed that worms in the treatment which poultry manure was used as major feed material couldn't survive much longer than a day to sustain the composting activity. This was probably due to toxic effect of the poultry waste which was possibly contaminated with chemicals used in the farm that paralyzed and finally killed the compost worms. The materials in the other combination was safely transformed in to vermicompost after 3 months to give a uniform humus like loamy material in which no food scraps and residue materials are identifiable. It is light and black or dark brown in color. The compost was collected by manual harvesting which involved hand-sorting, or picking the worms directly from the compost by hand. The vermicomposts were dried, heaped, and stored while their representative samples were taken and prepared for laboratory test and the analysis was done to determine their nutrient level

Vermicompost Laboratory Analysis

The prepared vermicompost samples were analyzed in JIJE Analytical Testing Service Laboratory for their major plant nutrient composition and some chemical properties worth considering in characterizing the materials to an extent.

Major Parameters and Test Methods

1. Organic carbon (OC) - FAO-Loss on Ignition at 450oC
2. Total Potassium (K) - FAO - Aqua regia digestion extract – Flame photometer
3. Total Nitrogen (TN) - FAO- Kjeldahl
4. pH water FAO-Potentiometric-Water extract
5. Total Phosphorous (TP) - FAO - Aqua regia Digestion extract – Flame photometer
6. Total Calcium (Ca) - FAO - Aqua regia Digestion extract – EDTA Titration
7. Total Magnesium (Mg) - FAO - Aqua regia Digestion extract – EDTA Titration

Result and Discussion

Chemical property and Nutrient Level of the Vermicomposts

pH, Organic Matter and Total Nitrogen

According to the result of laboratory analysis, the vermicompost obtained from the combination of Maize Stover, Niger seed residue and sheep manure as well as the compost from the combination of Soybean residue, Niger seed straw and Sheep Manure has shown higher value of 2.42% in total nitrogen content. The compost formed from the combination of corn pulp, Soybean Straw.and Sheep Manure and that of cattle manure only, hold second and third position with the value of 2.17% and 2.1% respectively (Table 1). The conventional compost is superior

Table 1. pH, organic matter and primary nutrient content of vermicompost

Tr.no	Feed Combination	pH (H2O 1:5 ratio)	% OC	%OM	%T.N	CN ratio
1	Ma .sto. + Ctl. Man.	8.29	32.11	55.36	1.53	20.99
2	Sb. str + Ctl. Man.	8.20	32.22	55.55	1.98	16.27
3	N.sd. str + Ctl. Man.	8.51	35.21	60.70	1.98	17.78
4	Ma.sto.+Sb.str.+ Ctl. Man.	8.4	35.38	61.00	1.37	25.82
5	Ma.sto.+N.sd.st.+Ctl. Man.	8.12	34.43	59.36	1.75	19.67
6	Ma.sto.+Sb.str.+Shp. Man.	8.74	33.00	56.89	2.17	15.21
7	Ma.st.+N.sd.str.+ Shp man.	8.88	35.09	60.50	2.42	14.50
8	Sb.str.+N.sd.str.+Ctl. Man.	8.12	37.24	64.20	1.98	18.81
9	Sb.str.+N.sd.str.+Shp. Man.	8.56	36.02	62.10	2.42	14.88

10	Crop Resd. + Animal Man.	8.05	35.50	61.20	1.98	17.93
11	Ch. -1 cattle Man.only	8.16	42.87	73.91	2.1	20.41
12	Ch.-2.conv. Compost	9.25	19.32	33.31	0.87	22.21

The values are means of triplicates

in its pH value which falls in the alkaline range of pH scale. Unlike the pH value of conventional compost which is detrimental to growth of plants, the pH values of all type of vermicompost are found in suitable range for plant growth. Considering the organic carbon, CN ratio and total nitrogen content, all types of vermicompost has out smart the conventional compost significantly. The modification of acidity was possibly due to nitrogenous waste excreted by the earth worms and the vermin wash released in the process which increased the moisture content thus neutralizing the pH of the vermicompost. This is in conformity with the study of Nagavallemma *et al*. 2004, who found that the worm castings (vermicompost) contain higher percentage of organic carbon (13.8%) and total nitrogen(1.61%) compared to the conventional compost that contained 12% organic carbon and 0.8% total nitrogen. The same trend was obtained by Musaida *et al*. 2012 who stated that earthworms play an important role in the recycling of N in different agro ecosystems evident in vermicomposting which converts household and agricultural waste into compost within 8 weeks, reduces the C:N ratio and retains more N than the traditional methods of preparing composts

Table 2. Basic cation composition of vermicompost

Tr.no	Feed Combination	%T.P	**% T.K**	%T.Ca	%T.Mg
1	Ma .sto. + Ctl. Man.	1.22	2.42	5.32	2.1
2	Sb. str + Ctl. Man.	1.39	3.94	7.91	8.7
3	N.sd. str + Ctl. Man.	0.69	2.29	3.08	1.85
4	Ma.sto.+Sb.str.+ Ctl. Man.	0.68	1.8	5.27	3.8
5	Ma.sto.+N.sd.st.+Ctl. Man.	0.69	1.75	8.39	3.78
6	Ma.sto.+Sb.str.+Shp. Man.	0.80	2.7	6.26	6.89
7	Ma.st.+N.sd.str.+ Shp man.	0.90	2.32	3.08	3.33
8	Sb.str.+N.sd.str.+Ctl. Man.	0.72	1.92	5.29	3.18
9	Sb.str.+N.sd.str.+Shp. Man.	0.83	2.53	5.29	5.71
10	Crop Resd.+ Animal Man.	0.83	2.22	3.17	8.24
11	Ch. -1 cattle Man.only	0.69	1.7	5.31	1.91
12	Ch.-2.conv. Compost	0.47	1.53	8.39	4.40

The values are means of triplicates

Total Phosphorus, Total Potassium, Total Calcium, and Total Magnesium

With regard to other plant growth limiting nutrients the vermicompost produced from soybean residue and cattle manure scored a higher value in total phosphorus, total potassium and total magnesium while the vermicompost produced from Maize Stover, Niger seed Straw and Cattle Manure has scored higher value in total Calcium (Table 2).

The higher total phosphorus content in the vermicompost is attributed to the mineralization and mobilization of phosphorous contained in feedstock due to earthworm activity as earthworms play an important role in the release of phosphates on organic matter. The increase in magnesium is boosted in similar way by the earthworm activity on the feed material. The result of this study is in line with the finding of Amir and Fouzia (2011) which indicated that vermicomposts have rich source of nutrient content, a higher Base Exchange capacity and more exchangeable sodium, magnesium and potassium than pit compost and garden soil. The analytical result of this experiment is also concordant with the observation of Pius and Thompson (2000) which showed vermicomposting resulted in a significant increase in total and available P, exchangeable K, exchangeable Ca and total Mg, emphasizing that the higher concentrations of plant nutrients in end product of vermicomposting indicate a potential for using agriculture wastes in sustainable crop production.

Conclusion

In terms of the nitrogen economy of the vermicompost, the material that is obtained from Maize Stover, Niger seed residue and sheep manure as well as the compost from the combination of Soybean residue, Niger seed residue and Sheep Manure out smarts the others. However, these type of vermicomposts are found to be very poor in other primary and secondary plant nutrient elements as it is shown in the table. With respect to other major plant nutrients such as Phosphorus, Potassium and Magnesium, the vermicompost prepared from Soybean Straw and Cattle Manure has out ranked the other types of compost.

The manuring value of this type of vermicompost can be illustrated by taking maize, which is one of the major crop in the experimental area and other parts of western Oromia as an example. The blanket fertilizer recommended for this crop which is being used nowadays is 200kg urea and 100kg DAP. According to the result of this study, 4.64 tons of vermicompost prepared from soybean straw and cattle manure can replace the recommended amount of urea in terms of nitrogen which at the same time supply 139 kg of DAP(64.49kg P_20_5), an amount which exceeds the recommended dose of phosphorus for the crop

Recommendation

According to the results of this study, integrated effect of all the nutrients present in vermicompost helps to avoid plant nutrient imbalance in the soil in general .And by virtue of the accessibility of raw materials, simplicity of its production and better availability of the nutrient contained in it to the plant, utilizing the vermicompost obtained of soybean straw and cattle manure has a paramount importance in enhancing crop productivity and improving soil fertility.

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References

Amir, K and Fouzia, I. 2011. Chemical nutrient analysis of different composts (*Vermicompost*and *Pitcompost*) and their effect on the growth of a vegetative crop *PisumsativumDepartment of Biotechnology and Biomedical Science. Dolphin (PG) Institute of Biomedicaland Natural Sciences, Dehradun, UK. INDIA* Asian Journal of Plant Science and Research, , 1 (1):116-130

Cristina, land Jorge D. 2010. *(*The use of vermicompost in sustainable agriculture: impact on plant growth and soil fertility)Centro tecnológico del mar-fundacióncetmar. C/ Eduardo Cabellos/n - e-36208 bouzas - vigo (pontevedra)departamento de ecoloxía e bioloxíaanimal, universidade de vigo,36310 vigo, spain)

Dominguez, J. 2004.State of the art and new perspectives on vermicomposting research. In:C.A. Edwards (Ed.). Earthworm Ecology (2nd edition).

Gandhi M, Sangwan V.,Kapoor K.K.and Dilbaghi, N.1997. Composting of household wastes with and withoutearthworms. *Journal of Environment and Ecology*. **1997**, 15(2): 432- 434.

Gezahegn, D., Seyoum, M., Jorge, D. 2012.Vermicomposting as a sustainable practice to manage coffee husk, enset waste (*Ensetverticosum*), khat waste (*Catha edulis*) and vegetable waste amended with cow dung using an epigeic earthworm *Eisenia andrei* (Bouch' 1972). Int J Pharm Tech Res 4:15–24

Glenn, M. 2009. Manual of On-Farm Vermicomposting and Vermiculture, Organic Agriculture Centre of Canada

Heluf, G,,Wakene, N.,Tolera A., Abdenna D.&Geremew E.2004.Evaluation of Compost for Increasing Maize Yield on Farms in Western Oromia, Bako Agricultural Research Center, West Shoa, Ethiopia,

Inbar, Y.,Chen,Y and Hoitink,H.A.J. 1993. Properties of establishing standards for utilization of composts in container media. p. 669-694. In H.M. Keener and H.A.J. Hoitink (ed.) Science and engineering of composting. Renaissance. Publ.. Worthington, OH.

Musaida, M. M., Manyuchi, A., Phiri, N., Chirinda, P., Muredzi, J., Govhaand, T. 2012 Vermicompostingof Waste Corn Pulp Blended with Cow Dung Manure using Eisenia Fetida. World Academy of Science, Engineering and Technology Vol:6 2012- 08-21

Nagavallemma, KP., Wani SP, Stephane, L, Padmaja, V.V, Vineela, C, BabuRao, M and Sahrawat K.L. 2004. Vermicomposting: Recycling wastes into valuable organic fertilizer. Global Theme on Agrecosystems Report no. 8. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 20 pp.

Ndegwa, P.M. and Thompson, S.A. 2001. Integrating composting and vermicomposting in the treatment and bio conversion of bio-solids.

Peter, G., Francesco G. and Montague Y., 2000.Integrated Nutrient Management, Soil Fertility, and Sustainable Agriculture: Current Issues and Future Challenges,*Journal of Food, Agriculture, and the Environment*, International Food Policy Research Institute, Washington, D.C. U.S.A.

Piper,S., Michael, D., Brent, P. and Kelly, D. 2005.Small-Scale Vermicomposting.Hawaii Rainbow Worms, CTAHR Departments of Human Nutrition, Food and Animal Sciences

Pius, M. Ndegwa and Thompson, S.A. 2000. Effects of C-to-N ratio on vermicomposting of biosolids,Department of Biological and Agricultural Engineering, DriftmierEngineering Center, University of Georgia, Athens, GA 30602, USA

Rajiv, S.K.,Sunita, A., Chauhan, K. andValani, D.2010.The wonders of earthworms & its vermicompost in farm production: Charles Darwin's 'friends of farmers', w ith potential to replace destructive chemical fertilizers from agriculture. Agricultural Science 1(2): 76-94.

Wani, S.P .and Lee, K.K. 1992. Bio fertilizers role in upland crops production. Pages 91–112 in Fertilizers, organic manures, recyclable wastes and bio-fertilizers (Tandon HLS, ed.). New Delhi, India: Fertilizer Development and Consultation Organization.

Wani, S.P., Rupela, O.P. and Lee, K.K. (1995). Sustainable agriculture in the semi-arid tropics through biological nitrogen fixation in grain legumes. Plant and Soil 174,29–49.
Aveyard 1988,

Soil Chemical Properties and Crop Productivity as Influenced by Pruning Options of Pigeon Pea and N Rate on Maize in Cereal-Legume Integrated Cropping System at Bako

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Abstract

The return from inorganic fertilizers application in maize monoculture system is seasonal, requiring amendment of nutrients removed from the soil and retention of yield declined due to nutrient depletion. This study was executed to evaluate the effect of branch removal of perennial pigeon pea and N level on yields of component crops and on some soil nutrients in maize/pigeon pea intercropping. The treatments consisted of maize/pigeon pea intercropping in factorial combinations of four pigeon pea branch removals while leaving the upper (0, 2, 4 and 6) and five nitrogen levels (18, 41, 64, 87 and 110 kg ha^{-1}) and sole maize and pigeon monoculture laid out in Randomized Complete Block Design with three replications. The experiment was carried at Bako, western Ethiopia during 2013, 2014 and 2015 main cropping seasons. Main effects due to pigeon pea branch removal and N level were significant for maize biomass weight during 2013 and 2014 and also significant for maize grain yield throughout the experimental periods. Removal of lower branches of pigeon pea while leaving the upper 2 in maize/pigeon pea intercropping increased grain yield of maize by 8% and produced a mean pigeon pea seed yield of 972 kg ha^{-1}. It also reduced soil acidity, increased soil organic carbon, total N and available P compared to the sole maize monoculture. The highest LER of 1.42 and the highest net benefit of Birr 32,347 were also obtained by maize/pigeon pea intercropping with the same management at reduced N level. The system is recommended for its maximization of system productivity and reduced resource use efficiency at sub-humid areas of Bako.

Key words: Maize, Pigeon pea, branch removal, intercropping

Introduction

The sub-humid areas of western Oromia are threatened by soil erosion, low soil fertility and soil acidity attributed to low crop and land productivity. Nutrient depletion due to intensive maize monoculture, limited use of organic fertilizers, P fixation and N leaching have limited crop growth and land productivity. Traditionally, farmers leave their degraded farm lands fallow but practice open livestock grazing aiming at mitigation of the threats. The case lead to the lowest organic carbon contribution compared to the mixed crop lands (Asif *et al.*, 2014), which initiated emergence of grass species more resistant to grazing and decomposition. Declining of soil fertility aggravated by wide scale continuous cultivation of maize which mines the soil nutrients remained the farmers struggling to maintain yields year after year (Snapp *et al.*, 2010). Rising human consumption from crop source is dramatically increasing depends on agriculture and natural resources which raises challenges for achieving food security (Foley *et al.*, 2011). Through strategic improved crop varieties and inorganic fertilizer use, it might not be enough to feed the growing population requiring production of more food on the same amount of land (Giller *et al.*, 2006).

Cereal/legume cropping system show considerable promise in boosting productivity, helping reverse the decline in soil fertility (Dagne *et al.*, 2012) and improves dietary sources. Incorporating nitrogen fixing legumes in to maize based cropping systems has the potential to improve soil fertility and mitigate the nutrient mining of maize (Snapp and Silim 2002). Pigeon pea in the systems with advantages of fertilizer value, dry season animal feed and seeds for human consumption (Abebe and Diriba, 2002) has the potential of reacting with iron-bond phosphate in the soil to release P (Hector and Smith, 2007).

Ethiopia with wide range of ecological suitability to pigeon pea didn't widely enter into the multiple uses from the crop. However, research findings by Zerihun *et al. (*2016) indicated that perennial pigeon pea can be used as a live-stake for climbing bean and production of finger millet as intercrop during the establishment phase. The litter fall reduces soil erosion, improves soil fertility and larger root mass contributes to improvement of soil organic matter. Faster establishment in subsequent years reduces cultivation cost when conservational agriculture is used. However no research works have been done for combination of branch removal of pigeon pea and N levels in West Oromia. Therefore, the objective of this study was to evaluate the effect of on crop yields, soil chemical properties and system productivity at maize belt areas of Bako, western Ethiopia.

Materials and Methods

Description of the Experimental Site

The experimental site was at Bako Agricultural Research Center, which is situated in the western part of Ethiopia at an altitude of 1650 masl. The area has a warm-humid climate with annual means minimum and maximum temperatures of 13.6^0 C and 29.1^0 C, respectively. Long-term average annual rainfall of the area is 1264 mm. The rainfall received during 2013, 2014 and 2015 cropping seasons was 1431, 1067 and 944 mm, respectively. The experimental site is characterized by reddish-brown clay-loam Nitosol, which is strongly acidic with pH of 4.98, organic carbon (2.02), total nitrogen (0.15%) and CEC of 17.8 cmol/kg.

Planting Materials

Maize variety (BH661), which is relatively suitable for the intercropping system due to its semi-erect morphology and stay green after maturity and a perennial multi-purpose pigeon pea locally adapted to the area were used for the study.

Experimental Design and Procedure

Twenty two treatments consisted of factorial combinations of four branch removals (pruning) but leaving 0, 2. 4 and 6 upper branches and five nitrogen levels (18, 41, 64, 87 and 110 kg ha^{-1} N) as well as sole maize with recommended NP and a sole pigeon pea (un-pruned) were used in a Randomized Complete Block Design with three replications. The experiment was carried out during 2013, 2014 and 2015 main cropping seasons. Tractor land preparation was implemented during the initial year whereas crop residue incorporation and minimum tillage using local digging hoe was used during the second and third years of the experiment. Maize was planted at a spacing of 75 cm x 30 cm on a plot area of 19.125m^2 (3.75m x 5.1m). Pigeon pea was also planted between rows of maize at 50cm spacing between plants and branches were removed 8 weeks after planting. During 2014 and 2015 cropping seasons branches were removed right at planting of maize according to the treatment set up. The removed branches were weighed (biomass weight in this context), chopped and incorporated to the soil of respective plots. Data for both crops were collected from 3 center rows (11.25m^2).

The composite soil sample was collected from each experimental plot at depth of 0-20 cm before planting (at establishment) and after harvest of each cropping season. The samples were air dried grinded and sieved at particle size of less than 2mm. Soil pH was determined using pH meter 1:2.5 soil: water; Available P was determined using Bray II method (Bray, R.H. and L.T. Kurtz 1945); Total nitrogen was determined using Kjeldhai method (Kjeldahl, J. 1983) while Walay-Black method (Walkley, A. and I.A. Black.1934) was used to obtain OC.

Data Collection and Management

Grain yield was corrected to 12.5% and 10% moisture content standards for maize and pigeon pea, respectively. Above ground biomass of maize and sample biomass of pigeon pea (pruned branches with leaves) were sun-dried until constant weight was maintained. Overall advantage of the intercropping, land equivalent ratio (LER) of the crops was determined using the formula developed by Devasenapathy *et al.* (2008),

$$LER = \frac{Ymp}{Ymm} + \frac{Ypm}{Ypp}$$

Ymp; yield of maize intercropped with pigeon pea, **Ymm**: yield of maize in pure stand, **Ypm**: yield of pigeon pea intercropped with maize, **Ypp**: yield of pigeon pea in pure stand.

Economic Evaluation

Economic evaluation was done following from agronomic data to farmer recommendation (CIMMYT, 1988). Three years' average costs of fertilizer, land preparation, planting, branch removal, harvesting and threshing were among variable costs considered in partial budget. Similarly, three years' average crop yield and price were considered for economic evaluation. Yield was down adjusted by 10% whereby sensitivity analysis was made subjected to cost and price changes considering minimum acceptable MRR as 100%.

Data Analysis

Data were analyzed using SAS version 9.1 (SAS, 2002) computer software and were subjected to ANOVA to determine significant differences among factors and their interactions. Means were separated using LSD test. For all analyzed parameters, $P<0.05$ was interpreted as statistically significant.

Results and Discussion

Maize Component

Mean maize biomass and grain yield reduction of 12% and 15% were obtained respectively during 2014 compared to 2013. The reduction during 2015 compared to 2014 cropping season was not magnified, 5% (for biomass) and 3% (for grain yield). Maize mean grain yield obtained from maize/pigeon pea intercropping regardless of pruning options resulted in 6% yield advantage over maize grown sole during the initial establishment of pigeon pea, 2013. With respect to the overall maize grain yield, 1.25% yield advantage was recorded from maize pigeon pea intercropping.

The main effect due to branch removal of pigeon pea was significant for maize biomass during 2013 and 2014 cropping seasons and for maize grain yield during the three experimental seasons. Removing pigeon pea branches but leaving 0 and 2 upper branches produced significantly the highest, but not significantly different from each other maize grain yield during the three cropping seasons. Indeed, mean maize grain yields of 8940 kg ha^{-1} and 8884 $kgha^{-1}$ were recorded for branch removals leaving 0 and 2 upper ones, respectively against 8471 kg ha^{-1} obtained by maize grown sole with recommended 110 46 kg ha^{-1} NP_2O_5. Higher maize grain yield in maize/pigeon pea intercropping might have attributed by less competition, improvement of soil moisture, and addition of organic matter to the soil. On the other hand, removing branches but leaving 6 upper ones produced significantly lowest maize grain yield throughout the cropping seasons (Table 1) presumably due to high shading effect and competition for resources. Study by Daniel and Ong, 1990 confirmed perennial pigeon pea intercropped with sorghum improved yield of component crop when lower branches were removed. Unaffected grain yield of component crop was also reported by ICRISAT, 1987 when plant population of pigeon pea was reduced below 28000 and lower branches were removed.

The main effect due to nitrogen level also affected maize biomass and grain yield during the three cropping seasons. Application of 110 kg ha^{-1} N and 87 kg ha^{-1} N produced significantly the highest, but not significantly different from each other maize grain yield during the three cropping seasons (Table 1). Application of 18 kg ha^{-1} N produced significantly the lowest maize grain yield throughout the three cropping seasons but, which was not significantly different from application of 41 kg ha^{-1} N during 2013 and 2015 cropping seasons. Despite of the significance of main effect of branch removal and nitrogen level, maize grain yield was not significant due to the interaction terms of branch removal by nitrogen level.

Table 1 Maize biomass and grain yield as affected by the main effects of pigeon pea branch removal and N level in maize/pigeon pea intercropping at Bako

Factor	Biomass weight kg ha^{-1}			Grain yield kg ha^{-1}		
Pigeon pea branch removal leaving upper	2013	2014	2015	2013	2014	2015
0	24677[a]	22501[a]	19547	9987[a]	8602[a]	8232[a]
2	23822[ab]	21347[ab]	19616	9822[a]	8569[a]	8260[a]
4	23189[ab]	20054[bc]	19891	9523[ab]	7933[b]	7897[ab]
6	22646[b]	19376[c]	20031	9011[b]	7658[b]	7429[b]
SE ±	637	210	547	456	109	221

LSD (5%)	1819	1303	NS	599	312	632
Sole maize	22411	18767	21363	9040	8193	8179
N level kg ha^{-1}						
18	21749^{b}	18783^{b}	17017^{c}	8426^{b}	7015^{c}	6819^{c}
41	24124^{a}	20959^{a}	17953^{c}	9017^{b}	8243^{b}	7158^{c}
64	23654^{ab}	20827^{a}	20041^{b}	10071^{a}	8145^{b}	8132^{b}
87	24366^{a}	21623^{a}	21340^{ab}	10205^{a}	8730^{a}	8671^{ab}
110	2406^{a}	21907^{a}	22505^{a}	10209^{a}	8818^{a}	8995^{a}
SE ±	712	234	612	510	122	247
CV %	10.45	8.49	10.78	8.47	5.17	10.72
LSD 5%	2034	1457	1750	669	349	707

Pigeon pea Component

Biomass weight increased as the rate of pigeon pea branch removal increased throughout the cropping seasons and showed increasing trend for subsequent cropping seasons. Pruning all branches but leaving the growing meristem produced significantly the highest weight (8299 kg ha^{-1}, 8546 kg ha^{-1} and 9255 kg ha^{-1}) but not significantly different from removing all branches but leaving 2 upper ones during 2013, 2014 and 2015, respectively (Table 2). Mean biomass weight for removal of all lower branches leaving the upper 6 and 4 were significantly the lowest but not significantly different from each other during the three cropping seasons. No matter how there is weight differences between branch removals, there was weight increase for all branch removals through the experimental periods. Biomass weight was not affected by the main effect of nitrogen level, yet there was weight increase from year 1to3 (Table 2).

Seed Yield

Unlike the biomass weight, seed yield increased as the rate of branch removal decreased throughout the cropping seasons. Similar to the biomass weight, seed yield also showed increasing trend consecutively. Seed yield was neither influenced by the N level nor by the interaction of factors. However, the main effect of branch removal affected seed yield of pigeon pea throughout the cropping seasons. Certainly, significantly high seed yields of 1234 kg ha^{-1}, 1339 kg ha^{-1} and 1441 kg ha^{-1} during 2013, 2014 and 2015, respectively were obtained from branch removal but leaving 6 upper ones. All branches removal leaving only the upper meristem produced significantly the lowest seed yields, but as high as 807 kg ha^{-1} during 2015 cropping season (Table 2). Fast re-growth habit of the branches favored annual seed harvest from perennial pigeon pea.

System Productivity and Economic Benefit

Applications of 87 kg ha^{-1} N and 110 kg ha^{-1} N associated with pigeon pea branch removal while leaving 2 and 6 upper branches produced significantly the highest LER of 1.42. Maize/pigeon pea intercropping with application of 87 kg ha^{-1} N regardless of branch removals has produced partial LER of maize greater than 1, indicating maize was not affected by intercropping; rather produced higher grain yield compared to sole grown maize. In maize/pigeon pea intercropping, application of 87 kg ha^{-1} N and pigeon pea branch removal while leaving 2 upper ones, 42% of a hectare of land was saved to grow both crops in pure stand to produce the grain yields obtained by their association. Moreover, on average, 7103 kg ha^{-1} $year^{-1}$ dry branch cuttings was obtained and incorporated to the soil of respective plots.

Table 2 Biomass and seed yield of pigeon pea as affected by the main effect of pigeon pea branch removal in maize/pigeon pea intercropping at Bako

Factor	**Branch weight kg ha^{-1}**			**Seed yield kg ha^{-1}**		
Pigeon pea branch removal leaving upper	**2013**	**2014**	**2015**	**2013**	**2014**	**2015**
0	8299^{a}	8546^{a}	9225^{a}	721^{d}	747^{c}	807^{c}
2	7016^{ab}	7238^{ab}	7813^{ab}	836^{c}	1001^{b}	1079^{b}
4	6937^{b}	7197^{b}	7642^{b}	931^{b}	951^{b}	1010^{b}
6	5763^{b}	5910^{b}	6360^{b}	1234^{a}	1339^{a}	1441^{a}
SE ±	471.29	466.57	512.39	31.76	37.16	41.87
LSD (5%)	1346	1334	1465	88	106	120
Nitrogen level						
18	6427	6629	7154	894	958	1034
41	7433	7657	8182	969	1063	1134
64	6892	7058	7629	947	1030	1115
87	6511	6756	7285	898	971	1044
110	7756	8018	8552	945	1026	1095
SE ±	34.61	521.64	572.87	52.7	41.55	46.81
CV %	12.88	25.02	25.57	26.04	14.25	14.96
LSD 5%	NS	NS	NS	NS	NS	NS

Three years' average net benefit of 500 Birr ha^{-1} was obtained by application of 87kg ha^{-1}N associated with pigeon pea branch removal while leaving 2 upper branches compared to similar N rate and pigeon pea branch removal while leaving 4 upper branches in maize/pigeon pea intercropping. Higher MRR of 238% was obtained for changing from application of 87kg ha^{-1} N and pigeon pea branch removal while leaving 4 upper branches to 87kg ha^{-1} N and pigeon pea branch removal while leaving 2 upper branches. In the latter case, for addition of 1 Birr investment, the return was Birr 2.38. Sensitivity analysis resulted in application of 87 kg ha^{-1} N and pigeon pea branch removal while leaving 2 upper branches remain profitable even if the cost of production rises by 25% and the output cost remain unchanged. Besides several advantages of pigeon pea biomass incorporated to the soil, it also saves cost of tillage whereby conservation agriculture was used for maize/pigeon pea during the second and third years of the experiment. It was also reported by Zerihun *et al., 2014,* conservational agriculture saves cost of tillage and weeding. Indeed, maize/pigeon pea intercropping system with reduced N level (87 kg ha^{-1} N) and the indicated branch management of pigeon pea is economically profitable.

Table 3 Mean LER and economic benefit of maize/pigeon pea intercropping at Bako, western Oromia, during 2013, 2014 and 2015 main cropping seasons

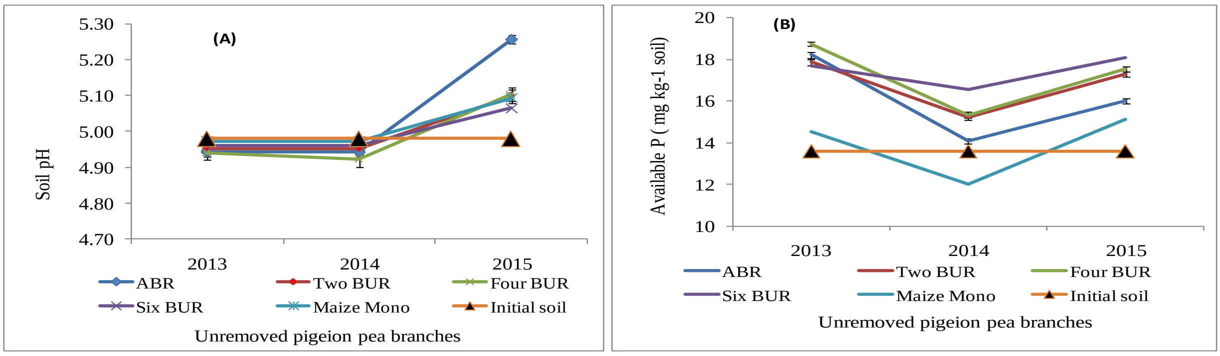
No	Pigeon pea branch removal leaving upper	N kg ha^{-1}	LER	TCV	Net benefit	MRR
2	6	18	1.31	1470	31148	
3	4	18	1.27	1680	30250	D
4	2	18	1.30	1890	30751	D
5	6	41	1.37	2008	31279	1.31
6	0	18	1.26	2100	29861	D
1	Sole maize mono cropping	110		2176	25608	D
7	4	41	1.33	2218	31181	D
8	2	41	1.36	2428	31682	D
9	6	64	1.37	2546	31452	D
10	0	41	1.32	2638	30792	D
11	4	64	1.33	2756	30555	D
12	2	64	1.35	2966	31055	D
13	6	87	1.42	3084	31145	D
14	0	64	1.32	3176	30165	D
15	4	87	1.39	3294	31847	0.38
16	2	87	1.42	3504	32347	2.38
17	6	110	1.42	3622	32237	D
18	0	87	1.38	3714	31457	D
19	4	110	1.39	3832	31339	D
20	2	110	1.42	4042	31840	D
21	0	110	1.39	4252	30950	D

Soil Recation

The pH of initial soil and after planting of 2013 and 2014 cropping seasons, regardless of treatment variations fall under similar ranges, strongly acidic. However, the pH was significantly increased from 5.06 to 5.3 (Fig 1A), moderately acidic rated by Takalign 1991 during 2015 cropping season as compared to soil pH obtained in the previous two years. Indeed, the main effect of branch removal affected soil pH; being significantly higher (5.26) for removal of all lower branches, leaving the upper meristem (Fig 1A). Complete decomposition of organic residues is expected from removal of all branches pending the time interval of the treatment and soil sample collection. Consequently, formation of weak organic acid favoring acidity due to intermediate decomposition was low pH.

Soil Available P

Available P at initial (during 2013) was significantly lower compared to other years. However, the highest available P was found during 2015 when all lower branches were removed leaving upper 4 followed by leaving upper 6 branches on the main stem. The available P obtained from pruning all branches leaving 2 and 0 upper ones were lower during 2014 (Fig. 1B). The lowest available P was recorded in each cropping season when continuous maize monocropping was practiced, which could be due to the depletion of P through continous cultivation of maize. In this study, highest available P in maize/pigeon pea intercropping might have attributed as reported by Hector and Smith, 2007, due to the ability of pigeon pea to access insoluble phosphates in soils low in P.



ABR- All bramches remuved; BUR-Branches unremoved

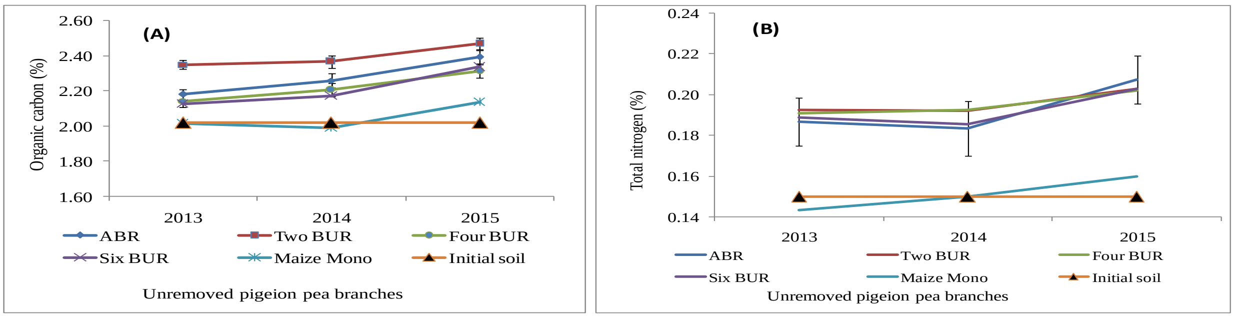
Fig. 1(A) Soil pH and 1(B) available P as affected by branch removal of pigeon pea in maize/pigeon pea intercropping at Bako

Soil Organic Carbon

Initial soil OC content of the soil was significantly lower compared to the OC after crop harvest regardless of treatment and seasonal variations. Soil organic carbon build up was significantly increased from initial cropping season (2013) to end of the experiment (2015). The highest OC was recorded for 2 upper branches unremoved through out the three cropping seasons. This could be due to root peeling off tht leads to varioos deposits of oraganic matter subjected to mineralization and humus formation. The result obtained could be justified by works of Hugues and Philippe, 1998 describing at least 30% of the total biomass produced from 1-2 years old herbaceous species was obtained from underground biomass. Soil OC content under continuous maize based mono-cropping practice in each cropping season was considerably lower compared to other treatments (Fig. 2A). The result obtained is further justified by Johnson *et al.*, 2007, organic carbon build up is favored by conservational agriculture, standing biomass, long term harvested products and living biomass in the soil.

Soil Total Nitrogen

Similar to soil OC content, the total N of the soil was significantly increased from year to year, and the maximum total N was recorded during 2015 cropping season when all branches were removed and incorporated into the soil. However, similar nitrogen content, regardless of treatment variation except for maize mono crops, were recorded in 2014 and 2013 cropping seasons (Fig. 2B). Indeeed, the presence of pigeon pea under different prunning options can significantly improve total nitrogen content while maize monocropping considerably reduced the N content of the soil.



ABR- All bramches remuved; BUR-Branches unremoved

Fig. 2 Soil organic carbon (A) and total N (B) as affected by branch removal of pigeon pea in maize/pigeon pea intercropping at Bako during 2013, 2014 and 2015 cropping seasons

Conclusions and Recommendation

In maize belt areas of western Ethiopia, a number of hybrid varieties with high yielding potentials are released by research. Obviously, the potential of the crop and land productivity could decrease due to continuous cultivation of the same crop. It is also very difficult to put single technological solutions for multiple productivity threats of the area. The study has demonstrated that pigeon pea is an important crop with great potential to reverse the soil fertility decline, improves the yield potential of component crop, reduces cost of production and increases net benefit. Removing all branches of pigeon pea while leaving the upper 2 and 0 produced the highest maize biomass and grain yields. Application of 87 kg ha^{-1}N was not significantly different from 110 kg ha^{-1} N for yields. Hence, removal of all branches of pigeon pea while leaving 2 upper ones and application of 87 kg ha^{-1} N were found system productive and were recommended. The large biomass improved soil organic carbon, increased soil total nitrogen and soil pH whereby competition for light was managed by branch removal and competition for moisture was compensated by the high rain fall distribution in the area. Thus, incorporation perennial pigeon pea to the maize dominated cropping system requires due attention by research and extension system.

References

Abebe Yadessa and Diriba Bekere. 2002. Effect of biomass transfer of *Cajanus cajan* with or without inorganic fertilizer on BH 660 hybrid maize variety at Bako, Western Oromia, Ethiopia, the sixth conference of Ethiopian society of soil sciences. Addis Ababa, Ethiopia

Asif, I., H. Shahadat and N. Islam. 2014. Soil organic carbon dynamics for different land uses and soil management practices in Mymensingh. pp. 16-18. *In*: ICEAB. Proceedings of 5th International Conference on Environmental Aspects of Bangladesh.

CIMMYT. 1988. From agronomic to farmers recommendations. An economic training manual. Completely revised edition. D. F. Mexico.

Dagne Wegari, Abaya Temesgen, Solomon Admasu, Solomon Jemal, Alemu Tirfessa, Leggesse Hideto, Fekadu Getenet Gezehagn Bogale, Temesgen Chibsa and Mulugeta Mekuria. 2012. Towards sustainable intensification of maize-legume cropping systems in Ethiopia. pp.120-125. *In:* Mosisa Worku, M.S. Twumasi-Afriye, Legesse Wolde, Birhanu Tadesse, Gzehagne Bogale, Girma Demissie, Dagne Wegari and B.M. Parasanna (eds.). Meeting the challenges of global climate change and food security through the innovative maize research. Proceedings of the third national maize workshop of Ethiopia, Addis Ababa, Ethiopia.

Daniel, J.N. and C.K. Ong. 1990. Prennial pigeon pea; a multi-purpose species for agroforestry systems. *Agrofrestry sytems. 10:113-129.*

Devaseanapathy, P., T. Ramesh and B. Gangwar. 2008. Efficiency indices for agricultural research. NIPA, New Delhi.

Foley, J.A., N. Ramankutty, K.A. Brauman, E.S. Cassidt, J.S. Gerber, M. Johnnston, N.D. Muller, C. O'Connell, D.K. Ray, P.C. West, C. Balzer, E.M. Bennett, S.R. Carpenter, J. Hill, C. Mofreda, S. Polasky, J. Rockstrom, J.Sheehan, S. Siebert, D. Tilman and D.P.M. Zaks. 2011. Solutions for a cultivated planet. Nature (478) 7369: 337-342.

Giller, K., E. Rowe, N. Ridder and H. Keulen. 2006. Resource use dynamics and interaction in the tropics: scaling up in space and time *Agric. Syst. 88: 8-27*

Hector, V. and J. Smith. 2007. Green manure crops: pigeon pea: sustainable agriculture green manure crops. Cooperative extension services. College of tropical and human resources, University of Hawaii.

Huges D., and D.L. Philippe. 1998. Trees and multi-story agriculture in Africa. CTA (Technical Center for Agriculture and Rural Cooperation). Wageningen, The Netherlands. 252-262pp.

ICRISAT (International Crop Research Institute for the Semi-Arid Tropics). 1987. *Annual report 1986.* Patancheru, AP502324., India.

Johnson, J.M.F., A.J. Franzluebbers, W. Lachnicht and S. Reicosky. 2007. Agricultural opportunities to mitigate green house gas emissions. *Environmental pollution. 99: 325-334.*

Kjeldahl, J. 1983. A new method for the estimation of nitrogen in organic compounds. *Z. Anal. Chem. 22, 366.*

SAS. 2002 . Statistical Analysis System (SAS), user guide, statistics SASA nc. cary. Northern Carolina, USA.

Snapp, S., and S.N. Silim. 2002. farmer preference and legume intensification for low nutrient environments pp. 289-300. *In:* Adu-Gyamfi, J.J. (ed). Food security in nutrient-stressed enviromnments: Exploiting plants' genetic capabilities.

Snapp, S., M. Blakie, R. Glibert, K. Bezener . and P. Kanyama. 2010. Biodiversity can support a greener revolution in Africa. *Natl.Acad. Sci. 107 (48): 20840-20845.*

Tekaligen Tadesse. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working document No.13. international Livestock Research Center for Africa. Addis ababa, Ethiopia.

Walkley, A. and I.A. Black.1934. An examination of Degtjaref method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci. 37:29-37.*

Zerihun Abebe, Shiferaw Tadesse and Meseret Tola. 2016. Multiple advantages of pigeon pea (*Cajanus cajan*) in maize based cropping systems: Used as live stake for climbing bean with phosphorus rates mazie productivity enhancement in mono cropping areas. *J. Natural Sci.Reas. 6(19): 58-69.*

Zerihun Abebe, Tadesse Birhanu, Shiferaw Tadesse and Kifle Degefa. 2014. Conservation agriculture: Maize-legume intensification for yield profitability and soil fertility improvement in maize belt areas of western Ethiopia. *Int. J. Soil and plant soil sci. 3(8): 969-985.*

Soil Test Crop Response Based Phosphorus Calibration for Maize (Zea mayis L.) Production in the Sub-Humid Areas of Bako

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Abstract

Soil fertility level and initial soil available P was not considered while applying the blanket recommendation, 46 P_2O_5 in the sub-humid high rainfall areas of Bako. Having this, site specific soil test crop response Phosphorus fertilizer calibration trial on maize was conducted in maize-belt area of Bako, western Oromia during 2015 and 2016 main cropping seasons. The experiment consisted six levels of P (0, 10, 20, 30, 40 and 50 kg ha^{-1}) and was arranged in Randomized Complete Block Design with three replications was executed on 21 farmers' field. Application of P increased biomass weight, grain yield and HI by 30%, 20% and 16%, respectively over the control. Available P concentration after 21 days of maize planting responded to application of phosphorus fertilizer. Hence, correlation of yields with soil test P values greater than 14.5 mg kg^{-1}, critical P concentration (P_c) was considered sufficient. Similarly, the average P requirement factor (P_f) calculated from soil test P values for the study area was 5.5 for maize production in the Bako area. Despite factors that limit P availability like low soil pH, soil erosion and runoff, maize mono cropping and poor crop residue management, the result obtained provides optimum P fertilizer requirements for maize production and soils in the Bako area. Liming, organic matter amendment and reducing potential P loss associated with erosion and runoff are management practices emphasized to regulate P availability in acidic maize mono cropping dominated areas of Bako.

Key words: Soil. Phosphorus, Calibration, Zea mayis,

Introduction

Land degradation and plant nutrient depletion has been the most important cause of declining in food crop production in most sub-Saharan Africa (Zeleke *et al.,* 2010). Plant nutrients like N, P and K are among plant growth limiting but depleted in alarming rate from about 200 hectares of cultivated land in 37 SSA countries representing an economic loss of USD 4 billion due to soil nutrient mining (Bationo *et al., 2006*). Ethiopia, as one of the Sub Saharan Africa, reported to restrain agricultural production and economic growth due to severe soil nutrient loss with 47 kg N, 7 kg P and 32 kg K ha^{-1} $year^{-1}$ (Haileselassie *et al.*, 2005). Continuous cropping, high proportion of cereals in the cropping system and the application of suboptimal levels of mineral fertilizers have aggravated the decline in soil fertility and crop yield (Agegnehu *et al.*, 2006). In maize mono cropping dominated areas of Bako, western Ethiopia, maize yield reduction of 30% and complete crop failure in continuous maize mono-cropping without fertilizer application was reported for Central Rift Valley of Ethiopia (Tesfa *et al.,* 2001).

Phosphorus is extremely important for crop growth, which found abundantly in some minerals as well as manures, the latter being the most economically exploitable source. Due to its many uses, P is in high demand globally and the fact that the many functions which it performs cannot be substituted by any other element. As a result, there is substantial global interest in minimizing P losses from the soil and the overuse of P fertilizers (Dodd and Mallarino, 2005). Eventually, excess P application beyond the crop requirement results in no more crop productivity; rather can be fixed to Al and Fe oxides in acidic soils and thereby become unavailable to plants (Corey, 1987). Obviously, fertilizer P recommendations depend on the existing level of available P, the optimum level of soil P for the crop grown and the level of fertilizer added to raise available soil P to the optimum level.

The blanket recommendation of 46 P_2O_5 in the sub-humid, high rainfall areas of Bako did not consider the differences of soil fertility levels of different farmlands whereby farmers apply the same P fertilizer rate to maize regardless of soil fertility and available P differences. For these reasons, the blanket recommendation will make in efficient use of these expensive nutrients which contribute to the depletion of scarce financial resources, increased production costs and potential environmental risks (Amsal and Tanner, 2001). Soil test crop response P fertilizer recommendation can offer the probability that a response to P fertilizer will occur. It also provides determination of critical concentrations and P requirement factors. This method devices risk aversion of excess application of P and provides insight into P nutrition that can serve as a guide to improved agricultural practice in maize production system of Bako area.

Objectives

- To asses and evaluate P fertilizer requirement for maze cropping system of Bako area
- To give quantitative guidelines and recommendations of P fertilizer for maize at Bako area

Materials and Methods

Description of the Study Area

Soil test crop response P calibration trials on maize were conducted on 21 farmers' field during 2015 and 2016 main cropping seasons in the sub-humid areas of Bako Tibe and Gobu Sayo districts where the area is characterized by reddish-brown clay-loam Nitosol which is acidic, with pH range of 4.85 to 6.13. The area has a warm-humid climate with annual means minimum and maximum temperatures of 13.6^0 C and 29.1^0 C, respectively. Long-term average annual rainfall of the area is 1233 mm extending from May to October with peak in June and July. The rainfall received during 2015 and 2016 cropping seasons was 944 mm and 1317mm, respectively.

The total amount of rainfall during 2015 was less than the mean for ten years (Fig. 1) but high enough to cause soil erosion because the rainfall pattern during maize production season, May to September, is erratic and the distribution is higher. In July 2015, the rain fall amount was 271mm (Fig. 2), much higher compared to the mean and the amount of the same month during 2016 cropping season. There was high rainfall amount and precipitation pattern during 2016 cropping season. The highest rainfall amount, higher than the mean was recorded during June that might have attributed to P unavailability due to soil acidity favored by soil erosion. The study by Francirose *et al*, 2006 confirmed higher P unavailability with runoff from a precipitation of 50 mm h^{-1} one day after application for all P sources.

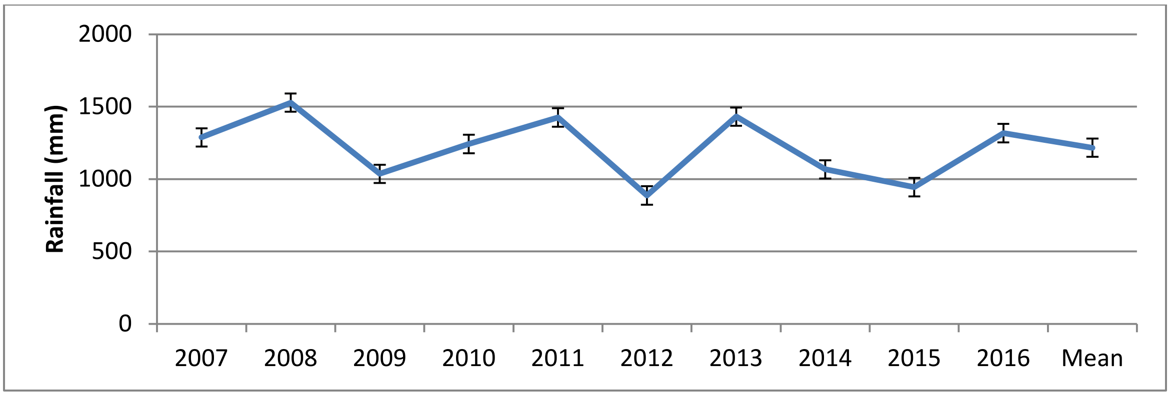

Fig. 1 Ten years' (2007-2016) rainfall distribution of the study area

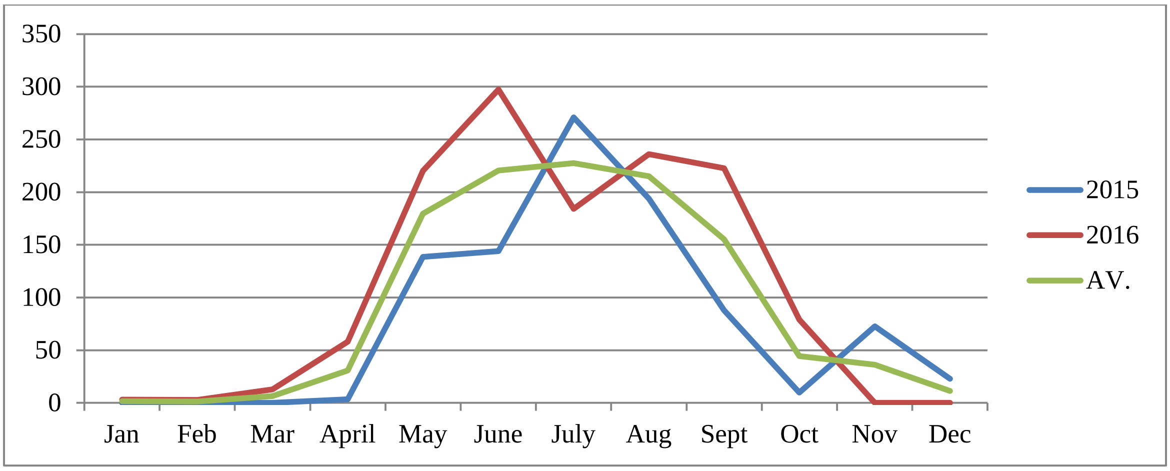

Fig 2 Rainfall distribution over months during 2015 and 2016

Experimental Design and Procedure

The study was conducted on 21 farmers' field around Bako Agricultural Research Center, in Bako Tibe and Gobu Sayo districts of West Shewa and East Wellega zones, respectively. The experiment consisted of 6 levels of P (0, 10, 20, 30, 40 and 50 kg ha^{-1}) laid out in a Randomized Complete Block Design with three replications during 2015 and 2016 main cropping seasons. Recommended N, 110 kg ha^{-1} was applied uniformly to all plots using split application method, 50% during planting and the remaining 50% at 35 days of planting. Maize variety, BH 661 was planted at the spacing of 75 cm between rows and 30 cm between plants on plot area of 22.95m^2 where by plot area of 15.3 m^2 was harvested and used for agronomic data collection. Maize grain yield was corrected to 12.5% moisture standard. Both maize grain and biomass yields were converted to kg ha^{-1}.

Ten representative sub-samples at the depth of 0-20cm from each farmer's field, amounting 210 soil samples were composited to 21 samples during the two main cropping seasons before execution of the experiment. Similarly composite soil samples were taken three weeks after maize planting from each experimental plot to evaluate P-available rose as the result of P-fertilizer application. Soil samples were analyzed for pH using 2.5ml water to 1 g soil; available P using Bray-II method (Bray, R.H. and L.T. Kurtz 1945), Organic Cusing Walkley and Black method (Walkley, A. and I.A. Black.1934) and Total N using Kjeldhal method (Kjeldahl, J. 1983) at the soil laboratory of Bako Agricultural Research Center.

Determination of Critical P Concentration (Pc)

Available P extracted from the soil samples taken three weeks after maize planting from each experimental plot was correlated with relative yields so that critical P concentration was determined using the Cate-Nelson correlation method (Nelson and Anderson, 1977). The relationship between grain yield response to P rates and soil test P values, relative grain yield % were calculated as:

$$Relative\ yield\ \% = \frac{yield}{maximum\ yield} \times 100$$

The scatter diagram of soil test P value (X-axis) versus relative yield (Y-axis) was plotted. Intersecting perpendicular lines were drawn to divide the scattered data into four quadrates whereby the responsive and non-responsive ranges are defined by the vertical line. Overestimation and underestimation of the fertilizer P requirements were defined by the upper left and lower right quadrates, respectively. The point where the vertical line crosses the X-axis was interpreted as the optimum critical soil test level (Nelson and Anderson, 1977*)*.

Determination of P Requirement Factor (P_f)

The amount of P in Kg needed to raise the soil P by 1mg (P_f), enables to determine the quantity of P required ha^{-1}. It also set aside to establish the quantity of P requirement $ha^{-1}$to raise the soil test by 1mg. Similarly, it helps to determine the amount of fertilizer required $ha^{-1}$to bring the level of available P above the critical level (Nelson and Anderson, 1977). It is calculated as:

$P_f = \frac{\text{kg P applied}}{\Delta\ soil\ P}$ Indeed, $P_a = (P_c - P_i) \times P_f$, whereas:

P_a =the rate of P fertilizer to be applied; P_c = P concentration; P_i = initial soil P vale; P_f = P requirement factor.

Statistical Data Analysis

Data were analyzed using SAS version 9.1 (SAS, 2002) computer software and were subjected to ANOVA to determine significance differences among treatments. Means were separated using LSD test. For all analyzed parameters, $P<0.05$ was interpreted as statistically significant.

Results and Discussion

Yields and Harvest Index (HI)

Maize mean biomass, grain yield and HI were significantly increased by application of P fertilizer. As a result, significantly lowest grain and biomass yields as well as HI were obtained by the check treatment (0 P) followed by application of 10 kg ha^{-1} P. Application of 30 and 50 kg ha^{-1} P produced significantly mean grain yields differences with control and 10 kg ha^{-1} p application while not significantly different from application of 20 and 40 kg ha^{-1} P (Table 1). Significance increase/differences of mean maize grain yield between treatments due to P application could be because of low available P which might have attributed due to prevailing soil acidity. Similar work by Wasomga *et al*, 2008 at western Kenya on acidic soil with inherent low soil P confirmed that the application of high P (39 kg ha-^{1} P) produced significantly highest grain yield.

Significantly the lowest mean maize HI, 0.317 was obtained by the check treatment (0 P) against the highest mean HI, 0.368 which was obtained by application of 30 kg ha^{-1}. Obviously, HI is governed by the ratio of grain yield to above ground biomass where in this case, application of 30 kg ha^{-1} produced significantly the highest grain yield but not the highest biomass yield. Indeed, more grain filling was attributed by this treatment compared to biomass production (Table 1). The work by Wasonga *et al.*, 2008 demonstrated similar result whereby highest HI of hybrid maize was higher for application of P at 26 kg ha^{-1} which produced relatively lower biomass.

Soil Reaction

The ranges of initial soil pH value of 21 test sites were between 4.85 and 6.13. Soil pH after 21 days of maize planting decreased to the ranges between 4.53- 5.35 with the mean of 4.84, even lower than the mean soil pH of 5.0, recorded during maize harvest (Fig 3). The mean reduction of pH by 0.4 during 21 days of maize planting could be attributed due to warm soil condition favoring combined effect of organic acid released by microbes and growing plant roots. The result obtained is justified by research results of Fatubarin and Olojugba (2014) recorded the lowest pH during the peak rain after planting and the highest pH during the dry season and beginning of rain.

Table 1 Biomass, grain yields and HI of maize as affected by P fertilizer application at Bako during 2015 and 2016 main cropping seasons

P kg ha^{-1}	Biomass kg ha^{-1}	Grain yield kg ha^{-1}	HI
0	20642c	6431c	0.317c
10	22648b	7705b	0.343b
20	23923ab	8225ab	0.349ab
30	23112ab	8346a	0.368a
40	23528ab	8254ab	0.356ab
50	24402a	8502a	0.353ab
Mean			
SE ±	602.99	197.74	0.0069
CV %	20.78	19.84	15.93
LSD 5%	1676.8	549.9	0.0194

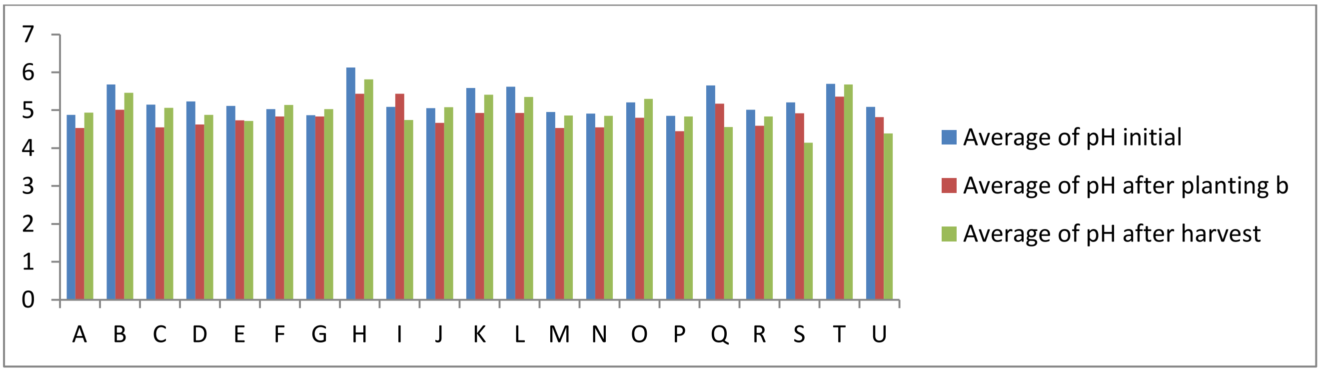

Fig. 3 pH values of initial, 21 days of planting and after maize harvest from 21 farmers' field during 2015 and 2016 main cropping seasons

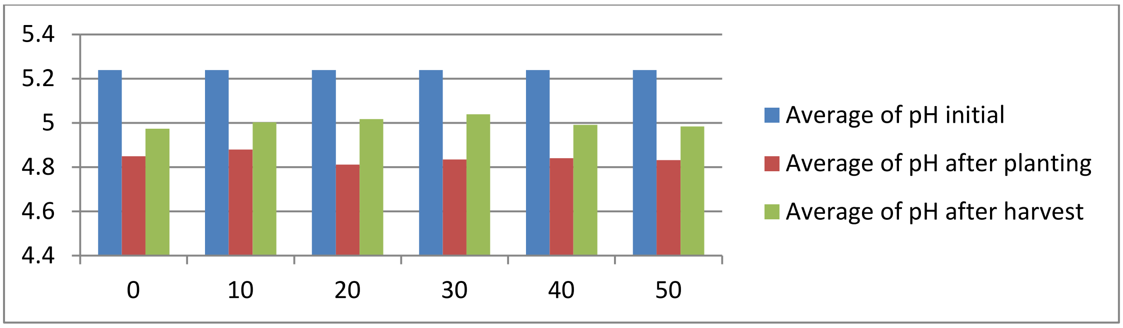

Fig. 4 Mean pH values as affected by time of sampling (initial, 21 days of planting and after harvest of maize) during 2015 and 2016 main cropping season

Critical P Concentration (P_c) and P Requirement Factor (P_f)

The critical P level in the top 20 cm soil depth was 14.5 mg kg^{-1} (Fig 5). The result obtained implies that P fertilizer could be applied to maintain soil P at this level. Moreover, in soils with available P less than 14.5 mg kg^{-1}, maize shows considerable yield response to application of P fertilizers. However, in soils with available P greater than 14.5 mg kg^{-1}, further addition of P fertilizer might have yield increase at increased cost of fertilizer.

The calculated P_f ranged between 4.2 and 6.4 with the overall average P_f 5.5 (Table 2). This value quantifies additional information required when the soil test value is below the critical level. Indeed, the P_f in this study, the amount of P in kg needed to raise the soil P by 1mg (P_f) that enables to determine the quantity of P required ha^{-1} is designated as 5.5. The calculated value also establishes the quantity of P requirement $ha^{-1}$to raise the soil test by 1mg.

Table 2 determination of P requirement factor for maize in the sub-humid areas of Bako, 2015 and 2016 main cropping season

P rate kg ha^{-1}	Average	P increase over control	P requirement factor (P_f)
0	7.2		
10	8.8	1.6	6.3
20	11.9	4.7	4.2
30	13.5	6.3	4.7
40	14.3	7.1	5.6
50	15.0	7.8	6.4
	Average		5.5

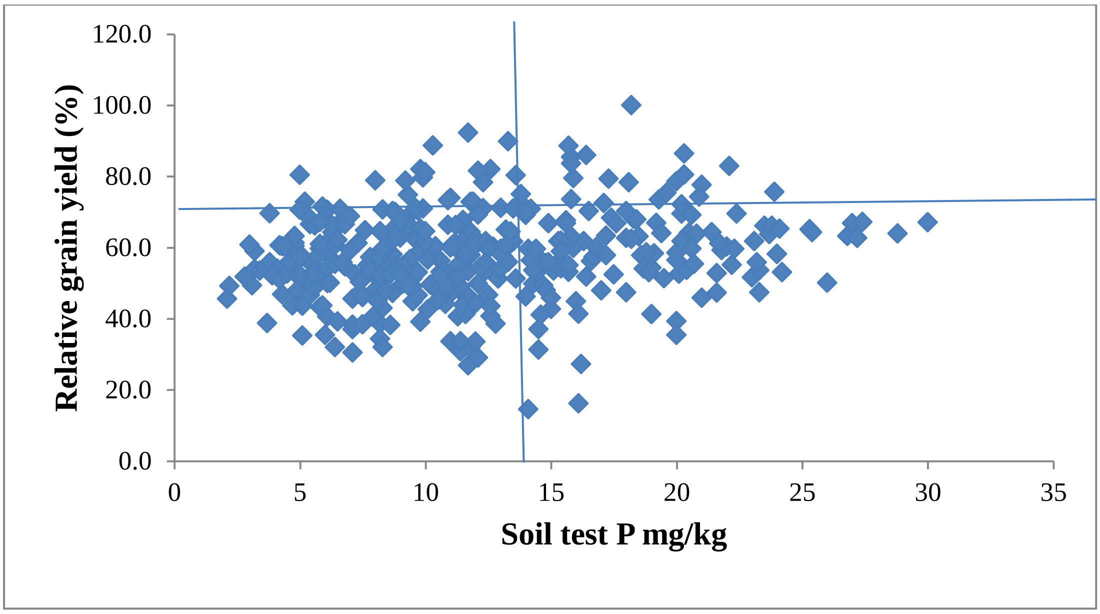

Fig. 5 determination of P critical for maize in the sub-humid areas of Bako, during 2015 and 2016 main cropping season

Conclusion and Recommendation

Phosphorous is required by plants throughout growth and development. It is required primarily for storage and transfer of energy produced by photosynthesis. Root and shoot growth is also enhanced by nutrient P whereby inadequate P sources affect energy storage, growth and reproduction in plants. Availability of soil P in the sub-humid high rainfall and acid soil varies depending on factors influencing its availability. The blanket fertilizer recommendation didn't consider the nutrient differences of farmlands which resulted in inefficient utilization of fertilizers. On the contrary, this study delivers P fertilizer requirement and gives quantitative guidelines and recommendations of P fertilizer for maize production at Bako area. Moreover, the critical P level (14.5 mg kg^{-1}) and P requirement factor (5.5), basis for determination of P fertilizer for a given farmland has been identified and considered paramount important section of the study.

References

Agegnehu Getachew, Amare Ghizaw and Woldeyesus Sinebo. 2006. Yield performance and land-use efficiency of barley and faba bean mixed cropping in Ethiopian high lands. *Europ J. Agron. 25: 202-207.*

Amsal Tarekegn and D. Tanner, 2001. Effects of fertilizer application on N and P uptake, recovery and use efficiency of bread wheat growm on two soil types in central Ethiopia. *Ehiop. J. Nat. Res.3:219-244.*

Bationo, A., A. Hartemink, O. Lungo, M. Naimi, P. Okoth, E. Smaling and L. Thiombiano, 2006. African soils: Their productivity and profitability of fertilizer use. *African fertilizer summit.* Abuja, Nigeria. *1-29.*

Bray, R.H. and L.T. Kurtz 1945. Determination of total organic carbon and available phosphorus in soils. *Soil Sci.59:39-45*

Corey, R.B., 1987. Soil test procedures, Correlation soil testing: Sampling, correlation and interpretation. pp. 15-22. *In:* J.R. Brown (ed.). SSSA Spec. publ. 21. SSSA, Madison, WI.

Dodd, J.R. and A.P. Mallarino, 2005. Soil-test phosphorus and crop grain yield responses to long- term phosphorus fertilization strategies for corn/soybean rotations. *Soil sci. Soc. Am. J. 69:1118-1128.*

Fatubarin, A. and R. Olojugba, 2014. Effect of rainfall season on the chemical properties of the soil of a Southern Guinea Savanna ecosystem in Nigeria. *J. of Eclogy. and the Natural Env.6(4):182-189.*

Francirose, S., S. Andrew and I.P. Luis, 2007. Rainfall intensity and phosphorus source effects on phosphorus transport in surface runoff from soil trays. *Sci. of The total Environ.373 (2007):334-343.*

Haileselassie A., J. Priess, E. Veldkamp, D.Teketay, and J.P. Lesschen, 2005. Assessment of soil nutrient depletion and its spatial variability on smallholders' mixed farming systems in Ethiopia using partial versus full nutrient balances. *Agric. Ecosyst. Env.108:1-16.*

Kjeldahl, J. 1983. A new method for the estimation of nitrogen in organic compounds. *Z. Anal. Chem. 22, 366.*

Nelson L.A. and Anderson R.L. 1977. Partitioning soil test – crop response probability pp.19-39. *In:* Peck, T.R. (ed.). Soil testing: correlating and interpreting the analytical results. American society of agronomy, Madison, W.I. , USA.

SAS. 2002 . Statistical Analysis System (SAS), user guide, statistics SASA nc. cary. Northern Carolina, USA.

Tesfa Bogale, Tolessa Debele, Setegn Gebeyehu, Tamado tana and Negash Geleta and Tenaw Werkayehu, 2001. Development of appropriate cropping system for various maize producing regions of Ethiopia. pp. 61-70. *In:* Mandefro Nigussie, D.Tanner and S. Twumasi-Afriye (seds.). Enhancing the contribution of maize to food security in Ethiopia. Proceeding of second national maize workshop of Ethiopia. 12-16 November 2001. Addis Ababa, Ethiopia.

Walkley, A. and I.A. Black.1934. An examination of Degtjaref method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci. 37:29-37*

Wasonga, C.J.;\, D.O. Sigunga and A.O. Musandu, 2008. Phosphorus requirement by maize varities in different soil types of western Kenya. *African crop Sc.J. 16(2): 161-173.*

Zeleke Gete, Agegnehu Getachew, Dejene Abera and Shahidur Rashid, 2010. fertilizer and soil fertility potential in Ethiopia: Constraints and opportunities for enhancing the system. Food Policy Research Institute. Washington DC, USA. 66p.

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Watershed Management Research

Assessment and Resources characterization of Ilasa Watershed in Goba distinct, Bale Highland of Southeastern Oromia, Ethiopia

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Abstract

Lack of baseline information on land degradation for agricultural development is one of the major obstacles to deliver appropriate technology to a given area based on agro ecological and farming system. The relevance of identifying Ilasa watershed problems is vital for better understanding, planning, and implementing of sustainable land management through integrated watershed management approach. Survey as well as delineation and mapping of the selected Ilasa watershed was conducted during 2016 fiscal year in Goba district of Bale highland southeastern Oromia, Ethiopia With the objectives of generate baseline information and document on biophysical, socio - economic characteristics in addition to mapping and delineation of a given watershed based agro ecological and farming system. The watershed was selected purposively based on the severity of land degradation. Moreover During the study simple random sampling technique was used with multiple methods of data collection such as household surveys (considering both upper and downstream), field observations, Focus Group Discussion and key informant/experts interviews. The results of base line survey indicated that land degradation is one of the major challenging problems for production and productivity improvement and the capability of the livelihood of smallholder farmers. Generally survey study identified five major preliminary categories of land degradation from very low to very high. To overcome these problems appropriate interventions using participatory integrated watershed management approach that encompass all concerned stakeholder is forwarded.

Keywords: Watershed, Characterization, Prioritization, baseline

Introduction

The importance of watersheds as ecological units in the context of natural resource management and conservation cannot be overstated. A watershed is the landscape that contributes surface water to a single location, such as a point on a stream or river, or a single wetland, lake or other waterbody (Langbein and Iseri, 1960; Dingman, 2002; Brutsaert, 2005).Watersheds provide a range of ecosystem services that are valued by the society (Costanza *et al.*, 1997, 2014; TEEB 2010). These include supporting services (e.g. soil formation, nutrients and primary production), provisioning goods and services (e.g. food, water, wood, fibre and fuel), regulating services (e.g. climate regulation, flood regulation and water purification) and cultural services, such as recreation and spiritual activities (de Groot et al., 2002; Millennium Ecosystem Assessment, 2005).

Watershed projects in developing countries generally however focus on typically three objectives, namely, to conserve the natural resource base, optimise agriculture with other natural resources and support rural livelihood to alleviate poverty (Kerr, 2007). For sustainable management of natural resources, various policies have been drafted, the most promising of which is the management of natural resources through participation of the local people (Bagherian, Goodarzi, & Shadfar, 2011). Before conducting the implementation of soil conservation and watershed management, problem identification with participation of people make farmers more willing to accept this technology.

So, to develop a successful soil conservation programme, the review of socio-economic challenges in a watershed is essential (Karimi & Lari, 1995). This had led to an increase in the success rate of watershed management projects (Hematzade & Khalighi, 2006; Shafiee, Rezvanfar, & Hohieni, 2008). Non conservation strategies for cultivating on steep slopes were the initial cause of the problem of land degradation, soil erosion, deterioration of soil physical properties and a steady decline of soil fertility in watershed regions in tropical areas (Aneckasampant *et al*. 1992). Similarly land use practice in the selected Ilasa watershed area was without consideration for the importance of soil and water conservation measure, which leads to the rapid degradation of land that affects soil fertility as well as soil productivity.

The country has been experienced watershed degradation due to rapid population growth and land use changes that impacting negatively on biophysical, socio- economic and institutional arrangement on the environment in the country (Tiften *et. al*., 1994, Munyasi *et al.,* 2010; GOK, 2012). The declining of soil fertility, poverty aggravation, deforestation, diminishing land holding and erratic rainfaal patterns contributed toward watershed degradation (Muriuki *et al.,* 2005). According to wamalwa (2009), watershed degradation is influenced by land use methods and modification, high population, increase demand for food and rapid economic growth with negative impact on bio physical and, socio- economic and institutional arrangements.

UNEP (2006) also stated as rapid population growth, poverty and social inequities contributed towered watershed degradation. Similarly selected Ilasa watershed area was under the pressure of rapid land degradation that impairing sustainable land productivity. So, to tackle this problem immediate measure has to require. While, understanding historical and present biophysical characteristics of the watershed are very important to develop action plans and intervention measures. But there is little or no information concerning type and depth of the problem, case of the problem, socio-economic condition of the farming community, and generally bio-physical as well as agroclimatic information of the study area to plan and implement intervention. Therefore this project was initiated for the following objectives:

Objectives:

- To establish common understanding in integrated watershed management among the stakeholders through training
- To delineate and map the selected Ilasa watershed area based on agro-ecologies, farming system, and level of land degradation.

- To characterize, identify, prioritize and analyze biophysical and socioeconomic issues
- To prepare action plans and intervention measures for the priority issues in the selected watershed with full community participation.

Material and Methods

Characterization of the Study Area

The study was conducted at Goba districts in Ilasa watershed which is situated 25km away from Goba town of Bale zone to East direction where soil erosion, gully formation and loss of agricultural land are a serious problem for production and productivities in the area. It is geographically located between UTM 40^0 4’81’’E $6^0$59’29’’ N which is the Northern or the lower part of watershed bounded by Walti Magida kebele to 40^0 5’61’’ E and $6^0$57’21’’ N which is the upper or southern part of watershed bounded by Barbare district , while on the western part of watershed $40^0$41’13’’E to $60^0$58’24’’N wich is bounded by Walti Qubsa kebele and $40^0$5’26’’E to $6^0$58’46’’N which is the eastern part of watershed bounded by Wacho Misirge. The altitude of the watershed generally ranged from 500 to 600 msl with total area coverage of 506 ha.

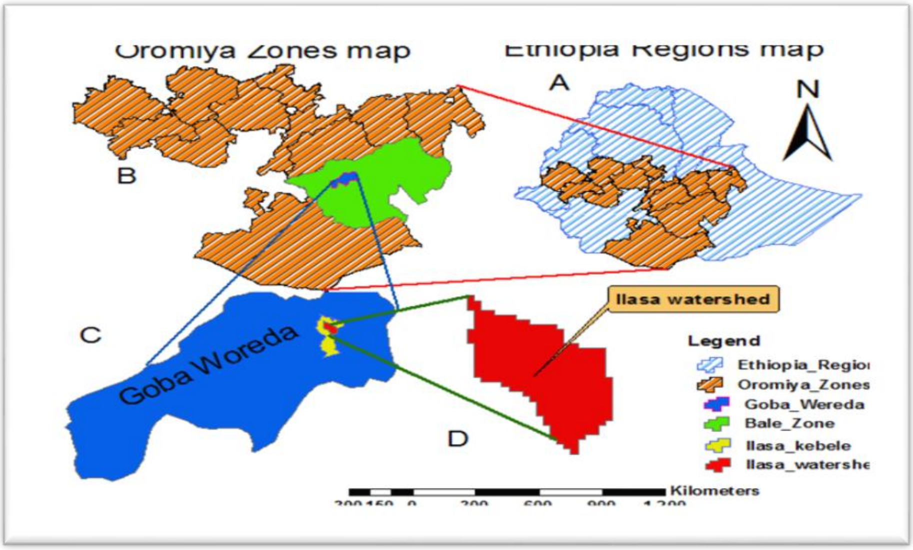

Fig 1. Topographic map of Ilasa watershed of Goba district

Project Phase Analysis

The project was implemented in two Phases. The first phase was survey and planning phase while the second phase will be an intervention phase.

Selection and Mapping of the Watershed

The map of the Ilasa watershed was developed and delineated based on the identified preliminary outlet, whereas the watershed boundary was delineated using primary data (GPS reading), Secondary data (topographic map 1:50,000) and in consultation with the local communities. The delineated watershed was geo-referenced and digitized for its contour, roads, rivers, and other features. The preliminary delineated boundary was verified in the field and finally, map of the watershed were produced; other information such as elevation ranges, area, slopes and aspect was extracted.

Biophysical Resource Surveys

The seasonal climate pattern of the watershed was determined using data collected from the nearest weather stations. The most rainfall features include onset date, end date, duration, dry spells and rainfall amount and intensity which serve as a basis for land capability and determination of the risk of production.

Socio Economic and Farming System Analyses

Surveying was conducted using structured questioner to identify the existing farming system and the associated opportunities and constraints of production. Important parameter for Socio economic and farming system database establishment was also collected. Survey conducted using questionairs to quantify important variable were included group discussion, trend analysis, and problem ranking to generate. SPSS computer software was used for socioeconomic data analysis. Based on the data obtained, statistical tools like cross tabulation, percentages, graphs, was used to analyze quantitative data. Generally, after data analys (biophysical and socioeconomic survey data), problems of the watershed were identified and prioritized accordingly.

Data Collection

Data Types and Collection Methods

The data used for this study were collected from both primary and secondary data sources. Primary data pertaining to demographic and socio-economic characteristics, participation in agricultural extension activities of farmers, farmers level of soil and water conservation practices, major agricultural productivities and production constrains were collected from sampled farm households using structured questioner. Participatory problems identification through close field observations both upper stream and downstream of Ilasa watershed were the process of the primary data collection. Primary data collection made between May and June, 2016. To supplement the primary data, secondary data were also gathered from concerned district Bureaus of Agriculture and Rural Development and from published and unpublished sources.

Sampling Technique

Farmers' household level survey was conducted to collect quantitatives data about biophysical and resource characteristic of Ilasa watershed. The study used multiple methods of data collection such as household surveys, field observations, Focus Group Discussant interviews (FGDs) and key informant/experts interviews to gather information by sampling households along a vertical transect lines. Twelve (12) respondents for focus groups discussion were interviewed whereas five (5) key informant respondents were drawn among the people with technical expertise and active role community issue. During the study simple random sampling technique was used to select sample respondent with some stratification based on watershed position considering both upper stream and downstream of the watershed and a total of 67 sample sizes were considered.

Data Analysis

The quantitative data collected through questionnaire based survey were entered into Statistical Package for Social Sciences (SPSS) computer program and analyzed using descriptive statistics as well as using various analytical tools based on the objectives of the baseline survey.

Result and Discussion

General Socio-Economic Characteristics of the selected Ilasa watershed

As indicated in Table 1, general socioeconomic characteristics assessed at household level were age catagory, educational level of household head, family size, farm size, etc. Such characteristics help in knowing the community for planning an intended intervention for the implantation of phase II watershed management. These characteristics also determine the extent to which the community will adopt the intervention and can be helpful in devising a strategy for entering into the community development work.

Population and Social Status of the Community in Ilasa Watershed

The total population of Ilasa was 3,822 and out of which 39.82 % was male and the rest was female as presented in Table 1. Household size and other characteristics are directly related to supply and demand, which exert impact on watershed that in turn influences on adoption of integrated watershed management technologies. Among 67 respondant, 97% were male household heads while 3% were female household heads. The livelihods of the rural farming community (households) were mainly depend on agriculture which requires more labor that include land preparation, planting, weeding, cultivation, harvesting, threshing, animal keeping, fetching water and fire wood and practices of any land management measure . Therefore, family size with age composition is important to carry out different agricultural activities, i.e., larger family size with the productive age category is important in rural households to share barden. According to the survey result, the minimum and maximum family size of the sample farming households was 1 and 13, respectively.

Age is one of the important characteristics of the community which plays a significant role in any kind of employment pattern, mobility and quality of work done, particularly in agriculture, because the use of child labor on the farms is quite high. The respondents are divided into three age groups (i.e. up to 15, 16 to 60, and above 60 years of age). The idea behind these classes is that the middle group (16-60 years) is the most productive age group in farming. Hence, according to baseline survey made, the mean age of the sample respondent is 44 while the maximum and minimum ages of the respondant household heads were 17 and 75, respectively (Table 2).

Education is one of the influential socio-economic factors which play’s considerable roles in the lives of the community. That means, education level of farming community affects scop of their understanding and decision-making processes as well as adoption of new farming technologies. Accordingly the baseline survey results (Table 2) indicated that , the majority of the respondents’ (47.8 %) education levels were ranged between grade 1-6 from total sampled house hold and 22.4 % were between 7-8 while 13.9% of sampled farmers were illiterates.

Table 1. Total population characteristics of the selected Ilasa watershed community

Sex Category	**Agro ecological zone**
	Ilasa watershed
Total population	3,822
Male	1522
Female	1319
HH heads (land owners)	
Male	428
Female	51

Source: District Agricultural Development Offices.

Table 2. Selected house hold characteristic in Ilasa watershed (N= 67)

Characteristic	**Descriptive Statistics**			**Frequencies**	
	Minimum	Maximum	Average	Frequency	In percent (%)
Number of house hold	1	13	7		
Gender respondent					
Male	65	-	-	65	97
Female	2	-	-	2	3
Mean average age of Household head	17	75	44	-	-
House hold family age categories					
1-15 Male	-	4	2	-	-
1-15 Female	1	4	2	-	-
16-60 Male	1	6	2	-	-
16-60 Female	1	6	2	-	-
Greater than 60 Male	-	1	1	-	-
Greater than 60 Female	-	-	-	-	-
House hold family size	1	13	7	-	-
Level of education house hold					
1-6	-	-	-	32	47.8
7-8	-	-	-	15	22.4
9-10	-	-	-	9	13.4
11-12	-	-	-	1	1.5
Greater than 12	-	-	-	1	1.5
Illiterate	-	-	-	9	13.9

Source: own computational result

Land Use type and Land Size Characteristic in Ilasa Watershed

Land is a major determinant of the farm income and control over land has a strong association with the adoption of new farming techniques. Farm productivity is closely related to the size of the farm (Sharif et al. 1986). Accoring to baseline survey result (Table 3), the majority of the respondant farmers (98.5 %)

owned land size that range from 0.33 to 7 hector and on the average 2.9 hector. The most common activity of household's for their livelihood was crop production including cereals, pulses and oil seeds in dominating order. The choice of livelihoods strategies, farmers' land use methods and land management practices, has impact on health of the watershed that affect sustainable production as well as the livelihood strategies of the farming community (Ifejiika *et al*, 2007; Muia and Ndunda, 2013). It has been observed that the distance between the farmland and a homestead were one of the factors enhanced land degradation particularly in maintaining soil and water conservation measure and field monitoring.

Table 3. Household land holding and Land use types Characteristic in Ilasa watershed (N= 67)

Characteristics	**Frequency**	**In percent (%)**	
Own agricultural land			
Yes	66	98.5	
No	1	1.5	
Occupation			
Agriculture	67	100	
Trade	-	-	
Government worker	-	-	
Secondary occupation	-	-	
Agriculture	-	-	
Trade	12	17.9	
Government worker	-	-	
	Minimum	**Maximum**	**Average**
Total land holding (ha)	0.33	7	2.9
Way of Land access			
Inherited	0.17	5	2
From government	-	5	1.98
Rent in	-	3	0.86
Land use type (ha)			
Cultivated land	0.13	5	1.93
Grazing land	-	2	0.46
Woodlot	-	17	0.75
Homestead	0.08	1.5	0.38
Distance of residence from farm land (km)	0.5	15	5.7

Source: own computational result

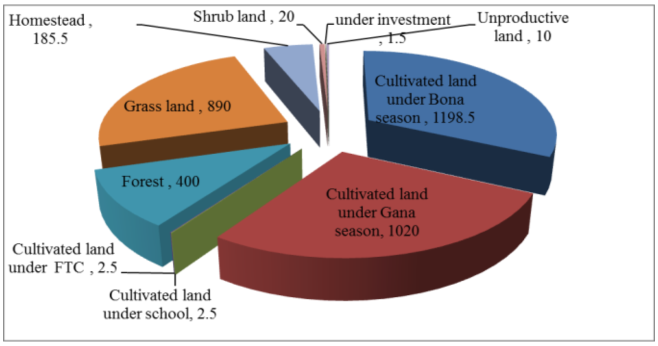

Fig 2. Land use type characteristic of Ilasa watershed in hector

Table 4. Major crop production and Cropping pattern in the selected Ilasa watershed

Major Crop type grown in the area	Descriptive statistic			
	Minimum	Maximum	Mean	Std. Deviation
Wheat				
Wheat area cultivated	0.17	4.00	1.24	0.97
Wheat total obtained	0.17	150.00	33.71	28.16
Wheat home consumption and seed	2.00	55.00	17.94	11.60
Wheat amount sold	.00	140.00	22.81	31.14
Barley				
Barley area allocated	0.17	13.00	0.75	1.74
Barley total obtained	0.17	160.00	15.09	20.62
Barley home consumption and seed	1.00	30.00	11.69	6.52
Barley amount sold	.00	12.00	4.21	4.19
Emmer wheat				
Emmer wheat area allocated	.00	2.00	0.41	0.34
Emmer wheat total obtained	.00	21.00	8.03	4.32
Emmer wheat home consecution and seed	.00	16.00	2.39	2.96
Emmer wheat total sold	.00	13.00	6.75	3.68
Faba bean				
Faba bean area allocated	0.17	1.00	0.36	0.26
Faba bean total obtained	1.00	10.00	4.55	2.37
Faba bean home consumption and seed	.50	4.00	2.59	1.24
Faba bean total sold	2.00	7.00	3.59	1.36
Field pea				
Fied pea area allocated	.00	.25	0.063	0.13
Field pea total obtained	.00	5.00	1.25	2.50
Field pea home consumption and seed	.00	1.00	0.25	0.5000
Field pea area total sold	.00	4.00	1.00	2.00
Cropping pattern	Frequency	Percent (%)		
Mono cropping	48	71.6		
Mixed cropping	3	4.5		
Crop rotation	16	23.9		

Source: own computational result

Major Crops and Crop production Constraint in the Selected Ilasa Watershed

The result of baseline survey (Table 4) indicated that Crop production is one of the major agricultural activities undertaken by community in the selected Ilasa watershed. The main crops cultivated are cereals and legumes with few horticultural practices, mainly potato. The major dominating produced cereal crops in the study were wheat followed by barely, emmer wheat and pulse crop such as Faba bean and field pea. The most crops produced in the area were used for home consumtion and seed, while a small part were sold at local markets to cover cost of agricultural impots and other. In addition to crop production and livestock rearing, households also engaged in off-farm activities. The common type of off-farm income generating activities is petty trade. About 17.9 % of households in the area are involved in these income generating activities in addition to agricultural practices.

On the other hand, as indicated in the Table 5, the major constraints identified for crop production in the area during baseline survey were land degradation, high price of chemical fertilizers, shortage of improved seeds, existence of pests, diseases and weeds that were contributed significantly to reduction of production. These major production constraints were ranked by farmers while Pair wise ranking method (Linkov et al. 2005) was employed for main constraints existed in Ilasa watershed (Table 5).

Table 5 problem analysis constraint for crop production in the selected Ilasa watershed

Constraint	**Rank**
Shortage of land	6
Insects, disease, pest's	3
Climatic change	2
Land degradation	1
Lack of agricultural inputs	7
Shortage of improved crop varieties	5
High price of input	4

Source: own computational result

Livestock Production and Feeding Source Characteristics in Ilasa Watershed

The major livestock and feeding source in the selected Ilasa watershed were presented in Table 6 and 7, respectively. The feeding source in the study watersheds is dominantly crop residue (73.1%) followed by grazing land and hay, which cover 17.9% of the total feed source in the area. The contribution of communal grazing land was lower this is because of shortages of grazing land due to expansion of crop lands as a result of increased population as well as degradation of the land.

Different constraints have been also identified during this baseline survey as the factors challenging animal production. Similarly, as indicated in Table 8, using Pair wise ranking method (Linkov et al. 2005) the major constraint for animal productions in Ilasa watershed were prioritized, standing first animal feed shortage followed by improved genotype, marketing and diseases, respectively.

Table 6. Major livestock potential in the selected Ilasa watershed

Livestock type	**Total number of live stock owned by the household**		
	Minimum	Maximum	Mean
Cows	1	6	2
Heifers	1	3	2
Oxen	1	6	3
Sheep	2	20	7
Goats	-	10	3

Donkeys	1	5	2
Horses	-	5	2
Poultry	1	21	5
Beehives	-	14	4

Source: own computational result

Table 7. Characteristics of respondent on livestock feed system in the selected Ilasa watershed

Categories	Frequency	Percent (%)
Own grazing land		
Yes I have	42	62.7
No I haven't	25	37.3
Source of animal feed		
grazing land	3	4.5
crop residue	49	73.1
Fodder	1	1.5
Hay	2	3.0
Grazing land , crop residue	12	17.9
Feel enough animal feed		
I believe that feed is enough	3	4.5
I believe that feed is not enough	64	95.5
Feed shortage season		
dry season	21	31.3
wet season	18	26.9
All year	27	40.3
Reason for animal feed shortage		
population	3	4.5
degradation of grazing land	8	11.9
Agricultural expansion	45	67.2
degradation of grazing land ,agricultural expansion	11	16.4
Reason for animal feed Sold		
Purchase of agricultural input (fertilizer, seed, and hire labor)	23	34.3
Purchase of food grain for house consumption	5	7.5
Because of their low productivity (low milk yield)	4	6.0
Shortage of animals feed	18	26.9
House hold income (taxi , school fee)	5	7.5
Purchase of agricultural input (fertilizer, seed, and hire labor), Purchase of food grain for house consumption and House hold income (taxi , school fee)	9	13.4

Source: own computational result

Table 8 problem analysis constraint for animal production in the selected Ilasa watershed

Constraints n	**Rank**
Animal feed shortage	1
Disease	4
Marketing	3
Lack of improved genotype	2

Source: own computational result

Beekeeping Status and Trend in Ilasa Watershed

According to baseline survey results (Table 9) of Ilasa watershed, beekeeping was practiced by some farming community but much attention was not given on the area to improve their income from the sale of honey, nutrition, and employment opportunities. As a result, the honeybee colony holding per household, trend of beekeeping and honey production became decreased. These changes were attributed due to reduction in honeybee floral resources, increase in agrochemicals, and increase in pests and predators attack, lack of beekeeping equipments and lack of farmer's awareness in solving constraint of beekeeping at watershed level.

Table 9. Beekeeping characteristics in the selected Ilasa watershed

Categories	**Frequency**	**Percent (%)**
Whether the respondent practices beekeeping		
yes I have	11	16.4
No I haven't	53	79.1
Total	64	95.5
Types of beekeeping		
Traditional	10	14.9
Movable frame	2	3.0
Total	12	17.9

Source: own computational result

Topography and Slope Characteristic of Ilasa watershed

The effects of topography on land degradation depends on the slope steepens and slope length. According to (wang *et al*., 2003) reported that ground flat slope is important when considering overall transportation of soil particles. The size and shape of the drainage area and generally its major slope affect runoff rate and velocity. The slope class of Ilasa watershed (Figure 3) range from gently slope to moderately slope which is 2-5% gentle slope, 5-10% slopping, 10-15% strongly slopping and 15%-30% moderately slope according to FAO (2006).

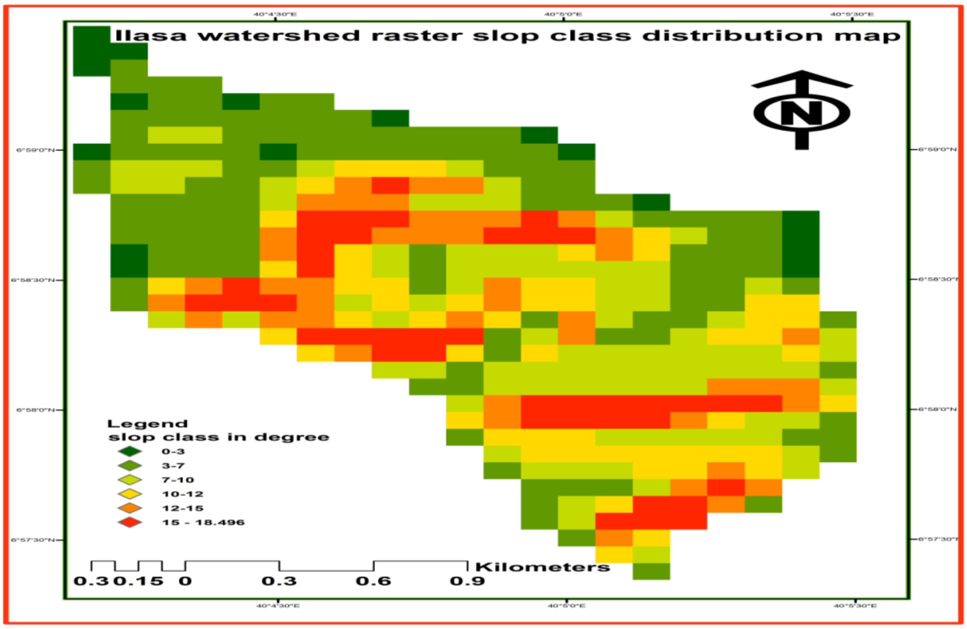

Fig 3. Physical characteristics of slope class map in the selected Ilasa Watershed

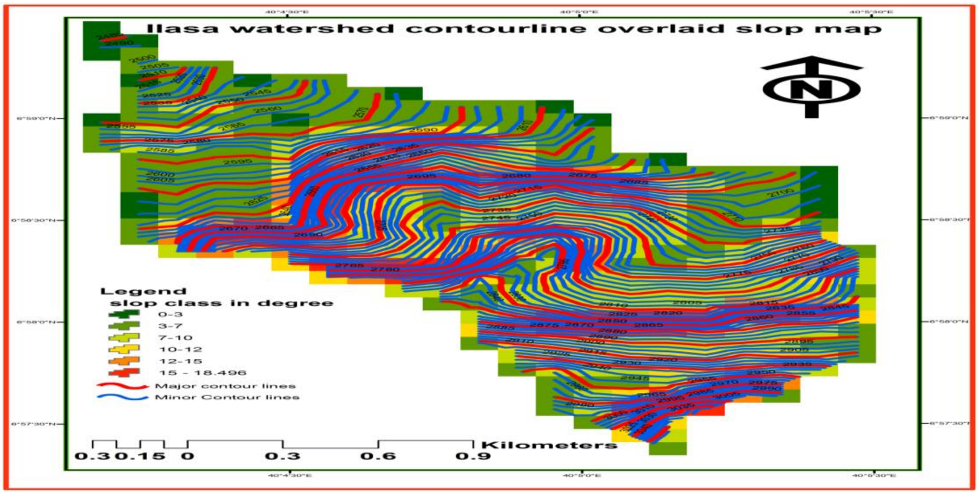

Fig 4. Physical characteristics of slope class map with contour line in Ilasa Watershed

Sub Watershed Characteristic in the Selected Ilasa Watershed

The baseline survey, mapping and delineation results (Fig 2) indicated that Ilasa watershed area coverage is 506 ha, which divided into six sub watershed based on principles that follow water way to river or tributaries to facilitate for integrated watershed management.

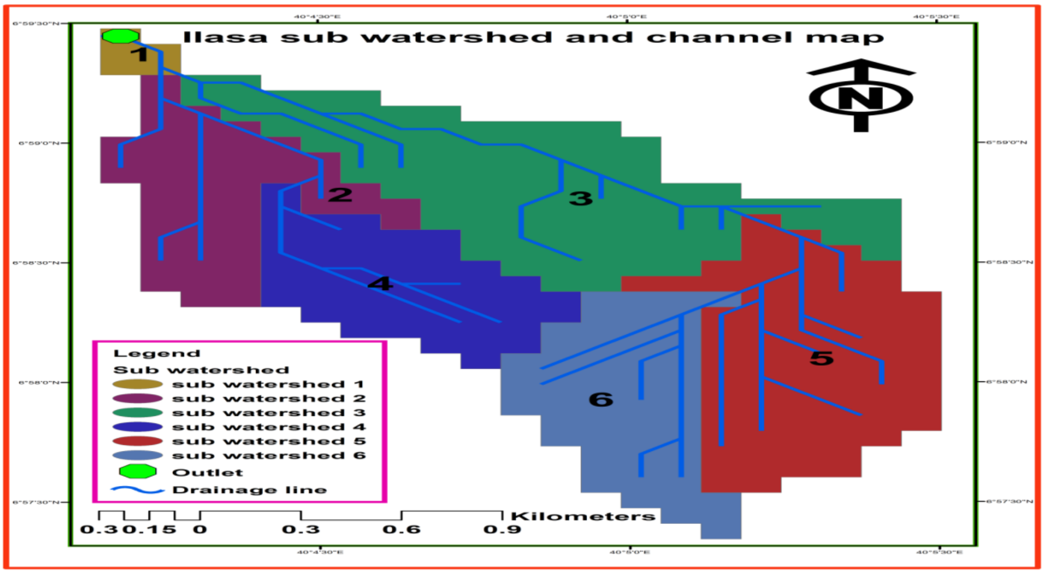

Fig 5 Physical characteristics of Sub watershed map in Ilasa Watershed

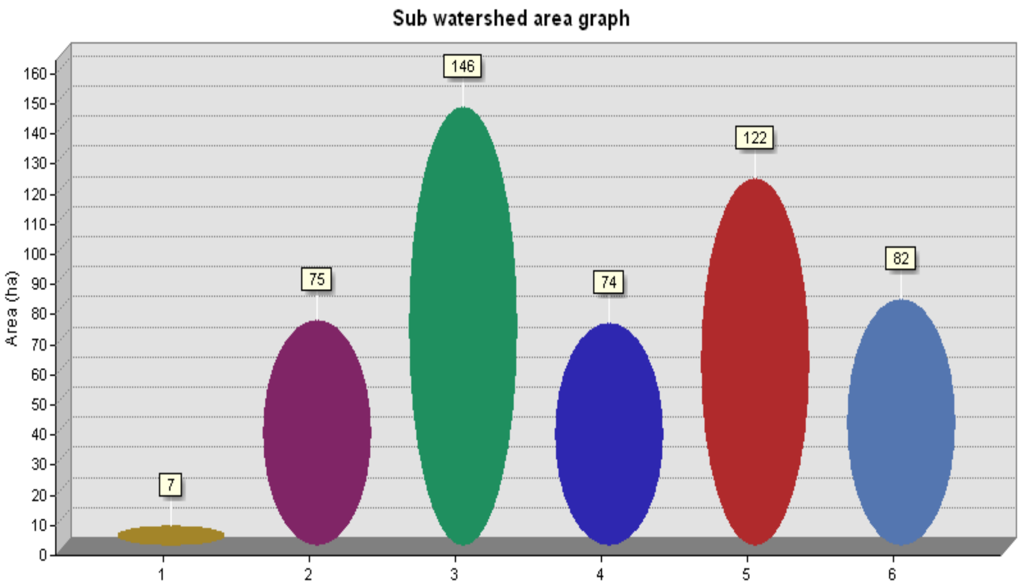

Fig 6 Sub watershed characteristics area coverage in Ilasa Watershed

Vegetation Covers Characteristics in the Selected Ilasa Watershed

Vegetation coverage has got great contribution in rainfall interception, interrupting sediment loss and protecting soil fertility losses. Even thogh, Juniperus procera, Eucalyptus, Olea europace, Hagenia Abyssnica, cordial africana, cuppressus and other shrub as well as bush encouragement are grown in the area, because of expansion farm land, demand for fire wood and construction material, most of the indigenous tree have been exposed to deforestation. According FAO (2010) assessment report, globally around 13 million hectors of forest were converted to other uses or loss through natural as well as anthropogenic activities that cause reeducation in forest area coverage and indigenous species.

Table 10 Characteristics of respondent on tree planting in the selected Ilasa watershed

Categories	Frequency	Percent (%)
Practices tree planting		
Yes	39	58.2
No	28	41.8
Purpose of tree planting		
Fire wood	2	3.0
Construction	20	29.9
Source of income	5	7.5
Environmental mgt	2	3.0
Construction , source of income	5	7.5
Fire wood , construction	5	7.5
Place the farmer plant tree		
Farm land	5	7.5
Homestead	20	29.9
live fence /boundary planting	10	14.9
Homestead , Live fence	4	6.0
Tree species the farmer prefer		
Juniperus procera	4	6.0
Eucalptus	10	14.9
Olea europace	1	1.5
Hagenia, cordia, Junpers, olefera	6	9.0
Juniperus procera and Olea europace	7	10.4
juniporus, Haginia , fodder & frut trees	10	14.9
Plan to plant more tree		
yes	40	59.7
No	1	1.5
Major challenge on natural forest		
deforestation for fire wood, Tiber and construction	40	59.7
Agricultural expansion	5	7.5

Soil Erosion Characteristic in Ilasa Watershed

The rate of soil erosion in Ilasa watershed became serious problem due to land features and anthropogenic factor that particularly related to deforestation and farming activities without proper management practices (Table 11). According to FAO (2005), land degradation encompasses the whole environment that includes individual factors concerning soils, water resources (surface, ground), forests (woodlands), grasslands (rangelands), croplands (rain fed, irrigated) and biodiversity (animals, vegetative cover, and soil). Similarly this survey indicated that in Ilasa watershed, soil erosion is regarded as one of the major and most widespread forms of land degradation, which press severe limitation to sustainable agricultural land use. According to the result of ranking made using Pair wise ranking methods (Linkov et al. 2005) during baseline survey, cause of land degaradation prioritized from high to low as poor farming system, deforestation, lack of soil and water conservations measure and topography.

Table 11 Characterization and analysis causes for land degradtion in the selected Ilasa watershed

Constraints n	**Rank**
Poor farming system	1
Deforestation	3
Lack of SWC measure	2
Topography of land	4

Source: own computational result

Characterization of Erosion Types Exist in the Selected Ilasa Watershed

Ilasa watershed have been affected by all types of erosion (Fig7), which include sheet erosion, rill erosion and gully erosion those contribute 19.4%, 46.3% and 31.3 %, respectively for the existing land degradation problem. According to Bewket and Sterk, (2003) report rill erosion is a result of surface runoff and associated sheet wash, which selectively removes fine material and organic matter that are very important determinants of land productivity. Therefore to overcome such problems the community and concerned sectors should feel sense of responsibility and take appropriate measure.

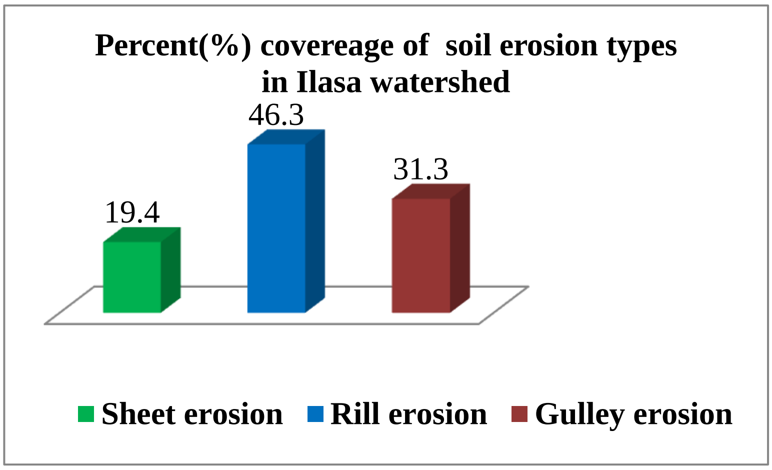

Fig 7. Soil erosion type percentage coverage in Ilasa watershed

Gully Characteristics in Ilasa Watershed

In Ilasa watershed the observed gully type was active gully that increased both in length and width over time showing land degradation severity in the watershed. Most gullies were on cultivated and steep slope areas and along the natural drainage routes.

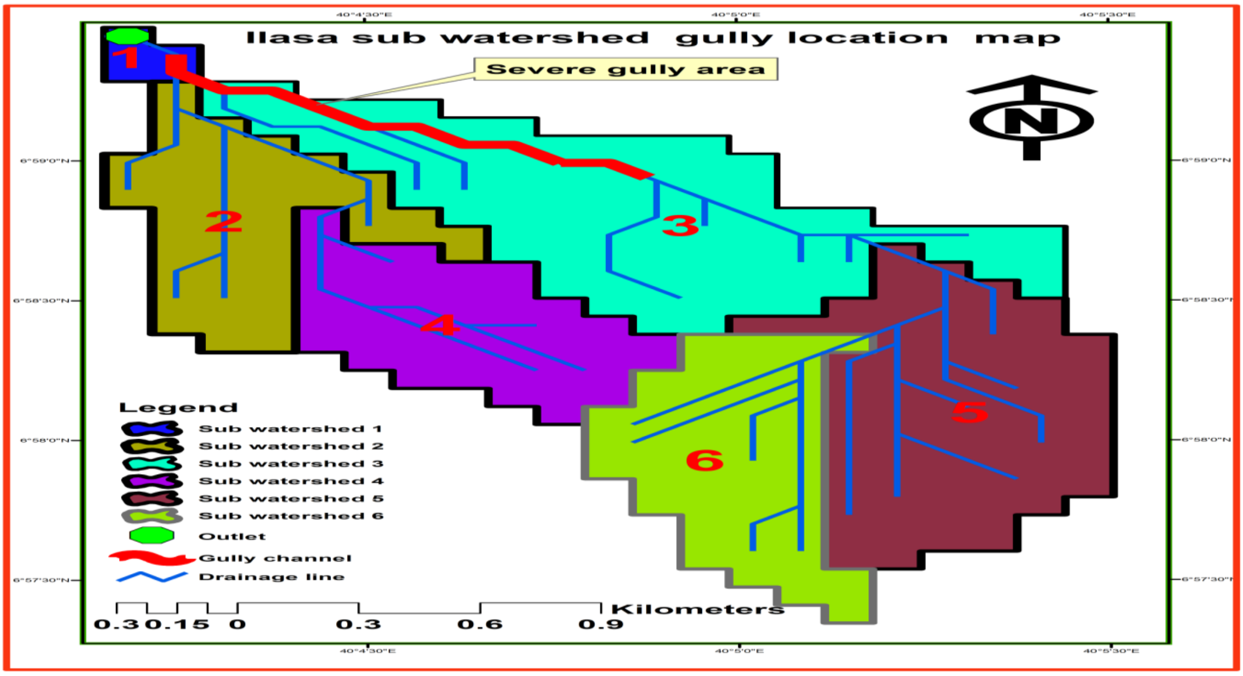

Fig 8 Gully characteristic map of Ilasa watershed

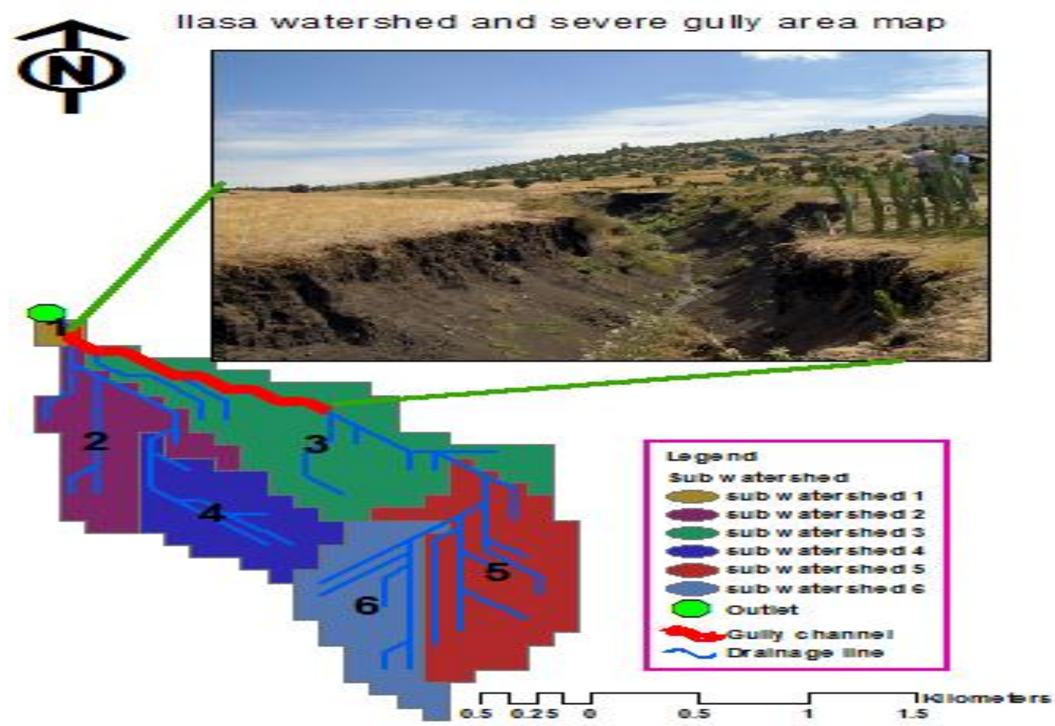

Fig 9. Gully severity and channel characteristics map of Ilasa watershed

Soil and Water Conservation Intervention

There were few soil and water conservation practice in the area mainly soil band and check-dam on farm land. The implemented soil and water conservation measures were not that much effective in reducing soil erosion. This was mainly due to poorly constructed structures, absence of soil water conservation structure on the upper stream of the watershed and due to absence of biological measures that support and stabilize constructed. This finding is also supported by Amsalu and de Graaff, (2006) who reported that the Ethiopia highlands have been exposed to soil fertility decline and severity of soil erosion due to intensive farming on steep slope of land.

Table 12 Farmers' characterization on capacity building and whether apply swc

Categories	Frequency	Percent (%)
Farmer sources of information on agricultural technology		
From experience	4	6.0
Neighbors	2	3.0
Development agent (DA)	18	26.9
Research center	3	4.5
NGO	2	3.0
Agricultural office	27	40.3
From experience, Neighbors, DA, Research center , NGO	10	14.9
Contact of Farmer with development agent (DA)		
Limited	38	56.7
Good	22	32.8
very good	7	10.4
Whether the farmer participate on training		
Yes I take training	34	50.7
No I haven't take any training	33	49.3
Partner give training for the farmers		
Agricultural office	23	34.3
Research center	10	14.9
NGO	3	4.5
Whether Apply SWC measure on his farmland		
Yes	12	17.9
No	55	82.1

Source: own computational result

Community Participation

Community participation in any development work is one of the most decisive factors for fruitful work and its sustainability. For planning purpose, these baseline surveys (phase I) also give much attention for community participation in identifying problem, opportunity, fear and interest of local community involvement in the implementation phase (Phase II).

The results of baseline survey (Table 13) indicated that among 67 respondant household 67.2% will promised to use or to adopt quickly integrated watershed management technology in Ilasa watershed that will be introduced. Because involvement of farmers in problems/gap and opportunity identifications at watershed levels increases their awareness on natural resource management in the watershed. Similarly report by Tenge *et.al*., (2007) also stated that participation of farmers in mapping soil erosion at catchment level creates farmers awareness on soil conservation.

Table 13 Farmers' perception on adoption of the newly introduced technology

Categories	Frequency	Percent (%)
I will pay to use the new techniques very quickly	45	67.2
I will prefer to stay with the old techniques for a few years until other farmers have tried it	18	26.9
I am always reluctant to switch to the new techniques even if other farmers have proved its usefulness	4	6.0
Total	67	100.0

Conclusion and Recommendation

The cause and impact of land degradation in Ilasa watershed had been investigated using various techniques highlighted in the study. It was observed that in addition to the nature of the topography of the land, anthropogenic (human induced) factors had got a great contribution for land degradation that challenging the resident's properties and their livelihoods. Field observation during these studies indicated that runoff caused severe gully formation hinders the production and productivities of the local community. From this survey it can be concluded that Watershed assessment play a vital role in identifying major problems, its causes as well as to come up with possible recommendations for the success of any development works on the watershed. Overall from baseline survey results, it can be concluded that land degradation and biodiversity loss was a serious concern of the area.

Recommendation

1. Awareness creation and strengthen capacity of farming community on Participatory integrated watershed management activities (including SWC measure, planting multi propose tree, grass stripping, use of improved forage grass, conserve animal feed resource and use of modern beehives) in order to reclamate watershed that inturn improve their livelihood.
2. Appropriate integrated watershed management or intervention plan through participatory approach.

3. Organizing and supporting land less young people on watershed for beekeeping practices that contribute for the sustainability and improvement of the area as well as livelihood of the organized group.
4. Stakeholders' involvement, like NGOs and other concerned groups, on integrated watershed management is also an imperative one.

Reference

AMSALU, A. &de GRAAFF, J., (2006), "Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed", in Ecological Economics Vol. 61, No. 2, pp. 294–302.

Aneckasampant C, Boonchee S, Saijapongse A (1992) Management of sloping land for sustainable agriculture in northern Thailand. In 'Asialand: The Management of Sloping Lands for Sustainable Agriculture in Asia (Phase 2, 1992-1994)'. pp. 165-204. IBSRAM Working Document no. 12. Bangkok, Thailand.

Bagherian, R., Goodarzi, M., & Shadfar, S. (2011). Relationship between attitude toward watershed management programs and level of participation. Middle-East Journal of Scientific Research, 9(3), 324–329.

Bewket, W. and Sterk, G.: Assessment of soil erosion in cultivated fields using a survey method-ology for rills in the Chemoga watershed, Ethiopia, Agr. Ecosyst. Environ., 97, 81–93, 2003.

Brutsaert W. 2005. Hydrology: An Introduction. Cambridge University Press: New York.

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P, van den Belt M. 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253–260.

Costanza R, de Groot R, Sutton P, van der Ploeg S, Anderson SJ, Kubiszewski I, Farber S, Turner RK. 2014. Changes in the global value of ecosystem services. Global Environmental Change 26: 152–158.

de Groot RS, Wilson MA, Boumans RMJ. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41: 393–408.

Dingman SL. 2002. Physical Hydrology, 2nd edn. Prentice Hall: Upper Saddle River, New Jersey

FAO (2006). Guidelines for soil descriptions, 5th Edition. FAO, Rome, Italy.

FAO. 2010c. Global Forest Resources Assessment 2010 – key findings.Rome. foris.fao.org/static/data/fra2010/keyfindings-en.pdf.

FAO.2005b. State of the World’s Forests 2005. Rome.

GOK., 2012. WRMA Strategic Plan 2012- 2017. 8-33pp

Hematzade, Y., & Khalighi, N. (2006). Effective factors survey on lake of participation of users in pasture and watershed management design (case study: Golestan Province). Journal of Agricultural Sciences and Natural Resources, 13(4), 32–44.

Karimi, E., & Lari, M. (1995). Farmers’ attitude toward soil conservation: A comparative study. Journal of Extension Systems, 11(1), 11–26.

Kerr, J. (2007). Watershed management: Lessons from common property theory. International Journal of the Commons, 1(1), 89–110.

Kiker, G. A., Bridges, T. S., Varghese, A., Seager, T. P., & Linkov, I. (2005). Application of multicriteria decision analysis in environmental decision making.Integrated Environmental Assessment and Management, 1, 95 – 108

Langbein WB, Iseri KT. 1960. Manual of Hydrology: Part 1. General Surface-Water Techniques. General Introduction and Hydrologic Definitions. Geological Survey Water Supply Paper 1541-A. United States Government Printing Office: Washington, DC.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-being: Synthesis. Island Press: Washington, DC.

Muia VK, Ndunda E (2013) Evaluating the impact of directanthropogenic activities on land degradation in arid and semi-arid regions in Kenya.

Munyasi JW, Esilaba RA, Emongor AO, Nyamwaro RA, Maina SO, et al. (2010) Training needs for mainstreaming integrated natural resources in agricultural research and development in institutions in the greater Makueni District, Kenya.

Muriuki GW, Njoka TJ, Reid RS, Nyariki DM (2005) Tsetse control and land - use change in Lambwe valley, south - western Kenya. Agriculture Ecosystems and Environment 105:99 - 107

Shafiee, F., Rezvanfar, A., & Hohieni, M. (2008). An assessment on the farmers' attitude on soil conservation program (case stude: Kharkhe and Dez Dam of Iran). Iran-Watershed Management Science & Engineering Journal, 2(3), 3–10.

Sharif, M. et al. (1986). Constraints Facing Small Farmers in Punjab. Economic Research Institute, Lahore. Siddiqui, R. (2007).A CGE Analysis of Global Rice and Agriculture Trade Liberalization Welfare and Poverty Implications for Pakistan. Pakistan Institute of Development Economics.

TEEB. 2010. The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations, Kumar P (ed)(ed.). Earthscan: London and Washington, DC.

Tenge. A. J. Okoba, B. O., and Aerk, G., 2007 Participatory soil and water conservasion planning using a financial analysis tool in the waste Usamara highlands of Tanzania. Land degradation and Development, 18(3); 321-337.

Tiffen M, Mortimore M, Gichuki F (1994) More people, less erosion: environmental recovery in Kenya. London: John Wiley & Sons. pp: 72-199.

Wamalwa, I. W. (2009) Prospects and Limitations of Integrated Watershed Management in Kenya: A case study of Mara Watershed. Unpublished MSc Thesis, Lunds Universitet. 1-12pp

Wani, S.P., Maglinao, A.R., Ramakrishna, A. and Rego, T.J. (Editors) (2003) Integrated Watershed Manage- ment for Land and Water Conservation and Sustain- able Agricultural Production in Asia. Proceedings of the ADB-ICRISAT-IWMI Annual Project Review and Planning Meeting, Hanoi, Vietnam, 10-14 De- cember 2001. ICRISAT, Patancheru, Andhra Pradesh, p. 268.

Irrigation Research

Performance Evaluation of Hot Pepper Varieties under Drip Irrigation System using Rooftop Rain Water Harvesting at Fadis on Station, Oromia, Ethiopia

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Abstract

Existing fresh water resources are subjected to an ever-increasing pressure due to extensive agricultural water demand for irrigated lands. A long-term perspective in shortage of fresh water resources, especially in arid and semi-arid area, highlights an urgent solution for innovative irrigation technologies and agricultural water management strategies. The experiment was conducted at Fadis agricultural research center farm in Boko station. The aim of the study was to evaluate performance of hot pepper varieties under drip irrigation system using water harvested from roof top on growth and yield parameters. The experiment was arranged in RCBD, replicated three times. Three hot pepper varieties namely: mareko fana, malka awaze and local check were used as experimental crop. The result on yield and plant height showed that there was significance difference (P<0.05) between mareko fana and malka awaze with local check hot pepper varieties when irrigated with equal water application. In case of hot pepper number of main branch, there was significant difference (p<0.05) between each hot pepper varieties under drip irrigation system. Number of fruit per plant, had significance difference between local check and malka awaze. The yield obtained for both mareko fana and melka awaze hot pepper varieties were satisfactory, therefore both varieties were recommended for further use under drip irrigation system in the study area and other similar agro ecologies.

Keywords: Crop water requirement; drip irrigation; hot pepper varieties performance.

Introduction

Water required by crops is supplied by nature in the form of precipitation, but when it becomes scarce or its distribution does not coincide with demand peaks, it is then necessary to supply it artificially, by irrigation. A major reason for the low and erratic rate of growth in agricultural production is the highly uncertain and unpredictable rainfall, combined with low soil fertility (FAO, 2003). Even in years of 'average' rainfall, a shortfall during critical periods of crop growth often leads to widespread crop failure. Therefore, water storage is absolutely crucial for stabilizing and increasing crop yields (FAO, 2003). Several irrigation methods are available, and the selection of one depends on factors such as water availability, crop type, soil characteristics, land topography, and associated cost. In the near future, irrigated agriculture will need to produce two-thirds of the increase in food products required by a larger population (English *et al.*, 2002).

Research and development of water saving agriculture is a challenging task today to make agriculture and industries sustainable in term of water consumption. Although satisfying crop water requirement can maximize production from the land unit, it does not necessarily maximize the return per unit volume of water (Oweis *et al*, 2000). Advanced irrigation methods and water management practices coupled with proper irrigation scheduling can help achieve high crop yields with minimum water applications.

Pepper is extensively used as spice and diet in Ethiopia. There are two important types: hot pepper and sweet pepper. Irrigation is essential in arid and semi-arid regions to provide adequate moisture for production of peppers. Today, many hectares of peppers are grown with irrigation in the semi-arid regions of the world. The total world production of this crop has been estimated to be 14 to15 million tons a year (Weiss, 2002). Della Costa and Gianquinto (2002) reported that continuous water stress significantly reduced total fresh weight of pepper fruits. Moreover, Antony and Singand (2004) found that the total pepper yield was less at lower levels of irrigation.

Ideally, in irrigation schemes, crops do not suffer from water shortages as water is applied before the crops are under stress. However, it may not be possible to apply the irrigation water exactly when it would be best. The farmers may be badly organized and lose too much water at the upstream end of the scheme, thus causing problems downstream. The scheme management may decide to spread the available water over a large area, thus allowing more farmers to irrigate, although less than the optimal amount.

About 90% of the irrigated land of the world is irrigated using relatively inefficient surface irrigation methods (FAO, 2002). Similarly in Eastern Ethiopia traditional surface irrigation methods (basin, border and furrow) are widely used to irrigate crops, though there is acute water shortage. In this region, traditional surface irrigation methods has long been practiced at different farm levels, however, there is no efficient and well managed irrigation water practice. There are very few or no information regarding appropriate irrigation water management practices for the rapidly expanding small scale irrigation farms in the country. Now a day the modern, high-tech and efficient micro irrigation methods (drip, bubbler, sprinkler etc.) are advocated worldwide. Efficient irrigation system or method, such as drip irrigation supply water directly to the plants effective root zone and thereby minimize water loss through evaporation, deep percolation and runoff as compared to surface irrigation. To overcome such problem in areas where water is scarce, the use of modern irrigation techniques will greatly demanding. Therefore; the aim of this study was to evaluate the performance of hot pepper varieties under drip irrigation system using rain water harvested from roof top.

Materials and Methods

Experimental Site

The experiment was conducted at Boko sub-station of Fadis Agricultural Research Center in Fadis woreda. The station is situated at 09^0 07’ 51.6” north latitude, 042^0 04’ 24.3” east longitude and elevation of 1715 m a.s.l. The study area is found at 554 km distance from the capital city of Ethiopia (Finfine) and 24 km from the capital city of Eastern Hararghe zone (Harar). Climatologically, the area received average annual rain fall of 827.59 mm and; mean minimum and maximum temperature of 9.28 and 28.4 ^{0}C respectively.

Experimental Design

Three treatments (Mereko Fana, malka awaze and local check hot pepper varieties) were laid out under drip irrigation in randomized complete Block design. The treatments were replicated three times. The sizes of each experimental plot were 2.4 m x 2.95 m. Distance between plots was 1m and distance between block was 1.5 m. The inter-row spacing of hot pepper was 60 cm which is equal with drip lateral line and plant spacing of 30 cm was used. Transplanting was under taken when the seedling height reached 12-15 cm. Transplanting was done late in the afternoon to reduce the risk of poor establishment and 200 kg/ha of P_2O_5 and 100 kg/ha of N fertilizer were applied through fertigation at initial and mid stage.

Soil Analysis

Soil samples from the experimental plots were taken to analyze bulk density, texture, moisture content at filed capacity and permanent wilting point from the field at three points along the diagonal of the experimental plot at two depth 0-20 cm, 20-40 cm and 40-60 cm and average value was described.

Infiltration Rate of Soil

To determine infiltration rate double ring inflitrometre was used. The measurement was done at two site randomly selected within experimental plot (FAO, 1998).

Crop Water Requirement

Irrigation water was applied based on crop water requirement estimated from the Fadis metrological station. Gross irrigation requirement, net irrigation requirement and all irrigation schedules was calculated with the help of FAO cropwat 8.0 model. Crop evapotranspiration (ETc) was determined for each growing stages as:

$$ETc = Kc * ET_o \tag{1}$$

Where:

ETc = Crop water requirement in mm per unit of time

Kc = Crop factor (crop coefficient)

ET_o = Reference crop evapotranspiration in mm per unit time and it was calculated from climatic data of Fadis meteorological station using FAO Cropwat 8.0 model.

Determination of Water Application Time

The duration of irrigation water application for each treatment was computed as follows:

$$\text{Duraation(hr)} = \frac{\text{Water requirment (mm)}}{\text{Application rate mm hr}^{-1}} \tag{2}$$

Wetted diameter was measured by exposing a vertical plane passing through the point of application by taking three samples from all points of application. Wetted area of each emitter was calculated as:

$$A = \frac{\pi D^2}{4} \tag{3}$$

where;

A = Wetted area covered by each emitter (m^2)

D= Average wetted diameter covered by each emitter (m)

Table 1: Climatic data used in determination of crop water requirement from Fadis meteorological station.

Month	Minimum temperature (^0C)	Maximum temperature (^0C)	Humidity (%)	Wind speed (km/hour)	Sun shine(hour)	Precipitation (mm)
2014/2015 - Growing season						
September	9.7	26.8	60.3	1.8	9.04	28
October	8.3	28.2	34.2	2.16	8.58	10.6
November	8.0	28	37	2.54	7.74	0.00
December	6.5	27.8	27.8	4.29	7.32	0.00
January	6.3	28.5	28.9	6.83	7.28	5.4
2015/2016 - growing season						
November	9.6	30.62	32.8	3.09	7.74	28
December	11.06	29.32	46.04	2.51	7.32	0.00
January	10.92	27.98	56.82	2.01	7.28	8.40
February	10.74	27.66	56.04	2.37	6.44	0.00
March	10.70	28.58	60.3	2.37	6.70	3.62

Irrigation System Design, Field Layout and Water Application Method

Irrigation water was obtained from rooftop rain water harvested during rainy season for the experiment which was then stored in concrete lined reservoir/tank near the experimental plots. Three concrete reservoirs were constructed at appropriate place around the houses for collecting rainwater. Each reservoir was designed to have a storage capacity of 25 m^3, and yielding a total of 75 m^3.

The required amount of irrigation water was applied by drip irrigation system from temporary water storing tank. The water in ground reservoir was fetched into elevated temporary water storing tank. This water was distribution on above ground thank placed at a height of 1.30 m at appropriate pressure head to supply required amount of water for each plot. The main line receives water directly from the water storing tank and distributed each laterals.

Drip system consisted of water storing tank, main lines; sub main lines, lateral lines, emitters and regular filter. The sub main line was connected to the mainline. The drip lateral lines in each plot received equal amount of irrigation water from the sub main line. The spacing between each emitter was 30 cm and between lateral was 60 cm which match with the intra- and inter-row spacing of the test crop.

Statistical Analysis

All agronomic and yield parameters were subjected to analysis of variance appropriate for randomized complete block design (RCBD). The data were analyzed using Genstat 15th edition statistical software. The mean separation was made using fisher protected list significant difference (LSD) method.

Results and Discussion

Soil Physical Properties of Experimental Site

The soil physical properties of experimental site were presented in Table 2. The analysis of particle size distribution indicated that the soil texture at depths of 0-40 cm was sandy loam, but at lower depth (40-60 cm) it was found sandy clay loam. The average soil bulk density (0-60 cm soil depth) was 1.51 g cm^{-3}. The top soil had relatively lower available water content when compared to the subsoil (Table 2). Average value of soil moisture content at field capacity and permanent wilting point was observed as 23.4% and 14.3% in volume base respectively.

Table 2: Soil physical properties of experimental area

depth (cm)	Particle size distribution (%) Sand	Silt	Clay	Soil textural class	PWP (%)	FC (%)	Bd (g/cm^3)
0-20	69	11	20	Sandy loam	13.8	22.4	1.51
20-40	68	12	20	Sandy loam	13.8	22.5	1.51
40-60	66	12	22	Sandy clay loam	14.9	24.0	1.51
Average	67.66	11.67	20.66	Sandy clay loam	14.3	23.1	1.51

Infiltration Rate of Soil

Infiltration rate was measured using double ring infiltrometer. The measurement was done at randomly selected site within experimental area. The field level infiltration test indicated that basic infiltration rate of the experimental area was 21 mm hr^{-1} (Table 3). This result agrees with basic infiltration rate range of USDA (16 -50 mm hr-[1]) for sandy clay loam (NRCS, 1995).

Table 3: Infiltration rate of experimental site

Elapsed time (min)	Time d/f (min)	Cum. Time (min)	Water level reading/ (mm)		Infiltration/difference (mm)	Cum. Infiltra. (mm)	Infiltration rate (mm/hr)
			Before filling	After filling			
-	-	-	-	100	-	-	-
2	2	2	89	100	11	11	330
3	1	3	96	100	4	15	240
5	2	5	94	100	6	21	180
10	5	10	92	100	8	29	48
15	5	15	92	100	8	37	96
25	10	25	89	100	11	48	66
45	20	45	88	100	12	60	24
60	15	60	92	100	8	68	20
70	10	75	95	100	5	73	36
90	20	90	93	100	7	80	21
110	20	110	93	100	7	87	21
130	20	130	93	100	7	94	21

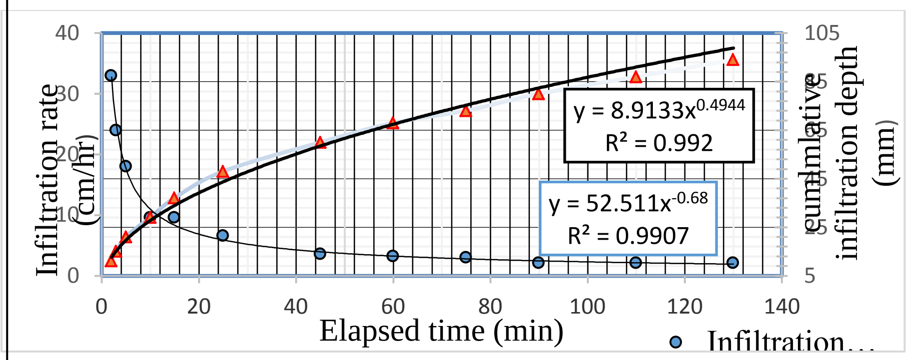

Figure 1: Infiltration rate of experimental site

Agronomic and Yield Related Parameters of Hot Pepper Varieties

Analysis of variance showed that there was significance difference ($P<0.05$) in yield and plant height obtained between mareko fana and local check as well as between malka awaze and local check irrigated with equal amount of irrigation water under drip irrigation system. But there was no significance difference in case of yield and plant height produced by using improved varieties in two consecutive years. Fresh fruit yield of 15.58 and 13.76 ton/ha was produce by mareko fana and malka awaze respectively (Table 4). This might be due to improved varieties selected were high yielder and vigorous in fruit size than local variety. Moreover from field observation more watering local variety resulted in promoting vegetative growth than yield when compared to improved varieties. Under equal water application fruit setting, was on single bunch local check had shown significant variation when compared to improved variety, which was resulted in lower in yield.

Number of fruit per plant, main branches and height of hot pepper were also evaluated. In case of number of main branch, there was significant different ($p<0.05$) between each hot pepper varieties. Statistical output indicated that mean number of fruit per plant, had no significant difference between improved varieties; but local check and malka awaze had significance different at $p<0.05$ (Table 4). The result indicated that regular watering of improved variety may change crop phonology at each growth stage, but local variety might need timing for physiological growth as observed. In addition to this, this result revealed that crop physiological growth and yield may not depend on water supply rather than crop variety.

Table 4: Agronomic and yield related parameters of hot pepper varieties (mean of two consecutive cropping season, 2015 and 2016 years)

Treatment	Yield (ton/ha)	Fruit per plant	No main branch	Plant height(cm)	ETc (mm)	Water used (m^3/ha)
Marakofana	15.58[a]	79.0[ab]	12.2[a]	42.7[a]	445.4	2254
Local check	8.24[b]	73.5[b]	7.5[c]	38.7[b]	445.4	2254
Melka Awaze	13.76[a]	85.3[a]	10.2[b]	44.0[a]	445.4	2254
CV	25.4	4.9	6.3	4		
LSD	3.9*	8.7	1.4*	3.7		

From first season, the yield produced in 2015 cropping season indicated that there was significant difference ($p<0.05$) between mareko fana and local check hot pepper varieties, but no significant difference among mareko fana and malka awaze, and also between malka awaze and local check (Table 5). Similarly mean yield recorded between mareko fana and local check as well as malka awaze and local check in second year (2016) was significantly different at ($p<0.05$), but mareko fana and malka awaze had no significant difference (Table 5).

Table 5: Yield performance of hot pepper varieties evaluated under drip irrigation system for 2015 and 2016 copping season

Treatment	Yield performance of hot pepper varieties in					
	First season (2015)			Second season (2016)		
	Yield (ton/ha)	Water used (m^3/ha)	ETc (mm)	Yield (ton/ha)	ETc (mm)	Water used (m^3/ha)
Marakofana	15.44^{a}	2230.64	433.80	15.72^{a}	456.93	2276.49
Local check	5.30^{b}	2230.64	433.80	11.18^{b}	456.93	2276.49
Melka Awaze	13.25^{ab}	2230.64	433.80	14.27^{a}	456.93	2276.49
CV	33.5			5.3		
LSD	8.61*			1.66*		

Conclusion and Recommendation

Most Ethiopian farmers depend on rain-fed agriculture. However, rainfall is very erratic, and drought occurs frequently in most part of eastern Ethiopia, especially in East Hararghe zone. Due to this problem, a huge activity of rainwater harvesting and also ground water utilization for irrigation sustaining vegetable production at household levels have been going on. Thus, efficient use of irrigation water using appropriate irrigation system and management is an important consideration in the drought prone areas of the region for improving water productivity and crop production.

Therefore, the study was conducted to evaluate the performance of three hot pepper varieties under drip irrigation system using roof top rain water harvesting at Boko sub-station of Fadis Agricultural Research Center.

The yield difference was observed between mareko fana and local check, as well as malka awaze and local check varieties when equal amount of irrigation water was applied by drip irrigation system. The highest fresh fruit yield of 15.58 ton/ha was obtained from mareko fana followed by malka awaze and local check (13.76 and 8.24 ton/ha) hot pepper varieties respectively. Whereas, the yield recorded by mareko fana and mmalka awaze had no significant difference among them for two consecutive growing period (2015 and 2016). Generally, both pepper varieties mareko fana and malka awaze performed well under drip irrigation system. Therefore both pepper varieties were recommended for farmers' as future uses under drip irrigation system in and around study area or in the similar agro ecologies.

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References

Antony, E. and Singandhupe, R.B. (2004) Impact of drip and surface irrigation on growth, yield and WUE of capsicum (Capsicum annuum L.), Agric. Water Manag., 65(2): 121-132.

Della Costa, L. and Gianquinto, G. (2002) Water stress and water-table depth influence yield, water use efficiency and nitrogen recovery in bell pepper: lysimeter studies, Aust. J. Agric. Res., 53: 201-210.

English, M.J.; Salomon, K.H.; Hoffman, G.J. (2002). A paradigm shift in irrigation management, *J. Irrigation and Drainage Engineering*, 128(5), 267-277.

FAO, 1998. Institution and technical operations in the development and management of Small Scale Irrigation. Proceedings of the third session of the Multilateral Cooperation Workshops for Sustainable Agriculture, Forestry and Fisheries development, Tokyo Japan, February 1995, FAO water paper, No. 17. Rome. pp 21 – 38.

Food and Agriculture Organization of the United Nations. 2002. Crops and drops: Making the best use of water for agriculture Natural Resources Environ. Dept., FAO, Rome
FAO (Food and Agriculture Organization of the United Nations). 2003. *A perspective on water* control in southern Africa*:* Support to regional investment initiatives. Land and Water Discussion Paper 1. FAO, Rome, Italy.

Oweis, T. Zhang, H and Pala, M. (2000) Water uses efficiency of rainfed and irrigated bread wheat in a Mediterranean environment. Agronomy Journal 92: 231-238

USDA NRCS (U.S. Department of Agriculture, Natural Resources Conservation Service). 1995. Soil Survey Geographic (SSURGO) Data Base: Data Use and Information. Miscellaneous Publication Number 1527. Washington, DC

Weiss, E.A. (2002) World Production and Trade, CABI Publishing, CAB International, Wallingford, UK.

Evaluation and Demonstration of Drip Irrigation System for Tomato Production at Babile and Dadar Districts of Eastern Hararghe Zone, Oromia Region

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Abstract

Efficient irrigation technologies help establish greater control over water delivery to the crop roots, reduce non-beneficial evaporation and non-recoverable percolation from the field, and return flows into "sinks" and often increases beneficial evapotranspiration. The experiment was conducted on farm at Burqa Gaba PA of Dadar district and Erer PA of Babile dstrict of Eastern Hararghe zone of Oromia. The aim of the study was to evaluate and demonstrate drip irrigation system performance on different tomato varieties in these districts. The experiment was arranged in RCBD, replicated three times. The experimental crops evaluated under drip irrigation were three tomato varieties namely: malka shola, malka salsa and local check. The result on yield showed that there was significance difference (p<0.05) between three tomato varieties at Erer PA of Babile district in two consecutive cropping season. malka shola produced the highest yield (32.60 ton/ha) whereas local check gave the lowest yield (12.73 ton/ha). Similarly, yield recorded by each tomato varieties at Burqa Gaba PA of Dadar had shown significant difference (p<0.05) in the two consecutive years. Malka shola produce the highest yield (31.44 ton/ha) followed by malka salsa (24.886 ton/ha) and local check tomato variety gave the lowest (14.28 ton/ha). The drip irrigation system technology was demonstrated through tomato production to the farmers at the study area. Farmers' perception and feedback towards the technology was collected. The evidences from participants during demonstration show that they prefer and select malka shola tomato variety under drip irrigation and ranked in first place, followed by malka salsa tomato variety which was ranked in second place and local check in the third place based on tolerance to disease, large leaf canopy cover, higher fruit yield, less damage by insects, high juice content, and market demand in both PA's. Based on yield and farmer's perception, malka shola tomato variety was recommended for further promotion under drip irrigation system in the study area and other similar agro ecologies.

Keywords: Crop water requirement; drip irrigation; demonstration; tomato yield

Introduction

Demand management becomes the key to the overall strategy for managing scarce water resources (Molden *et al.,* 2001) since irrigated agriculture is the major competitive user of diverted water. Demand management in agriculture in water-scarce and water-stressed regions would be central to reducing the aggregate demand for water to match the available future supplies (Kumar, 2003a and 2003b). Improving water productivity in agriculture is important in the overall framework for managing agricultural water demand, thereby increasing the ability of agencies and other interested parties to transfer the saved water to economically more efficient or other high priority domestic and industrial use sectors (Barker *et al.*, 2003; Kijne *et al.,* 2003).

Water productivity is an important driver in projecting future water demands (Amarasinghe *et al.*, 2004; Kijne *et al.*, 2003). Efficient irrigation technologies help establish greater control over water delivery to the crop roots, reduce non-beneficial evaporation and non-recoverable percolation from the field, and return flows into sinks and often increases beneficial evapotranspiration. Water productivity improves with reduction in depleted fraction and yield enhancement. Since at the theoretical level, water productivity improvements in irrigated agriculture can result in saving of water; any technological interventions, which improve crop yields, are also, in effect, is water saving technologies.

Research and development of water saving agriculture is a challenging task today to make agriculture and industries sustainable in term of water consumption. Although satisfying crop water requirements can maximize production from the land unit, it does not necessarily maximize the return per unit volume of water (Oweis *et al*, 2000). Advanced irrigation methods and water management practices coupled with proper irrigation scheduling can help achieve high crop yields with minimum water applications.

Tomato (*Lycopersiconesculuntum L.*) is the most important and widely grown vegetable in the world. Its importance is increasing in Ethiopia too (Lema, 2004). It is widely accepted and commonly used in a variety of dishes as raw or cooked or processed products more than any other vegetables.

Ideally, in irrigation schemes, crops do not suffer from water shortages as irrigation water is applied before the crops are go under drought stress. However, it may not be possible to apply the irrigation water exactly when it would be best. The farmers may be badly organized and lose too much water at the upstream end of the scheme, thus causing problems downstream. The scheme management may decide to spread the available water over a large area, thus allowing more farmers to irrigate, although less than the optimal amount.

In Eastern Ethiopia, smallholder farmers largely depend on erratic and often insufficient rainfall, which is significantly reduced their production and productivity. In addition, other factors that have contributed to this are continuous land degradation, and excessive deforestation. Therefore, to overcome such problems, water harvesting, has importance role for farming community. Even though, it needs special emphasis to enhance rain water harvesting for irrigated agriculture and development and promotion government have no or give less attention.

A huge activity of rain water harvesting for irrigation and irrigation scheme are going in the region especially in Eastern Harerge zone, however, the proper management of irrigation water has received inadequate attention given the high cost of irrigation development. Until now the paradigmatic irrigation strategy has been to supply irrigated areas with sufficient water so that the crops transpire at their maximum potential and the full evapotranspiration requirements are met throughout the season (Howell, 2001).

Irrigation systems, such as drip irrigation supply water directly to the plants effective root zone and thereby minimize water loss to evaporation and seepage compared to surface irrigation. Malash *et al.* (2005) recorded higher yield of tomato under drip irrigation than surface irrigation system. In areas where water is scarce, these techniques can greatly increase the efficiency of water delivery. However, most of the drip irrigation technologies were not promoted and utilized by the farmers due to lack of awareness and technical knowledge on the technology. Therefore this study was conducted to evaluate and demonstrate drip irrigation system on performance of different tomato varieties in Babile and Dadar District of Eastern Hararghe Zone of Oromia.

Materials and Methods

Description of Experimental Site

The study was conducted on-farm at Burqa Gaba PA in Dadar district and Erer PA in Babile district of Eastern Hararghe Zone of Oromia. Burqa Gaba and Erer were situated at 07^0 75'56.5" North latitude, 39^0 33' 64.2" East longitude with elevation of 1876 m a.s.l and 09^0 10' 41.5" North latitude, 42^0 15' 27.3" East longitude with elevation of 1274 m a.s.l respectively. Climatic condition of the study site was; Burqa gaba has 10.25 ^{0}C, 25.67 ^{0}C and 1209 mm average minimum and maximum temperature, and annual rain fall (Dadar meteorological station) respectively. Whereas the average minimum and maximum temperature, annual rain fall of Erer PA are 15.08 ^{0}C, 31.33 ^{0}C and 672.59 mm respectively (Erer and Babile meteorological station).

Experimental Design

Three treatments (malka shola, malka salsa and local check tomato varieties) were laid out under drip irrigation in randomized complete block design (RCBD). The treatments were replicated three times. The sizes of each experimental plot were 2.4 m X 1.8m. Distance between plots was 1m and distance between block was 1.5m. The row spacing of tomato was 0.80m which was equal with drip lateral line with plant spacing of 0.30m. Transplanting was under taken at seedling height of 12-15 cm. Transplanting was done late in the afternoon to reduce the risk of poor establishment. 200kg/ha of P_2O_5 and 100kg/ha of N fertilizer were applied through fertigation.

Drip Irrigation System Design, Field Layout and Water Application Method

The well near by the research plot provides the irrigation water for the experiment. The required amount of irrigation water was applied by drip irrigation system which was connected with a water storing tank. The drip system consisted of water storing tank, main lines; sub main lines, lateral lines, emitters and filtration. The water from the well was flow to a barrel, which was placed at a height of 1.30m (at shoulder height) above the ground to provide the required water pressure. The main line receives water directly from the barrel. The sub main line was connected to the mainline from where it gets its supply. The drip lateral lines in each plot received equal amount of irrigation water from the sub main line. The tomato spacing was equal with emitters spacing found on the laterals which was 0.30m and row spacing was also equal with the spacing of lateral lines which was 0.80m.

Soil Texture and Water Holding Analysis

Soil samples from the experimental plots were taken to analyze bulk density, texture, moisture content at filed capacity and permanent wilting point from the field at three points along the diagonal of the experimental plot at two depth 0-20 cm, 20-40 cm and 40-60 cm and average value was described

Weather Data

For estimation of reference evapotranspiration (ETo), 15 years climate data of (rainfall, minimum and maximum temperatures, relative humidity, wind speed, sunshine hour, and solar radiation) were collected for both Dadar and Bisidimo/Erer Meteorological Station from National Meteorological Agency (NMA). The climatic data of cropping season at Dadar and Bisidimo/Erer are shown in Table 1and 2.

Table 1: Climatic data of Burqa gaba site in Dadar district for two successive growing season

Month	Min temp (^{0}C)	Max temp (^{0}C)	Humidity (%)	Wind (km/hr)	Sun shine (hr)	Rain fall (mm)
2015/2016 – Growing season						
October	10	25	42	7.20	7.9	23.0
November	11.5	24.5	66	6.125	8.1	0.00
December	9.5	26.5	80	7.21	8.1	0.00
January	11	27	88	6.125	7.9	1.3
February	10.5	26.5	89	5.75	8.1	0.54
2016/2017 – Growing season						
October	9	24	42	5.75	7.9	30
November	11	26	36	5.41	8.1	1.2
December	8	28	42	5.42	8.1	0.1
January	10	24	66	4.67	7.5	0.30
February	9.5	25.5	80	7.21	7.5	0.00

Table 2: Climatic data of Erer site in Babile district for two successive growing season

Month	Min temp (^{0}C)	Max temp (^{0}C)	Humidity (%)	Wind (km/hr)	Sun shine (hr)	Rain fall (mm)
2014/2015 – growing season						
October	13.1	26.1	64	2.87	7.6	25.4
November	14.5	26.6	75	3.58	7.2	20.0
December	14.8	25.1	66	2.875	7.0	0.00
January	14.6	25.5	72	2.875	7.0	0.00
February	14.0	24.1	77	2.83	6.6	0.00
2015/2016 – growing season						
September	13	32	38.50	7.91	8.5	0.00
October	14	32	70.21	7.61	7.6	30.0
November	12	33	38.50	8.16	7.2	0.00
December	17	35	40.50	6.81	7.0	0.00
January	17	36	38.50	5.83	7.0	20.0
February	17.85	29.90	35.00	4.35	6.6	0.00

Determination of Crop Water Requirement

Irrigation water was applied based on crop water requirement estimated from both Dadar and Babile metrological station. Gross irrigation requirement, net irrigation requirement and all irrigation schedules was calculated with the help of FAO CROPWAT 8.0 models. Crop evapotranspiration (ETc) was determined for each growing stages as:

$$ETc=Kc*ET_o \quad (1)$$

where

ETc = Crop water requirement in mm per unit of time

Kc = Crop factor (crop coefficient)

ET_o = Reference crop evapotranspiration in mm per unit time and it was calculated from climatic data of both meteorological station using FAO CROPWAT 8.0 model. Based on climatic data the reference evapotranspiration (ETo) was the same for the three varieties of tomato and equal amount of irrigation water was applied for each. Infiltration rate of the study area was determined by the double ring infiltrometer.

Determination of Water Application Time and Drip Layout

The duration of irrigation water application for each treatment was computed as follows:

$$\text{Duraation(hr)} = \frac{\text{Water requirment (mm)}}{\text{Application rate mm hr}^{-1}} \qquad (2)$$

Wetted diameter was measured by exposing a vertical plane passing through the point of application by taking three samples from all points of application. Wetted area of each emitter was calculated as:

$$A = \frac{\pi D^2}{4} \qquad (3)$$

where;
A = Wetted area covered by each emitter (m^2)
D= Average wetted diameter covered by each emitter (m)

Evaluation and Demonstration of Drip Irrigation System

The activity was conducted on farmers' fields in Dadar and Babile districts of Eastern Hararghe zone of Oromia with practical evaluation and demonstration of drip irrigation through tomato production by involving farmers, development agents, and experts from district offices of agriculture. Sites and farmers selections were carried out together with woreda experts, and then discussions were made with the farmers, and development agents on the implementation and evaluation processes of the activity. Accordingly, Farmers Research Groups (FRGs) consisting of male and female farmers were organized at each PA/Kebele and they involved in the implementation, monitoring and field evaluations. The FRG farmers were selected based on their interest, accessibility of the farm fields, having irrigable area, water for irrigation, and ability to allocate land for the intended purpose. Accordingly, One FRG per PA/Kebele having a total of fifteen members (one trial farmer and 14 followers), and a total two FRGs having a total of 30 members were organized, with 60% male and 40% female at both district.

Demonstration of the Technology, Capacity Building and Knowledge Sharing

Tomato is one of the major cash crops grown in Babile and Dadar districts of eastern Hararghe zone of Oromia, which is produced using rain fed and irrigation. However, its production in the area was limited by lack of improved varieties, disease and moisture stress due to drought and irrigation water scarcity. Hence, farmers produce local varieties which are low yielding using rain fed. To improve tomato production, income generation and capacity of the farmers, two improved tomato varieties (Melkashola, Melkasalsa) and local check with drip irrigation system were introduced through participatory demonstration and evaluation in the target area.

For effective implementation of the trials, training was provided for the farmers, development agents and experts on the importance of stakeholder's participation in agricultural research evaluation process, advantage of drip irrigation system for tomato production, installation of drip irrigation, tomato production and irrigation water management. Moreover, mini field visits were organized and given for 40 farmers, 6 DA and 4 SMS to create awareness and experience sharing among farmers and other stakeholders in the area. The performance of both improved and local tomato varieties, and drip irrigation technology were demonstrated to the participants, and awareness was created on improved tomato varieties, and drip irrigation technology in the area.

Method of Data Analysis

Gen-STAT 15th edition software was used for analysis of collected data. Mean separation were compared using least significant difference test (LSD) at 5% level. In addition, farmers' view, feedbacks, and their preferences were collected during field evaluation process using record sheets and narrated using descriptive statistics.

Results and Discussion

Physical Properties of Experimental Site

Soil physical properties of experimental site are presented in Table 3. Result from laboratory analysis of particle size distribution indicated that the soil texture at depths of 0 - 20 cm is sandy loam, but at lower depth (40-60 cm) the soil textural class was falls in sandy clay loam. The average soil bulk density (Bd) of 0-60 cm soil depth was is found as 1.51 g cm^{-3}. The top soil has relatively lower available water content as compared to the subsoil. Average value of soil moisture content at field capacity and permanent wilting point (0-60 cm of soil depth) is found as 24.2% and 14.9% respectively in volume base for Burqa Gaba PA. Similarly soil physical properties of Erer PA were presented in Table 4.

Table 3: Soil property of Burqa Gaba PA, experimental site

depth (cm)	Particle size distribution			Soil textural class	PWP (%)	FC (%)	Bd (g/cm^3)	Infiltration rate mm/hr
	Sand%	Silt %	Clay%					
0-20	70	14	16	Sandy loam	11.5	20.0	1.49	
20-40	65	12	22	Sandy clay loam	14.9	24.2	1.51	
40-60	60	10	28	Sandy clay loam	18.3	28.3	1.51	18
Average	65	12	22	Sandy clay loam	14.9	24.2	1.51	

Table 4: Soil property of Erer PA, experimental site

depth (cm)	Particle size distribution (%)			Soil textural class	PWP (%)	FC (%)	Bd (g/cm^3)	Infiltration rate mm/hr
	Sand	Silt	Clay					
0-20	75	10	12	Sandy loam	9.2	16.8	1.48	
20-40	70	15	18	Sandy loam	12.6	21.1	1.50	
40-60	65	12	20	Sandy loam	13.8	23.1	1.50	24
Average	70	12	16	Sandy loam	11.5	20.0	1.49	

Yield and Some Agronomic Parameters of Tomato Varieties Evaluated at Erer PA

The result of yield showed that there was significance difference ($p<0.05$) between three tomato varieties at Erer PA of Babile district in two consecutive years. The highest yield (32.60 ton/ha) was produce by malka shola followed by malka salsa (22.76 ton/ha). While the lowest yield 12.73 ton/ha was produced by local check. From field observation the lowest yield obtained in local variety, because it produces two to three fruit per bunches of flowers which is formed along the stem again thus it resulted in low yielder than improved one. The result was agreed with **(**Olaniyi, *et al.*,2009) the low yield obtained for some tomato varieties used might be due to non-development of flowers into fruits as about 50% of the flowers developed into fruits. Most of the flowers were dried up and fell off or they might form tiny fruits which shriveled up and fall off without further development.

Other parameter like number of fruit per plant and main branch, and height of tomato varieties were also evaluated. Analysis of variance showed that, plant height had no significance difference among tested tomato varieties. However, number of main branches were significantly different ($p<0.05$) among tomato varieties at Erer PA for two consecutive growing years. Malka shola variety produced the highest number of main branch (7.33) and the lowest (5.00) is by local check. Mean number of fruit per plant, recorded by malka shola and local check shows significant ($p<0.05$) different, but there were no significant difference observed between malka shola and malka salsa, and malka salsa and local check tomato varieties (Table 5). From traditional point of view local variety requires less amount of water in low land area or no need of water at high land area after establishment to produce required yield. The varietals differences in growth and yield might be attributed to the differences in ecological distribution of the tomato varieties (Olaniyi, 2007)

Table 5: Mean yield and agronomic parameters of tomato varieties evaluated at Erer PA

Treatment	Yield (ton/ha)	Plant height (cm)	No main branch	Fruit per plant	ETc (mm)	Water used (m^3/ha)
Malka shola	32.60^{a}	72.83^{a}	7.30^{a}	42.17^{a}	627.5	2398
Malka salsa	22.76^{b}	72.17^{a}	6.00^{b}	35.00^{ab}	627.5	2398
Local check	12.73^{c}	71.50^{a}	5.00^{c}	32.83^{b}	627.5	2398
CV	7.7	-	9.7	17.5		
LSD	2.171*	NS	0.738*	8.00*		

N.B: means represented by the same letter are not significantly different at P=0.

Maximum irrigation water was consumed in the second year (2016) than the first year (2015) by tomato varieties due climate change (*Eli no*) aggravate temperature increase in the second year at Erer PA. Equal amount of irrigation water 2163.89 m^3/ha was applied in 2015 for each treatment but, due to weather or climatic fluctuation crop evapotranspiration (ETc) in 2016 increased, hence seasonal CROPWAT output gave 766.4 mm per season ETc or 2632.20 (m^3/ha) of water per season was applied for each treatment as shown in Table 6. Temperature plays a major role in phenological development and productivity of crop plants. High temperature influences crops to mature earlier (Awal *et al*., 2003)

Table 6: Seasonal water applied and yield performance of tomato varieties at Erer PA

	2015 growing season			2016 growing season		
Treatment	Yield (ton/ha)	ETc (mm)	Seasonal Water applied (m^3/ha)	Yield (ton/ha)	ETc (mm)	Seasonal Water applied (m^3/ha)
Malka shola	35.49^a	488.52	2163.89	32.02^a	766.40	2632.20
Malka salsa	23.91^b	488.52	2163.89	21.60^b	766.40	2632.20
Local check	13.11^c	488.52	2163.89	11.18^c	766.40	2632.20
CV	6.4			4.9		
LSD	3.52*			2.39*		

N.B: means represented by the same letter are not significantly different at P=0.05

Yield and Some Agronomic Parameters of Tomato Varieties Evaluated at Burqa Gaba PA

At Burqa Gaba PA, ANOVA showed that there was significant difference (p<0.05) of yield recorded among each variety for two consecutive years. The highest and the lowest yield as 31.44 and14.28 ton/ha obtained from malka shola and local check tomato varieties respectively. Statistical output revealed that, tomato height had no significantly different between all tomato varieties. On the other hand analysis of variance indicated that mean number of main branch recorded by each tomato varieties for two consecutive growing season had significant difference at (p<0.05). Malka shola produce the highest number of main branch than malka salsa and local check tomato varieties. Mean number of fruit per plant, recorded by malka shola and local check showed significant difference (p<0.05), but none observed between malka shola and malka salsa, and malka salsa and local check tomato varieties (Table 7).

From field observation regular watering of improved varieties shown change in crop phonology at each growth stage, but on local variety regular watering had negligible impact on physiological growth parameter. Thus from the result it clearly seen that local variety growth parameters were not depend on water supply rather than inherent morphologic growth on the bases of growth stage. Phenological development governs the plant growth and productivity (Awal and Ikeda, 2003b)

Table 7: Mean yield and agronomic parameters of tomato varieties evaluated at Burqa PA

Treatment	Yield (ton/ha)	Plant height (cm)	No main branch	Fruit per plant	ETc (mm)	Water used (m^3/ha)
Malka shola	31.44^a	73.83^a	7.333^a	41.33^a	579.6	2138
Malka salsa	24.88^b	72.67^a	6.167^b	34.17^{ab}	579.6	2138
Local check	14.28^c	71.67^a	4.667^c	32.33^b	579.6	2138
CV	16.1	-	10.0	17.4		
LSD	4.731*	NS	0.752*	7.80*		

N.B: Means followed by the same letter in columns are not significantly different at P=0.05

ANOVA showed that in both year there is significant ($p<0.05$) difference in yield between all tomato varieties evaluated under drip irrigation at Burqa Gaba PA of Dadar District as described in Table 8.

Table 8: Seasonal water applied and yield performance of tomato varieties at Burqa Gaba PA

	2015 growing season			2016 growing season		
Treatment	Yield (ton/ha)	ETc (mm)	Seasonal Water applied (m^3/ha)	Yield (ton/ha)	ETc (mm)	Seasonal Water applied (m^3/ha)
Malka shola	27.01^a	583.20	2169.38	35.88^a	576	2107.39
Malka salsa	21.99^b	583.20	2169.38	27.78^b	576	2107.39
Local check	13.50^c	583.20	2169.38	15.05^c	576	2107.39
CV	4.5			6.0		
LSD	2.142*			3.551*		

N.B: Means followed by the same letter in columns are not significantly different at P=0.05

Farmers' Perception and Evaluation of Tomato Varieties under Drip Irrigation System

The FRGs, development agents, experts and researchers were closely evaluating the performances of the improved tomato varieties under drip irrigation system based on their own criteria. The most important criteria used in evaluating the tomato varieties under drip irrigation were disease resistance, fruits yield; fruit juice content and market demand were used as evaluation criteria by FRGs in study area.

Based on those criteria, the FRGs evaluation showed that, melka shola tomato variety under drip irrigation system was preferred by farmers and ranked first in both PAs due to its better tolerance to disease, large leaf canopy cover, higher fruit yield, its less damaged fruit by insects, high juice content, and oval shape and medium size of fruit suits to the market attributes which preferred by traders on the market (Table10). Melka Salsa tomato variety under drip irrigation system was selected and ranked in the second place by farmers based on the above criteria as that of melka shola tomato variety in both PA. The Local tomato variety under drip irrigation system was selected in the third place due to its susceptible to pests, low fruit yield, small fruit size, shape and its juice content was too much little as compared to improved varieties in both PA.

Table 10: Farmer's perception and evaluation of tomato varieties under drip irrigation system

Treatments	Number of farmers participated in evaluation	Frequency of farmers accepts the technology.	Acceptance (%)	Rank
Malka shola tomato variety	50	40	80	1st
Malka salsa tomato variety	50	10	20	2nd
Local tomato variety	50	0	0	3rd

 

Figure: Training for farmers at Erer, Babile district

Conclusions and Recommendation

As discussed there was significance difference between malka shola and malka salsa, between malka shola and local check as well as between Malka salsa and local check tomato varieties when evaluated under drip irrigation system at both district of study area. Malka shola produced high yield (32.60 ton/ha) than malka salsa and local check at Erer PA of Babile District and also gave high yield (31.44 ton/ha) than malka salsa and local check tomato varieties at Burqa Gaba PA of Dadar district.

Drip irrigation technology through tomato production was also demonstrated to the farmers at the study area. Farmer' perception and feedback towards drip irrigation system with three tomato varieties was collected. The evidences from participants during demonstration show that they prefer and select malka shola tomato varieties under drip irrigation and ranked in first place, malka salsa tomato varieties was selected and ranked in second place and local tomato variety in the third place under drip irrigation system based on tolerance to disease, large leaf canopy cover, higher fruit yield, less damaged by insects, high juice content, and market demand in both PA's. On the basis of yield and farmer's perception malka shola tomato variety was recommended for further promotion under drip irrigation system in the study area and other area with similar agro ecology of the study area.

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References

Amarasinghe, Upali, Bharat R. Sharma, Noel Aloysius, Christopher A. Scott, Vladimir Smakhtin, Charlotte de Fraiture, A. K. Sinha and A. K. Shukla (2004), Spatial Variation in Water Supply and Demand across River Basins of India, IWMI Research Report 83, Colombo, Sri Lanka.

Awal, M.A. and T. Ikeda (2003b). Controlling canopy formation, flowering, and yield in field-grown stands of peanut (*Arachis hypogaea* L.) with ambient and regulated soil temperature. Field Crops Research, 81 (2-3), pp: 121-132

Awal, M.A., T. Ikeda and R. Itoh (2003). The effect of soil temperature on source–sink economy in peanut (*Arachis hypogaea*). Environmental and Experimental Botany, 50 (1), pp: 41-50.

Barker, Randolph, David Dawe and Arlene Inocencio (2003), Economics of Water Productivity in Managing Water for Agriculture, in Jacob Kijne and others (Eds.) Water Productivity in Agriculture: Limits and Opportunities for Improvement, Comprehensive Assessment of Water Management in Agriculture. UK: CABI Publishing in Association with International Water Management Institute

Howell, T.A. 2001. Enhancing Water Use Efficiency in Irrigated Agriculture. Argon. J., Vol.93, No.2, pp. 281-289

Kijne, Jacob, R. Barker and D. Molden (2003), Improving Water Productivity in Agriculture: Editors' Overview, in Jacob Kijne et. al. (Eds.), Water Productivity in Agriculture: Limits and Opportunities for Improvement, Comprehensive Assessment of Water Management in Agriculture. UK: CABI Publishing in Association and International Water Management Institute.

Kumar, M. Dinesh (2002b.), Reconciling Water Use and Environment: Water Resources Management in Gujarat, Report of the Hydrological Regime Subcomponent of the State Environmental Action Program, submitted to Gujarat Ecology Commission, Vadodara.

Kumar, M. Dinesh (2003a.), Food Security and Sustainable Agriculture in India: The Water Management Challenge, paper presented at the 2nd Annual Partners meet of IWMI-TATA Water Policy research program, January 27-29.

Lema Desalegn. 2004. Tomatoes. Research experiencesand production prospects. Research report No. 43. Ethiopian Agricultural research Organization. Addis Ababa, Ethiopia.

Malash N, Senzanje A, Rockstrom J, Twomlow SJ. 2005. On farm evaluation of the effect of low cost drip irrigation on water and crop productivity compared to conventional surface irrigation system. Physics and Chemistry of the earth, part A/B/C. 30:783-791.

Molden, David, R. Sakthivadivel and Zaigham Habib (2001) Basin-Level Use and Productivity of *Water: Examples from South Asia*, IWMI Research Report 49, Colombo: International Water Management Institute, Colombo, Sri Lanka

Oweis, T. Zhang, H and Pala, M. (2000) Water uses efficiency of rainfed and irrigated bread wheat in a Mediterranean environment. Agronomy Journal 92: 231-238

Olaniyi JO (2007). Evaluation of Yield and Quality Performance of Grain Amaranth Varieties in the South western Nigeria Res. J. Agron., 1(2): 42-45

Olaniyi , J. O., W. B. Akanbi, T. A. Adejumo and O. G. Akande,. 2009. Growth, fruit yield and nutritional quality of tomato varieties. African Journal of Food Science Vol. 4(6), pp. 398 - 402, June 2010, Available online http://www.academicjournals.org/ajfs

Range Land Management Research

Assessment of Water Resources Management and Past Works on Water Points Development in Borana Rangelands, Southern Oromia, Ethiopia

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Abstract

This paper focus on assessment of water resources management and past works on water points development in pastoral area of southern Ethiopia. Five districts were selected purposively for this study. PRA and Semi-structured interview has been employed as a tool to gather information. Types of water source available and their trends of use, watering methods of livestock, water management of the community, the introduction of 'kota' system for water harvesting its benefit and drawback, and the mobility in search of water were assessed. 143 respondents selected and interviewed. This paper also reveals that the role policy makers to oversee any development intervention in water resource as per integration of science and indigenous knowledge in order to sustain the solution to scarcity of water in the area.

Key Words: Water resources, community, indigenous knowledge, watering points

Introduction

From the total of Earth`s land surface, 41% is fall under category of dry land (arid and semi arid areas) and sixty-five percent of this global dry lands host the land which is a base for livestock production called rangeland (Mortimore, 2009). Dry land in Africa constitute about 43% of inhibited surface area and most of this land used for pastoral and agro-pastoral activities to support over 268 million people (IIED and SOS Sahel, 2010). In East Africa, more than 60% of the total land area in the region is covered by grassland or savanna ecosystem (Neely and Bunning, 2008). Of the total land mass of the country, Ethiopia have about 61 to 67% arid and semi-arid rangelands (Alemayehu, 1998) and Borana rangelands accounts for 7.6 to 12.3% (63 940km^2) of the total land mass located in southern part of the country in Oromia regional state (OBPED, 2000).

Rangeland is a type of land found predominantly in arid and semi-arid regions that is managed as a natural ecosystem supporting indigenous vegetation, predominately grasses, grass-like plants, forbs, or shrubs. Those areas are characterized by Low human population density and highly variable and uncertain rainfall. In the pastoral community, grazing biomass is entirely determined by the amount, pattern and timing of rainfall.

There has been a general concern regarding to the current situation of rangelands (arid and semi -arid lands) in sub-Saharan Africa and areas inhabited by pastoralist. This concern is due to the fact that these areas experience sever recurrent drought thus having a dreadful negative effect on environment, people in it and livestock (Ouma O., 2001).

Pastoral areas of Ethiopia has been changed over last 40 years (Nassef and Ludi, 2012) . The Borana pastoral system which has long been considered as one of the productive and successful rangeland in Eastern Africa is recently drawing concern about its sustainability. This concern is due to recurrent drought, loss of key grazing land and water resources, and inadequate infrastructural developmental investment as well as massive death of cattle followed by restocking and destocking are the major ones (Hurst M. et al 2012).

In southern Ethiopia drought has recurred more frequently and for longer periods of time than documented previously. This changing climate in the region has resulted in diminished both quality and quantity of local water and forage resources, thereby its negative impact and severity is provoked the problem of livestock production system and the livelihood of nomadic pastoralists` such as Borana, who depend on the animals for livelihood and subsistence.

Despite many positive efforts, rangelands are littered with failed development interventions, degradation of natural resources is widespread around water points, and competition and conflict over water by a growing population with competing demands have become more common. Coppock, (1994) reported that Borana plateau is characterized by a general scarcity of surface water. About 95 ponds were constructed. Some of these ponds are inefficient because water is lost due to high infiltration (seepage) or siltation. Water is lost from deep wells during the process of livestock watering. Development works over water point has been practiced by SORDU (Southern Rangeland Development Unit) and CARE Ethiopia as well as other GOs and NGOs for long time. But part of these works is not effective and water points fail to function.

Objectives

- To assess the current status of traditional as well as modern wells and different ponds mapped to clearly understand the existing situation.

Materials and Methods

Study Area

The study has been carried out in 2015 at five districts in the Borana rangelands; namely Yabello, Duda Dawa, Miyo, Dire and Moyyale. There are four seasons in the area; *Ganna*- long rainy season, *Adolessa*- cool dry season, *Hagaya*- the short rainy season and *Bona*- the warm dry season. The climate is generally semi-arid with annual rainfall averaging 500 mm in the south to 700 mm in the north and the altitude ranges from 1000 masl in the south to 1500 masl in the North West (Desta, S., 2000).

Five districts have been chosen to carry out the research. Purposive selection techniques have deployed to choose the kebeles/Peasant association within the districts. Customary institutions are also contacted to gather the required information.

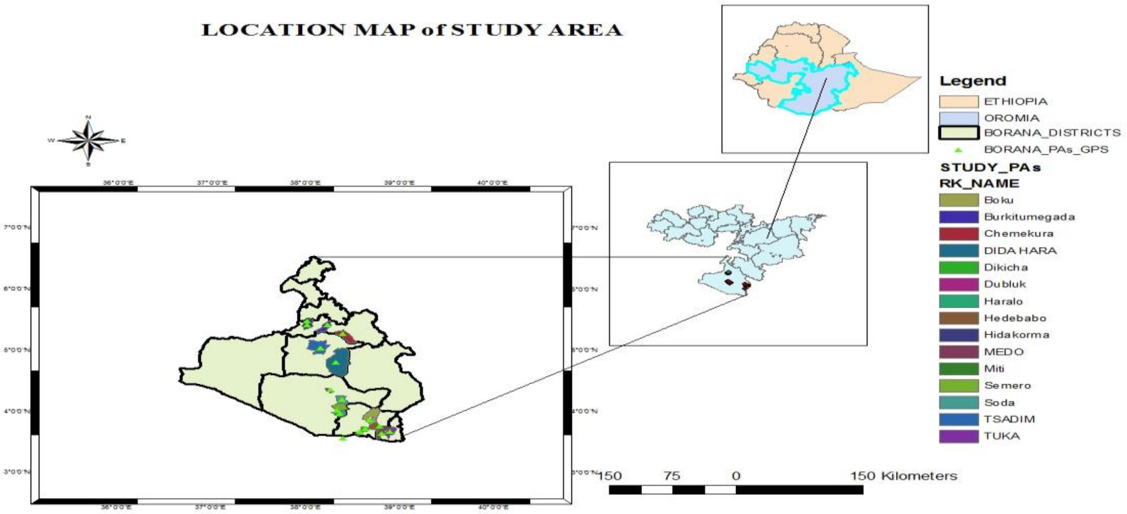

Figure 1. Map of the study area

Data Collection, Sampling Procedures and Data Management

PRA and Semi-structured interview has been employed to gather information. Besides, discussion was held with key informant and different water management bodies at local and district level. The major issues contained in the questionnaires includes traditional knowledge of water use, watering frequency, length of water available time for use, critical periods of water shortage and proximity and farness of watering points. Data of efficiently functioning level of traditional and man-made wells were collected to make comparison. The amount of water lost due to watering efficiencies also considered. Labor availability at different seasons was assessed. Pastoralists' perceptions over water resources depletion were also captured. GPS (global positioning system) and GIS (geographic information system) software were used to collecte and mapping watering points, respectively. Totally 143 households were interviewed whereas statistical package (SPSS version 21) was used for final analysis.

Result and Discussion

Types of Water Source and their Trends

Borana zone ephemeral drainage system is located within the Genale-Dawa river basin. Generally ground waters levels of the study area are deep and there is no perennial river in the zone. Major type of water source for pastoralist in the study area are open surface water which include runoff/flood water, ponds and micro dams and ground water which include boreholes, shallow wells/ "adadi", motor pumps and Tula wells. Those water sources had been serving for both domestic use and livestock consumption depending up on the season. According to the respondents (greater than 80%) runoff/flood water sources are utilized during wet season while ponds, boreholes and micro-dams are used on dry season. The rest type of water sources had been used mostly during drought season. Runoff/flood water and small family ponds are temporary water sources collected around the village during rainy season and are generally called 'Hara' by the Borana community. On the other hand 'Haro' is the term to represent medium ponds and micro-dams which are used during the normal dry period. More than half of the respondents agreed that, ground water sources such as boreholes, shallow wells/ "adadi" and Tula wells are preferred water sources for livestock watering due to the salinity content that improve livestock.body condition.

Majority of water source in the region are communal except some small family ponds that may possessed by private. According to most respondent (81%) explanation, during water source development processea the community near the water development point are involved in at almost all stages of the activities with their labor and material contribution.

Watering Livestock and its Frequency

Availability of water, pasture and season are determinant of movement distance of herd from home village. During wet and normal dry season water is available at a distance of less than 1km and at around 9-12 km, respectively whereas during drought season, 'oolaa', the distance of watering point increases from 25km to hundreds of kilometers as per 79% of the respondents. This long distance mobility to fetch water and pasture during drought season is termed as the 'Furaa' herd movement where movement from village is done based on information on weather, availability of water and pasture, livestock diseases and safety or security situation (Tujuba J., *et al*, 2017) following traditional tracts of communal grazing land.

Travel hours for livestock watering also dependent of the season. In wet season the travel hour may less than an hour (62% of the respondent), at normal dry season it range from 1 to 3 hours (78% of respondent) and during drought season the watering distance take 6 to 12 hours or possibly more time (according to 65% of the respondents). The same is true for quench hours at watering points that 70% of the respondents agree during wet season it may not take more than an hour; for normal dry season, 1 to 5 hours (63% of respondents) and during the drought season 9 to 12 hours used for watering livestock at one watering point (67% of the respondents). But according to more than 82% of the respondents' confirmation, watering of calves, weak animals and lactating cows during both normal dry and drought season is at home by fetch using human back or animals like donkey and camel from long distance.

Livestock watering frequency in the past 20 years ago also depends on season. For example: during wet season livestock watering was made daily due to less livestock number and availability of water at short distance as per 71% of the respondents. During normal dry season one to two days was the frequency of livestock watering (64% of the respondents) while at drought season the watering frequency ranges between two to three days according to 70% of the respondents. In current time for wet season, because of less water availability, one day (67% of respondents); in normal dry season two to three days interval and during drought season at three days interval livestock is to be watered due to long distance between the water points and the villages (greater than 80% of the respondents).

Table 1: Water utilization for livestock

Livestock types	Past watering frequency 20 years ago (days)						Current watering frequency (days)					
	Dry seasons	Respondents (%)	Wet seasons	Respondents (%)	Drought year	Respondents (%)	Dry seasons	Respondents (%)	Wet seasons	Respondents (%)	Droughot year	Respondents (%)
Cattle	Daily	71	2	75	2-3	70	Daily	78	2	60	3	76
Sheep & Goats	After 1day	55	4-5	60	4-6	73	Daily	60	3-5	71	3-5	78
Camel	None	70	>8	60	8-10	70	None	77	3-6	65	3-6	69
Donkey	Daily	66	1	78	1-2	75	Daily	79	Daily	83	Daily	79

The frequency of livestock watering is also affected by the availability of pasture in the area according to 89% of the respondent. The more the available pasture the more will be the resistant for delayed watering frequence. Accordingly resistance difference to watering frequency between the past and current livestock is that the past livestock had more or less enough pasture which makes them more resistance than the current livestock. According to 72% of the respondents, Boran breeds are resistant to long interval watering frequency than other breeds. Water point distance, quantity of water in its source, feed availability, number of livestock on water points and body condition of livestock are the determinant factors of watering frequency in Borana rangeland. In the Borana community watering frequency supervised by an officer known as 'abba Herregaa ' appointed by the well council (cora eelaa) which is composed of the users of the water points.

Water Management

For centuries Borana community has been managing water resource and pasture using its customary institutions. The governing body the 'Abba Gada' formulates and enforces general laws - which are known as the 'aada seera' - that govern access to and use of communal water and forage. Each newly elected governing body revises existing tenure, arrangements and Rangeland management in Borana is a social and political affair. The households reported to be abided by the traditional bylaws on how to keep ones turn in watering animals as ordered by the traditional water resource administrators or 'abba Herregaa ', assigned by the Gada council as routine practice.

Each water sources is subject to a complex set of restrictions, rules and regulation that are administered and enforced by selected agents like 'abba Herregaa ' under the surveillance of the traditional elders. Failure to supply labor to the well and failure to participate in the politics of well council will lead to rapid exclusion. Depending on the degree of problem punishment by money, de-silting and fencing to water source are among the simple punishment. The major sanction under the Borana system of water control is exclusion.

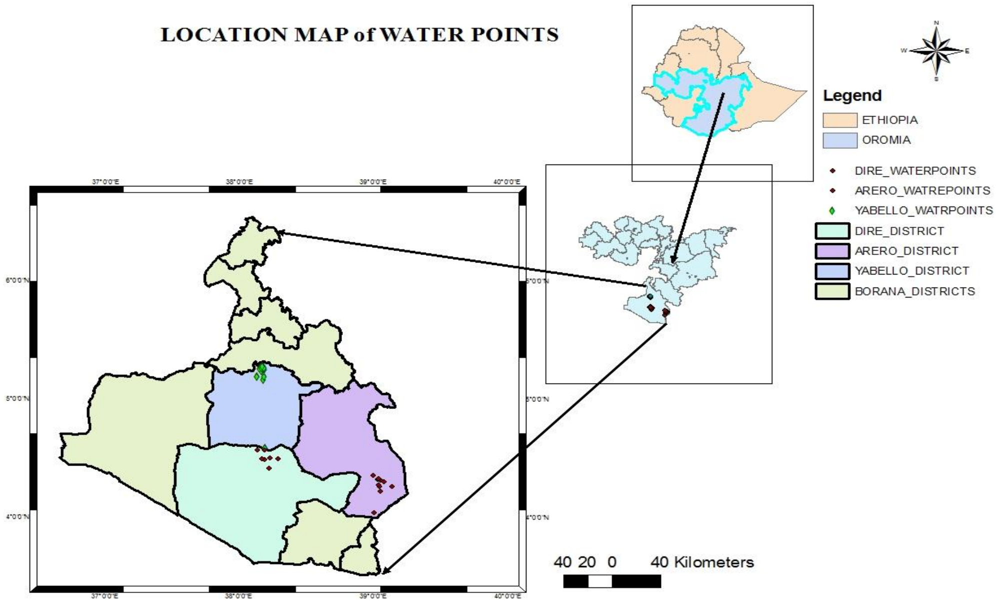

Figure 2. Map of water points

The development of water points by different organization in the past has negative impact on traditional systems in managing and usage of the resource. This is because of the fact that lack of proper land use planning practice by planners and lack of sufficient resource to effectively maintain and manage water points by local government. Even if they agree that management of water points developed by external bodies (more than 90% of the respondents) had to be by the whole community, those problems resulted in discrimination of watering point management by the community. Lack of propare land using a head resulted in overgrazing around the water points, aggravation of soil and incidence of human and livestock diseases. Moreover due to the absence of rules and regulation, free access of both water and grazing resource created a room for conflict. Large ponds constructed in dry season grazing area, leads to shift the dry season grazing land to wet season which resulted in shortage of feed at dry season. The traditional wells known as the 'Tulas' which is the 'singing wells' used during drought time. Among 9 Tullas scattered in Borana traditional grazing horizons at least five of them are now reported not to be accessible for Borana. This is due to recent re demarcation of the area out of the traditional range land administration legacy of the Borana Gada system without moderating the contending societies on mutual access to the common water and grazing natural resource (Tujuba J., *et al*, 2017).

Watering right in any particular water source is gained and maintained through participation in the water resource council. Upkeep, control, utilization and maintenance of the traditional water sources are constant concern of all Borana`s. The continuous and coordinated supply of labor is essential for the operation of traditional or community water points. Even though, the decision on tenure arrangements and Rangeland management is primarily involves male-dominated governing councils headed by elders, women are participating on erasure it (greater than 93% of the respondents).

The trend of surface water points in Borana rangeland in terms of quality has been declined, siltation increase through time due to loss of vegetation cover, land degradation by erosion and expansion of cultivated land (71%.of the respondents). De-silting micro-dams and small ponds are the common practice to increase the volume of water harvested and quality of water during the dry periods. However, lack of materials/tools and high labor consumption nature of the activities was the major problem of de-silting surface water points, according to 97% of the respondet confirmation.

Kota System Water Harvesting Policy of 2003/2004

The Kota system of water harvesting technology introduced in 2003/2004 has been reached the pastoral community. According to the respondents (85%), the purpose of construction was for both small scale irrigation and livestock watering, however, when compared to traditional water harvesting technologies it has been found below or not suitable at all due to small volume of water harvested, seepage loss and lack of awareness as well as difficulty of watering for livestock. So, by now there is a demand for the improved water harvesting technology by the community due to high scarcity of water in the area and lack of technology that tackle existing water harvesting problem.

Mobility for Water Resources

Generally, the Borana rangeland is characterized with no Perennial River, recurrent drought and erratic rainfall pattern. Respondents of this assessment pointed out that most of them did not have enough water for both domestic and livestock watering. In order to cope with this critical shortage of water, mobility is the only solution especially for livestock watering during dry and drought periods in the region (greater than 80% of the respondents). As cattle is more sensitive to watering frequency, mobility for water accounts at first degree but if the situation is barbed all of livestock migrate to the place where water and pasture are relatively available. The right to use water with local people is relatively equal because access to water and pasture depends up on equal participation in management. But it is important that to notify and gather information about the resource in the area because it is mandatory to participate with labor and sometimes in cash at mobility sites.

Conclusion

Even if much effort has been made to develop water resource, Borana rangeland is an area with chronic water shortage. The major water sources in the area are surface water like runoff/flood water, ponds and micro dams and ground water source which are boreholes, shallow wells/ "adadi", motor pumps and Tula wells. Distance, traveling hours to water point and for quench hours at watering points are dependent on the season, which is high and very high in dry and drought season, respectively. The frequency of watering livestock in general has been increased due to recurrent drought which results in diminishing the grazing and water resource in the region about three days of interval for cattle watering.

Costmary institution of Borana pastoralist has very sophisticated means of crucial resource management such as water and pasture for more than millennia. Those institutions build bylaws, rules and regulations that are overseen and revised by the governing councils headed by elders. The weakening of those customary institutions over time is a result of many factors. Among the factors population growth, massive immigration, political marginalization, land privatization and land conversion to cultivation, ignorance of indigenous knowledge by planners during developmental activities and lack of sufficient resource to effectively maintain and manage water points by local government are some of the evident.

This problem contribute to the further filer for the water and pasture proper management even lead to cause for rangeland degradation and conflict over limited resource. So any intervention measures should be consider local knowledge in integration with the scientific ones and policy makers need to intervene for its implementation.

Recommendation

1. Supporting local customary institution, proper planning of developmental activities incorporating local knowledge, combining technical, science and customary knowledge systems for water and pastoral development.
2. Proper water harvesting technologies which are easily adaptable by the community must revel in such a way that accommodate the local indigenes institution and create ownership by the pastoralists and agro- pastoralists of the region not 'Kota' system.
3. Introduction of participatory natural resource management as an approach for water development is important.

Reference

Mortimore, M. (2009). Dryland Opportunities: New paradigm for people, ecosystems and development. New York/Gland, Switzerland/London: UNDP/IUCN/IIED. Available at: http://pubs.iied.org/pdfs/G02572.pdf.

IIED and SOS Sahel UK 2010. Modern and mobile The future of livestock production in Africa’s drylands, available at http://pubs.iied.org/pdfs/12565IIED.pdf

Neely, C. and S. Bunning. (2008). Review of Evidence on Dry land Pastoral Systems and Climate Change: Implications and opportunities for mitigation and adaptation. FAO – NRL Working Paper. Rome, Italy.

Alemayehu M (1998). The Borana and the 1991-92 droughts. A rangeland and livestock resource study. Institute for Sustainable Development and French Catholic Committee against Hunger and for Development, Addis Ababa, Ethiopia. P. 90.

OBPED (2000). Oromia Bureau of Planning and Economic Development. Physical and Socio-economic Profiles of 180 Districts of Oromia. Physical Planning Department, Finfinne

Ouma O.(2001). Pastoralists' Dilemma. Assessment of changes in livestock production and household dynamics among the Maasai due to development of boreholes in Moindabi, Kenya.Msc. Thesis, International Institute for Aerospace Survey and Earth Sciences (Itc), Enschede, The Netherlands.

Magda Nassef and Eva Ludi, (2012). Providing and Managing Water in Ethiopia’s Pastoral Regions – Lessons Learned in the Last 40 years, Save the Children USA.

Hurst M, Jensen N, Pedersen S, Sharma A, Zambriski J. 2012. Changing Climate Adaptation Strategies of Boran Pastoralists in Southern Ethiopia. Working Paper No. 15 Cali, Colombia; CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available online at: www.ccafs.cgiar.org

Coppock DL. 1994. The Borana Plateau of Southern Ethiopia: Synthesis of Pastoral research, development and change, 1980-91. ILCA (International Livestock Center for Africa), Addis Ababa, Ethiopia. 418pp.

Desta, S., 2000. Pastoralism and Natural Resources Management: the case of the Borana in southern Ethiopia, Proceedings of 8th annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, 24-26 August, 2000. pp 17-25.

Tujuba J, Harpal S, Merga B, Tefera Y, Abraham A, Belay W, Getachew G.2017. Borana Cattle Breed Production, Their Economic Role for Pastoralists under Drought, Diseases and Policy Constraints in Borana Zone, Oromia Sate, Southern Ethiopia, The International Journal Of Science & Technoledge (ISSN 2321 – 919X). http://www.theijst.com

Participatory Situation Analysis of Termite in Borana Rangelands, Southern Oromia, Ethiopia

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Abstract

This study was conducted during in five districts of Borana zone selected purposively depending on the extent of termite spread. The objective was to analyze the situation of termite in the rangeland and assess the indigenous concept about the termite of the community. Semi-structured questionnaires were administered to 32 community representatives in each of the selected peasant associations per district. A total of 160 community representatives were interviewed that supported by direct observation and key informant discussion to understand status of termite expansion trends and timelines. Based on this survey data analysis, historical background of termite infestation in the study area was identified. Besides, major damage caused by termite on cultivated crop, building and on rangeland, their relationship with the environment and the controlling mechanism were identified.

Key words: termite infestation, damage, range land, knowledge

Introduction

Worldwide the infestation of termite has been increasing especially in tropics where the livelihood is under pressure by its distribution, extent of spread, problems and constraints resulted particularly among rural small scale farmers. The African continent is diverse in both climatically and geographically. As a result tremendous amount of termites species have been exist in the continent. More than 1,000 of the Out of greater 2,600 recognized termite species more than 1,000 species found in African whereas most of them are mound building species.

According to Fenemore and Prakash, 2006, the infestation problem of termite can have several effects such as economic, agronomic, or social constraints. The economic impact of termites involves the destructive tendencies due to their foraging activities on plants and wood products, which cause economic hardship to individual producers. On the contirery, termite mounds contain a considerable store of plant nutrients and the use of mound material as a soil amendment shows great potential for improving soil chemical fertility (Tilahun A., *et.al*. 2012).

The problem of termites from a broader systems perspective is complex. Various factors in the Borana rangelands might have been contributed to the expansions of termites. But the recent expansion and intensification of termites' damage is not well understood and documented. Because, past research and extension activities were not focused on the understanding of root causes of termite expansion. However the approach to manage termite damage, which is a bottleneck problem of the study area, require knowledge and well understanding of there historical back ground and damage coused by them. Hence it is quite important to a greater level to analyze the situation of termite damage and infestation. In addition it is also important to identify potential social and informal institutions that are responsible for the termite control including pastoralists' access to resources, technology support and other. Therefore this survey study was designed having the following objectives.

Objectives

- To analyze the situation of termite damage and infestation in the study area.
- To identified potential social and informal institutions that are responsible for the termite control
- To assess the extent of termite damage, community indigenous knowledge, trend analysis, and ecological impact of termite in the rangelands

Materials and Methods

Description of the Study Area

The survey study was made at Yabello, Dire, Miyo, Moyale and Dugda Dawa districts of Borana zone, South Oromia in 2015. The rainfall of the area is characterized as bi-modal. There are four seasons in the year namely; the Gana-long rainy season, the Bona-dry season, Hagaya-short rainy season and the Adolesa-cool dry season. The study area comprises important cultural landscapes that have been utilized for centuries. The study area is also confronted with the problem of bush expansion in the native savannah grass lands. Besides the study area is characterized by savanna grass land.

Questionnaires

Aplying purposive selection/sampling method a total of 160 respondents, 32 peoples from five districts, has been interviewed for the assessment. And using open ended and closed ended questions, individual's face to face interviews were carried out by the administration of a questionnaire to the respondent from 2 PA's per districts and 16 respondents per PA. The age of respondents were older than 25 years in order to ascertain the efficacy of their experience with termite infestation of the area.

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Direct Observation

To know the existing termite condition during the study time the research team was intensively observed the termite situations in some areas. During observation, the status of termite expansion and trends, timelines has been considered in depth.

Key Informants

The key informants were among the following; local chiefs, elders, Corporal and program coordinators such as program coordinator of rangelands in different offices. The aim was to solicit additional data on local peoples' perception towards conflict and its management. Informal discussions were also made with the key informants.

Data Management and Statistical Analysis

Data was managed using computer Excel software program while Computer based data coding, storage and retrieval mechanisms was applied. Both quantitative as well as qualitative statistical analyses were applied in the data analysis using SPSS (Statistical Package for Social Science) software.

Result and Discussion

History and Spread of Termite in Borana

All of the respondents agreed that the existence of termite and their problems in their corresponding area. According to 46% respondent, termite induced damage on everything while 54% were listed that termite have damage on grass, crops and building. On the other hand about 40% of the respondent estimated the start of termite envisions around thirty to fourth year's age whereas 60% of the respondent unable to estimate the time of the beginning of termites envision in their area.

Locally the community identified the common species of termites based on mound building bases as mound builder, non mound builder and in terms of size small, medium and large. Accordingly, 71% of the respondent evidenced the existence of both mound builder and mound less termites in the Borana rangeland while 16% of them evidenced existence of only termite that build mound and the rest 13% respondent evidenced existence small, medium and large size termite.

When respondents compare the condition of termite spread in the study area before 25 years ago with existing condition, before 25 years termite spreading condition was good (by 31%), fair (by 49%) and worst (by 20%). On the other hand 96% of the respondents were confirmed that the worsening of termite spread from time to time since 25 years a go. While there spreading mechanisms/system to new uninfested areas have been by underground tunnel, following camel urine which increase soil moisture during dry period, tressing cattle dug as a source of food and spreading over surface by building tunnel are the major systems in the area.

According to the respondents the main causes for termite spread intensification are climate change and overgrazing whereas this climate change is evidenced by repeated occurrences of drought in the study area.

Damage of Termite

More than half of respondents think that both mound building and mound less termites are affecting rangeland and crops by eating both grass and crops. But according to 87% of the respondents, eating grass, destruction of crops and degradation of rangeland are the main damage induced by mound less termites. The severity of termite intensification is highest in communal grazing land followed by degraded rangeland. However there are certain assumption of respondent concerning termite mound and production. 44% of the respondent argued that the dead or destroyed mound give high production due to its high level of plant nutrient content (that supported by Tilahun A., *et.al*., 2012 findings) whereas 32% of the respondent this reality.

Crop types those were more affected by termite infestation according to the respondents ranked as teff, wheat and maize, respectively which is also supported by HDRA - the organic organization 200. However, due to this effect only 32% of the respondents were changed the crops while the majority, 68% of the respondent were not changed the crop type grown. According to the respondent the time of severe damge by termite are during flowering and seedling growing stage of the crop whereas roots are the most affected part. Even though there have been termite infestation problem in the study area, according to more than 98% of the respondents, that there were no termite resistance fodder species introduced to the area. Generally, according to respondents views, list of most susceptible/resistant fooder and tree species are listed below in the tables (Table 1, 2, 3, 4).

Table1. Susceptible /most affected fodder

Scientific name	**Local name**
Cenchrus ciliaris	Matagudessa
Plectranthus cosmosus	Barbaarersa
Bidens hilderrandti	Abune
Digitaria milanjiana	Hiddoo
Themedatriandra	Gaaguroo
Cynodon dactylon	Sardoo/qarcaa
Bothriochloa insculpta	Luucolee

Table2. **Resistant fodder species**

Scientific name	**Local name**
Pennisctum mezianum	Ogondhichoo
Elcusina intermedia	Coqorsaa
Cymbopogon commutatus	Alchiisoo
Bothriochloa spp	saalaa

Table3. Susceptible /most affected tree/shrubs

Scientific name	**Local name**
Combretum molle	Rukeessaa
Acacia bussei	Halloo
Commiphora spp	Hameessaa
Commiphora kua vollensen	Calanqaa
Dodonea angastifoli	Dhitacha
Ehretia cymosa	ulaagaa
Acacia nilotica	Burquqqee

Table4. **Resistant** tree/shrubs

Scientific name	**Local name**
Olea europaea	Ejersaa
Grewia bicolor	Harooressa
Boscia mossambicensis	Qalqalchaa
Croton macrostachyus	Makkanisaa
Juniperus procera	Hindheensaa
Cordia gharaf	Madheeraa
Acacia tortilis	Dhadachaa

On the other hand about 88% of respondant from D/dawa district explained that termite may serve as a host to certain disease like Awarsa (snake disease), while 'luxa' (body weight loss) problem, which come from shortage of feed, is the out come of termite destruction made on paster land. Similarly they also ilustrate that physical distraction and snake disease are among the other problems induced by mound building and mound less termites. But more than 98% of the respondents of other districts evidenced as there were no relation between termite invention and livestock disease.

Generally, according to respondent, among major problems which have been induced by termite were crops (before and after harvesting), building, feeds (in terms of space occupied by mound, eating grasses and land degradation) and physical damages on livestock and children are ranked from first to fourth respectively. More than 70% of the respondent agrees that termites have impact on copping strategies of drought by destroying conserved feeds. Mounds did not have mineral lick in Borana rangelands instead according to 65% of the interviewed community locally mound give a benefit to construct house and "naniga" which is water canal for livestock watering at water points throughout the rangeland.

Environmental Relationship of Termite

More than 55% of the respondents indicate that absence of relation between bush encroachment and termite infestation and spread while about 40% of the respondents justified that due to the fact that bush serve as feed source for termite, it aggravate termit infestation and spread. On the other hand 60% of the respondent evidenced bush clearing reduces termite spread because bushs serve as feed sources for termite. Similarly, according to half of the respondent, cultivation reduces mound building by physical destruction and flooding.

Land form and position as well as season of the year also affect severity of termite damage and infestation, according to most respondent. The severity of damage and infestation of termite is higher in flat lands than of hilly and valley bottom. While the seasons for termites to spread on new or uninfected area is greater in long rainy season and cool dry season as well as "wayama" red deep soil is the soil type where termite infestation and damage is severe. During cool dry season the termite damage also pronounced on grass, building and crops than the other season and mound building by termite also increased during cool dry season whereas lowered during short rainy season. Accordingly, 47% of the respondents agree that drought and termite have relationship in that termite are increase during drought season and 44% agree that no relation with climate because, termite infestation decease in drought season.

Controlling Mechanisms

Traditional techniques or existing local knowledge and mechanisms to control/manage termite infestation are physical destruction, ash, olio, manure and salt application. But these indigenous knowledge and skill were not supported by any extension activity, research, and policy factors to minimize the effect of termite infestation on pastoral and agro-pastoral area of Borana rangeland, even thogh more than half of the respondent agrees that better rangeland management minimize the intensity and spreads of termite. In addition, during survey study, the identified termite’s predator of the study areas includes 'Gandulessa' (large ant), birds, chicken and ants.

Conclusion

Borana rangeland has been under termite infestation stress starting from past four to five decades. Termite intensification in this area has been increasing from time to time. Even if termites believed as ecological engineers, the destruction of crop and fodder need to minimize at optimum level. This controlling mechanism has to be considering the integrity of scientific and indigenous knowledge as well as capacitating the indigenous knowledge of termite controlling mechanism which is organic. In addition, introduction of termite resistance fodder species to the region is mandatory.

Recommendation

1. The rate of Termite intensification must quantified using remote sensing techniques.
2. It is important to study the termite species to quantify the rate of infestation.
3. The use of termite mound as fertility remedy of soil need to assess in further studies for the area.
4. The indigenous knowledge of termite control mechanism must be evaluated and documented for farther use along the safe scientific controlling mechanisms.

Reference

Sileshi G, Akinnifesi FK, Ajayi OC, Chakeredza S, Mngomba S, Nyoka BI (2008). Towards sustainable management of soil biodiversity in agriculture and landscape in Africa. J. biodiversity, Zambia. 9:64-67.

United Nations Environment Programme,2000. Finding Alternatives to Persistent Organic Pollutants (Pops) for Termite Management. Prepared by members of the UNEP/FAO/Global IPM Facility Expert Group on Termite Biology and Management - established in 2000 to support international activities on Persistent Organic Pollutants (POPs) covered by the Stockholm Convention.

Fenemore FG, Prakash A, (2006). Applied Entomology. Second edition. New Age International (P) Ltd publishers. 200-203.

A. Tilahun , F. Kebede , C. Yamoah , H. Erens , B.B. Mujinya , A. Verdoodt , E. Van Ranst ,2012. Quantifying the masses of Macrotermes subhyalinus mounds and evaluating their use as a soil amendment. Agriculture, Ecosystems and Environment

Termite Control without Chemicals, 2001. HDRA - the organic organization Ryton Organic Gardens COVENTRY CV8 3LG United Kingdom.

Forestry Research

Adaptation and Growth Performance of Lowland Bamboo Species in West Hararghe, Mechara on Station, Oromia, Ethiopia

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Abstract

Bamboo has a dozen utilities than any other plant species in the world is its trait. It uses as food and feed preservative, construction, medicine purpose, natural conservation, charcoal and energy, arts and culture, aesthetic value, financial return and environment protection. Bamboo has additional unique characteristic that a fast growing plant than any other tree species and starts to yield within three or four years of planting time. Even though Ethiopia is one of the most endowed countries in having huge coverage of bamboo resource in Africa, the country has narrow genetic diversity only has two species those are Yushania alpine (highland bamboo) and Oxytenanthera abyssinica (lowland bamboo). The adaptation of lowland bamboo at Mechara Agriculture Research Center conducted from 2011 to 2016 to evaluate the adaptability and potential of different provenance of lowland bamboo species and to select the best performing of lowland bamboo species around Mechara and for similar agro ecologies. Three different exotic lowland bamboo species (namely; Dendrocalamus hamlitonii, Dendrocalamus memebranceous and Guadua amplexofolia) were collected from Debrezit Agriculture Research Center and one indigenous lowland bamboo species (namely; Oxythenantera abyssinica) was taken from Assosa Agricultural research center, Benishangule Gumuze regional state. The experiment was laid out in RCBD with three replications. The selected bamboo species had no problem on survival and adaptability at Mechara area except some growth variation and the outcome had a significant value at ($p<0.05$) between treatment's parameters. Regardless of this fact; mean value of Dendrocalamus hamlitonii specie was showed high difference and followed by Dendrocalmus Membracias that in number of new emerging bamboo shoots, root collar diameter of the emerging shoots, Culm diameter, Culm height, lower internodes length, middle internodes length, upper internodes length and number of nodes except number of bamboo seedling survives in first year whereas, Guadua amplexofolia mean values revealed low in almost all growth parameters except number of bamboo seedling survives in first year under comparison of exotic bamboo species. On the other hand, Guadua amplexofolia showed the higher mean value than Oxytenanthera abyssinica which is an indigenous lowland bamboo species with the number of bamboo seedling survives in first year, number of new emerging bamboo shoots, root collar diameter of the emerging shoots and Culm diameter. On the contrary side; Oxytenanthera abyssinica was showed higher mean value than Guadua amplexofolia only with Culm height, lower internodes length, middle internodes length, upper internodes length and number of nodes. Despite this fact, we recommend that Dendrocalamus hamlitonii is the first advocated and, Dendrocalamus memebranceous is the second advocated in different aspect of utilities to the study area and to similar agro ecologies zones because of they have a good quality in number of new emerging bamboo shoots, root collar diameter of the emerging shoots, culm diameter, culm height, lower internodes length, middle internodes length, upper internodes length and number of nodes, while the growth parameters of Guadua amplexofolia and Oxythenantera abyssinica are relatively different when compare with the first and second advertisers. Generally, the *adaptation of lowland bamboo species under Mechara is trustworthy so, we advocate these adaptable species for further economic and livelihood benefits for different stakeholders through expanding the plantation after testing propagation mechanism.*

Keywords: Lowland Bamboo species, exotic and indigenous bamboo species, unique characteristics of bamboo

Introduction

Bamboo is a multipurpose plant and giant grass with great ecological safeguards and vital economic values from subsistence to commercial food (young shoots contains vitamin, carbohydrate, fat and protein), building, medicine and furniture. Bamboo is also a perennial, woody-stemmed grass and usually hollow and semi-solid to solid culms with distinct nodes and internodes, rhizomes and branches. Bamboo has many utilities which are expanded to new industries and products in worldwide. Growing of bamboo is gratifying for whatever end product anyone wants it for requires less of time, money and effort. Large scale growing of bamboo is desirable, in a small scale farms and yet become successful too because of incite worldwide attention as a versatile plant with multifarious uses (Rojo *et al.,* 2000).

Bamboo protects the environment and cleanses the air we breathe. Bamboo stands release 35% more oxygen than equivalent stands of trees. Some bamboo can sequester up to 12 tons of carbon dioxide from the air per hectare. It can also lower light intensity and protects man against ultraviolet rays. Bamboo is a good soil conservation plant. With its widespread root system; it can provide an effective erosion control, sustains riverbanks and serves as good windbreaks (Virtucio, F.D. and Roxas, C.A, 2003).

There are over 1,500 species of bamboo (Sharma, 1987) and Africa alone has 43 species (Kigomo B. N. 2007). Ethiopia is one of the most endowed countries in area coverage of natural bamboo forest of the country that estimated to have about 1 million ha in western and southern part of the country, which is about 7% of the world total and 67% of the African bamboo forest areas (Embaye, 2000). Bamboos are native to both temperate and tropical climates, and therefore naturally distributed all over the world, with the exception of Europe and Antarctica (McClure, 1966). Bamboo is versatile plant with a very short and fast growing cycle on this planet that some species can grow up to 0.25m meter per day. This growth pattern makes it easily accessible in a minimal amount of time and therefore can be harvested in 3-5 years versus 10-20 years most soft woods. Its size ranges from short to towering culms of 9-30 m. Bamboo is a high yield renewable natural resource for agro-forestry and engineering based products and renewal of sullied lands (McClure, 1966).

Even though Ethiopia is one of the most artistic countries in having huge coverage of bamboo resource in Africa, the country has narrow genetic diversity only has two species: Yushania alpine (High land) and Oxytenanthera abyssinica (Lowland). With these two species, it is very difficult to secure constant supply of bamboo raw material for multifarious uses if those might be faced with unconditional pathogens. In addition, the most puzzling aspect of the bamboo life cycle is its flowering behavior. The flowering in bamboos is extremely amusing event because, most of the species flower either gregariously or intermittently only once every 60 to 120 years and this is not all, bamboos are monocarpic, i.e. they flower only once, set seeds and then die. Worldwide including Ethiopia, death in large populations of bamboo is a cause of distress due to ecological, social and economic crises that set forwards without appreciating its economic return due to lack of scientific information (John & Nadgauda, 2002).

Oxytenanthera abyssinica is lowland bamboo of Ethiopia which is a clumping (sympodial) type with solid Culm at maturing age, an average Culm diameter of 5 cm, and 7 m high and one of fast growing species that has potential in improving the livelihood of people. This species grows at an elevation of between 800 to 1800 m above sea level. Despite the fact that; Oxytenanthera abyssinica is widely distributed in lowland areas of the country, it has been facing with distress problems from both manmade and natural bases. It has immense potential in reducing carbon dioxide that is blamed for environmental pollution and the most valuable species for ecological sustain. Bamboo in Ethiopia, it is a millennium golden grass that contributes to government vision of getting itself in the list of the middle-income countries of the world in about the forth coming two decades by boosting the income of farmers. It has considerable potential to the socioeconomic development and environmental protection (Baghel *et al.*, 1998; Kumar *et al.*, 1998; Perez *et al.*, 1998).

Commonly in Ethiopia and particularly in Hararghe; as population size is increased, deforestation and land degradation problems have been gradually aggravating. Therefore; important of the study is, to introduce higher adaptable of exotic bamboos species in well economic value improvement for small farm holders, to divers the genetic resources of bamboo species and to safeguard for environmental protection through rehabilitation of degraded lands.

Material and Methods

Description of the Study Areas

The trial could be conducted at Mechara Agricultural Research Center (on station) during the year 2011 to 2016 G.C. The center is located at 431 Km East of Addis Ababa. The altitude is 1650 m.a.s.l.. The area experiences bimodal rainy season extending from March to October, but the effective rain is from May to September (IAR, 1991). The mean annual rainfall is about 1018 mm with a peak in July. Mean annual temperature is 20 ^{o}c, with mean minimum temperature of 21^{o}c and maximum of 27^{o}c. The soil of the area is dominantly reddish brown Nitosols.

They are generally clay dominated and are characterized by low available phosphorous with a pH ranging from 5.3 to 6 in surface soils (Dawit and Legesse, 1987). The vegetation cover of the area is woodland types.

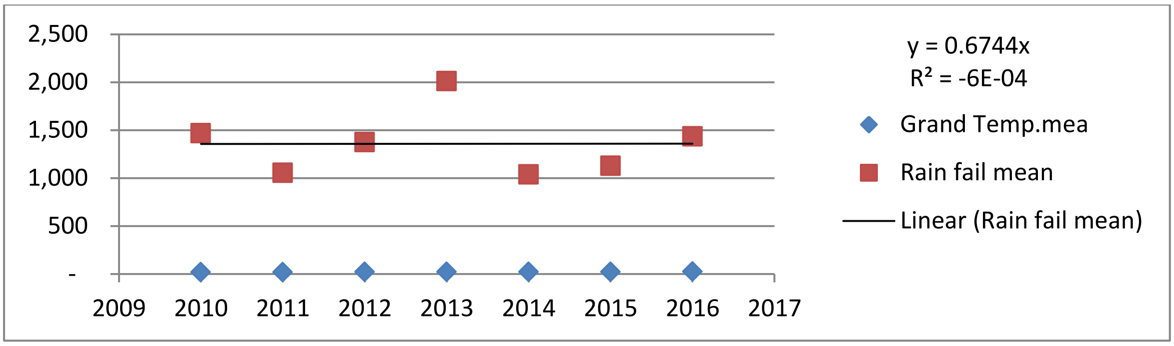


Fig.1 (2009-2016 G.C) Rainfall and temperature of Darolabu District

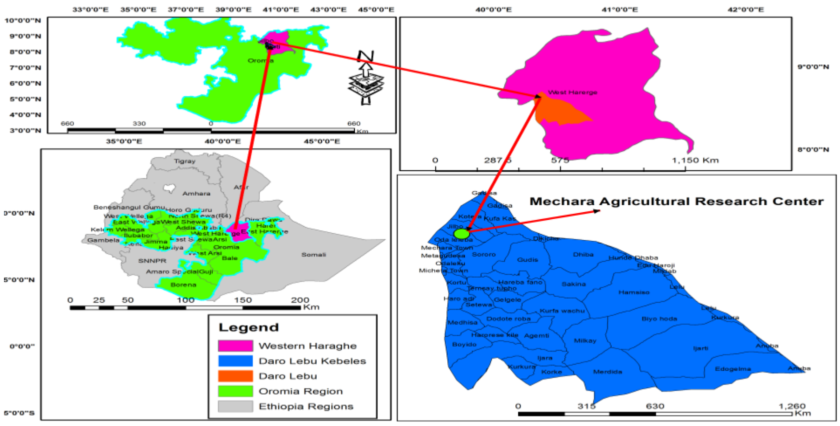


Fig.2. Description of Darolabu Wereda

Treatments and Experimental Design

The experiment was arranged with Randomize Completely Block Designed (RCBD) in three replications. The block was folded to accommodate the four treatments within fairly uniform soil condition as a result of replication. The distance between blocks and plots was 3m. And also the space between each plant was 2m and the plot size was 7*4 m with a total of 6 plants per plot and 72 total plants. Over all plantation area was 666m^2 that 37*18m. As a treatment, four lowland bamboo species were used: *Oxytenanthera abyssinica*, *Guadua amplexofolia*, *Dendrocalamus hamlitonii* and *Dendrocalamus memebranceous*. Among those mentioned species *Oxytenanthera abyssinica* is the indigenous bamboo species for Ethiopia. So the seed or seedlings of those exotic bamboo species were obtained from Debrezeyit agricultural research center and indigenous bamboo species also from Assosa gricultural research center.

Data Collection

Adaptation trial of lowland bamboo at Mechara agriculture research center was carried out from 2011 to 2016 with 6 month data collection interval. The purpose of the trial was to evaluate the adaptability and growth potential of different lowland bamboo species, and also to get the best performance of bamboo provenance for similar agro ecologies of the study area in East Hararghe zone. On the subject of adaption and growth performance matter, the collected data were: number of bamboo seedling survives in first year, number of new emerging bamboo shoots, root collar diameter of the emerging shoots, culm diameter, culm height, lower internodes length, middle internodes length, upper internodes length, and number of nodes.

Data Analysis

The collected data were analyzed with analysis of variance (ANOVA) following the General Linear Model (GLM) procedure using SAS statistical software of 91.3 versions. The important variation, mean separation using LSD was conducted at 5% point of significance level.

Result and Discussions

Number of Bamboo Seedlings Survived in the First Year

The present study indicated that the mean value of Bamboo seedlings survived in the first year were revealed high significant difference at ($p<0.05$) level between the planted bamboo species. The highest numbers of Bamboo seedlings survived in the first year were *Guadua aplexifolia* and *Dendrocalmus membracias* species, while the least number of Bamboo seedling survived in the first year was *Oxytenanthera abyssinica* species. During the three year trail period of the selected bamboo species' seedling, highly muscularly adapted species were *Dendrocalmus membracias* and *Guadua aplexifolia* followed by *Oxytenanthera abyssinica* and *Dendrocalmus Hamletonii*, respectively (Table 1).

Except *Dendrocalmus Hamletonii*, all selected lowland bamboo species were not attacked by any disease and pest indicating well performance and adaptability of the species in in the study area, west Hararghe. However; *Dendrocalmus Hamletonii* recorded the highest mean value in all observed parameter except number of bamboo node (Table 1). This variation may be due to the growth and adaptability characteristics of the species.

New Emerging Number of Bamboo Shoots

The mean value of the given parameters that on new emerging number of bamboo shoots showed significant difference at the level of ($p<0.05$) point between the planted bamboo species. The capacity of lateral buds forming new rhizome and shoots is may be closely related to rhizome age, vigor, and nutrient storage. Based on the analysis result of the three years data, *Dendrocalamus hamlitonii* bamboo species disclosed a highest mean value on the number of new emerging shoots throughout the pursue periods followed by *Dendrocalmus Membracias*, *Guadua aplexifolia* and *Oxytenanthera abyssinica* (Table 1).

The mean value of *Dendrocalamus hamlitonii bamboo* species on the given parameter was greater than that of *Dendrocalmus membracias by* 6.89%, *Guadua aplexifolia by* 7.67%, and *Oxytenanthera abyssinica by* 17.33%. This is may be due to high capability of producing new emerging shoots of the specie when compare to the other lowland bamboo specie. This result is similar with the report from Bako agricultural research center, 2016; which shows higher shoot emerging for *Dendrocalamus hamlitonii*. *Guadua aplexifolia* and *Dendrocalmus membracias* species illustrated a good performance in emerging new shoots next to *Dendrocalamus hamlitonii*. Whereas, *Oxytenanthera abyssinica* specie disclosed a low performance in emerging new shoots number during the pursue periods (Table 1).

Root Collar Diameters

The mean value of the given parameter that on Culm diameter showed high significant difference at the level of ($p<0.05$) point between the planted bamboo species. The highest mean observed from *Dendrocalmus Hamletonii* species that followed by *Dendrocalmus Membracias* and *Guadua aplexifolia*, while the least mean recorded from *Oxytenanthera abyssinica*. *Dendrocalmus Hamletonii* mean greater than that of *Dendrocalmus Membracias, Guadua aplexifolia* and *Oxytenanthera abyssinica* by 0.82%, 0.89% and 1.62%, respectively (Table 1). This may be based on the growth performance and adaptability of the species.

Culm Diameters

The mean value of Culm diameter showed significant difference at ($p<0.05$) level between a given treatments. The highest mean observed from *Dendrocalmus Hamletonii* species that followed by *Dendrocalmus Membracias* and *Guadua aplexifolia*, while the least mean recorded from *Oxytenanthera abyssinica*. *Dendrocalmus Hamletonii* mean greater than that of *Dendrocalmus Membracias*, *Guadua aplexifolia* and *Oxytenanthera abyssinica* by 0.47%, 1.24% and 1.89%, respectively (Table 1). The Culm diameter indicated by the thickness or size of the Culm is directly or indirectly related with the quality of bamboo productions. This may depend upon the growth performance and adaptability of the species.

Culm Height

The mean value of a given parameter showed significant difference at ($p<0.05$) level between treatments. According to the current analysis; *Dendrocalamus hamlitonii* displayed the highest mean, *while Guadua amplexofolia* showed the least mean of Culm height when compare to the others. The mean of *Dendrocalamus hamlitonii* was greater than that of *Dendrocalmus Membracias, Oxytenanthera abyssinica* and *Guadua aplexifolia* by 43%, 1.69% and 2.68%, respectively (Table 1). The result agreed with the report from Pawe by Yared, 2013 (unpublished) which shows higher Culm height for *Dendrocalamus hamlitonii* and lower Culm height recorded for *Guadua amplexofolia.* On the other hands, these result disagreed with the report from (Regassa *et al.*, 2016) by *Guadua amplexofolia* and *Oxythenantera abyssinica values.* The Culm diameter is indicator of the thickness and size of the planted bamboos which is directly or indirectly referred the quality of bamboo production. The full length of the Culm is varied among the species; this disparity may be due species vary on its adaptability and performance conditions based on agro ecology zones.

Table 1: ANOVA table of treatments' value based on the given parameters

Treatments	Parameters								
	NBSSY	NENBS	RTCD (cm)	CLMD (cm)	CLMH (m)	LRINDL (cm)	MDINDL (cm)	URINDL (cm)	NOND
Dendrocalmus hamletonii	3b	28.11a	3.82a	3.30a	4.52a	19.20a	24.78a	19.00a	19.76a
Dendrocalmus Membracias	6a	21.22b	3.40a	2.83ab	4.09ab	16.54b	21.85ab	17.64a	24.39a
Guadua aplexifolia	5a	20.44b	2.93a	2.06b	1.84bc	10.36c	13.78c	10.69b	14.75b
Oxytenanthera abyssinica	4b	10.78c	2.20b	1.41c	2.51b	14.02b	19.50b	11.57b	14.28b
Mean	5	19.9	3.1	2.4	3.24	15.03	20	14.7	18.3
LSD	0.51	8.45	1.05	0.97	2.13	2.66	3.30	3.20	5.87
CV %	5.69	21.27	17.09	20.23	32.92	8.86	8.28	10.89	16.06
P-value	0.001	0.0142	0.0411	0.0124	0.0618	0.001	0.001	0.0015	0.0167

Means with the same letter are not significantly different

NBSSV –Number of Bamboo seedling survival in first year, NENBS - Number of new emerging bamboo shoots, RTCD - Root collar diameter in, CLMD (cm) –Culm diameter, CLMH –Culm height in meter, LRINDL - Lower internodes length , MDINDL -Middle internodes length , URINDL- Upper internodes length and NOND- Number of node in number

Lower, Middle and Upper Internodes Length and Number of Node

The mean value of a lower internodes showed significant difference at ($p<0.05$) level between treatments. The highest mean observed from *Dendrocalmus hamletonii* species that followed by *Dendrocalmus membracias* and *Oxytenanthera abyssinica*, while the least mean recorded from *Guadua aplexifolia*. Based on the given parameter, *Dendrocalmus hamletonii* mean was greater than that of *Dendrocalmus membracias*, *Oxytenanthera abyssinica* and *Guadua aplexifolia* by 2.66%, 5.18% and 8.84%, respectively (Table 1).

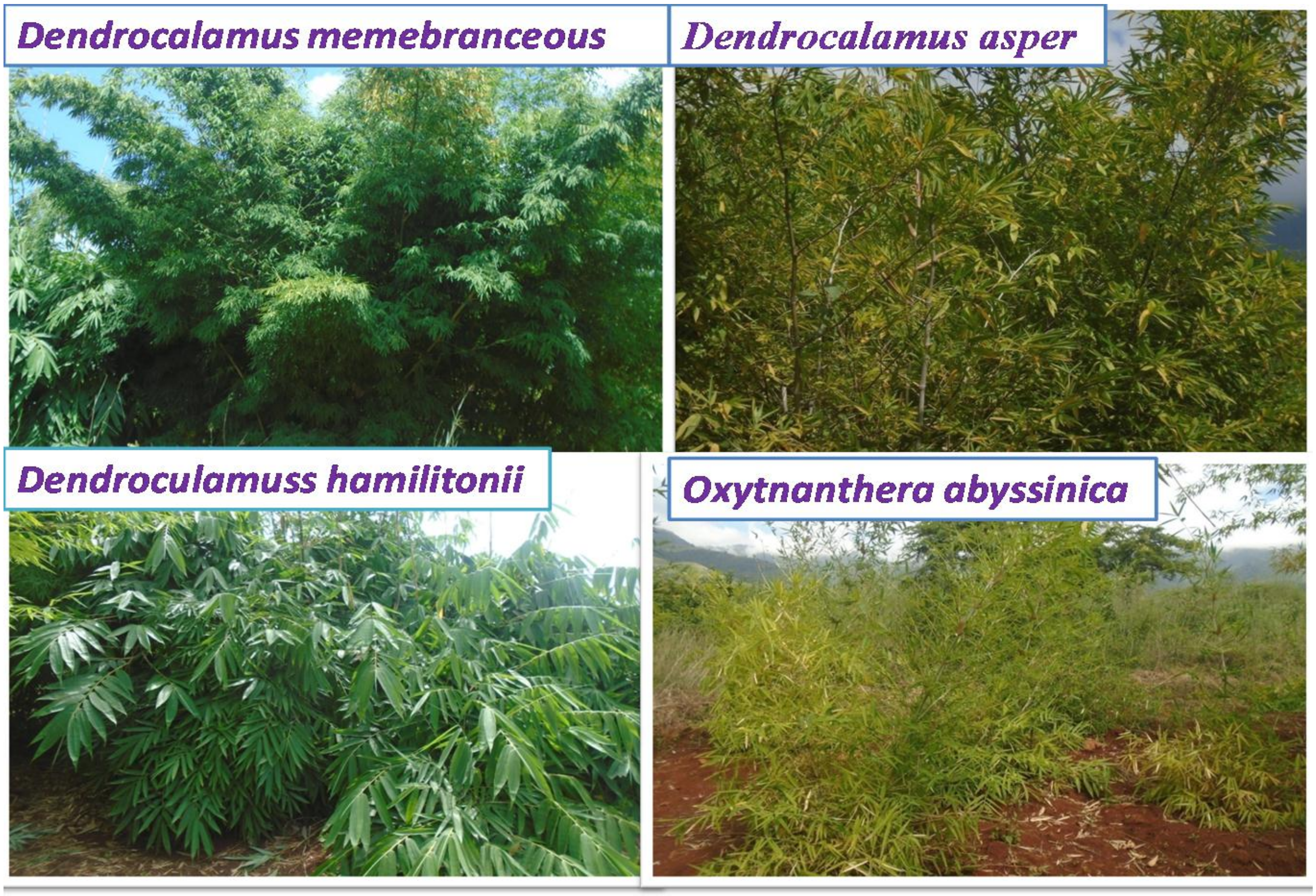
The mean value of middle internodes length showed significant difference at ($p<0.05$) level between treatments. The highest mean observed from *Dendrocalmus hamletonii* species that followed by *Dendrocalmus membracias* and *Oxytenanthera abyssinica*, while the least mean recorded from *Guadua aplexifolia. Dendrocalmus hamletonii* mean was greater than that of *Dendrocalmus membracias*, *Oxytenanthera abyssinica* and *Guadua aplexifolia* by 2.93%, 5.28% and 11%, respectively (Table 1).

The mean value of upper internodes length showed significant difference at ($p<0.05$) level between treatments. The highest mean observed from *Dendrocalmus hamletonii* species that followed by *Dendrocalmus membracias* and *Oxytenanthera abyssinica*, while the least mean recorded from *Guadua aplexifolia. Dendrocalmus hamletonii* mean was greater than that of *Dendrocalmus membracias*, *Oxytenanthera abyssinica* and *Guadua aplexifolia* by 1.36%, 7.43% and 8.31%, respectively (Table 1).

The mean value of the number of node showed significant difference at ($p<0.05$) level between treatments. The highest mean observed from *Dendrocalmus membracias* species that followed by *Dendrocalmus hamletonii* and *Guadua aplexifolia*, while the least mean recorded from *Oxytenanthera abyssinica. Dendrocalmus membracias* mean was greater than that of *Dendrocalmus hamlitonii*, Guadua aplexifolia and *Oxytenanthera abyssinica* by 4.63%, 9.64% and 10.11%, respectively (Table 1).

Generally, Bamboo culm structure is cylindrical and is divided into section by node. The section between two nodes is called internodes. Internodes are hollow in most bamboos, but solid in some species. Direct or indirectly bamboo internodes length can indicate the quality of bamboo product which is used for different purpose. *Dendrocalamus hamlitonii* show higher internodes length as compare to others which is similar with the report of Yared K, 2013 (unpublished) which showed higher internodes length for *Dendrocalamus hamlitonii*, while *Guadua amplexofolia* showed lower internodes length.

Guadua amplexofolia bamboo species advocated the least value than the others bamboo species based on a given parameters; however, it has the unique character which is not easily damaged by animals due to its spine over the culms which is used for protects itself from palatable by animals, so that it may be better to use for soil and water conservation purpose on degraded and rehabilitation areas.



Finger 1- Lowland Bamboo species

Conclusion and Recommendations

Bamboo plants' growth is more miracle than any trees, and starts to give yield within a short year of planting time. So, bamboo is one of the fast growing and responding well against drought which can make the species more acceptable in making ever green environment in addition to soil and water conservation, and rehabilitation of degraded lands.

Regardless of this fact, *Dendrocalamus hamlitonii* species showed highly significant difference followed by *Dendrocalmus Membracias* in number of new emerging bamboo shoots, root collar diameter of the emerging shoots, Culm diameter, Culm height, lower internodes length, middle internodes length, upper internodes length and number of nodes except number of bamboo seedling survives in first year. Whereas, *Guadua amplexofolia mean values* revealed low in almost all growth parameters except number of Bamboo seedling survives in first year under comparison of exotic bamboo species. On the other hand, *Guadua amplexofolia* showed the higher mean value than *Oxytenanthera abyssinica* with the number of bamboo seedling survives in first year, number of new emerging bamboo shoots, root collar diameter of the emerging shoots and Culm diameter only. *Oxytenanthera abyssinica* was showed higher mean value than *Guadua amplexofolia* only in Culm height, lower internodes length, middle internodes length, upper internodes length and number of nodes values.

Based on these results, we recommend that *Dendrocalamus hamlitonii* is the first and *Dendrocalamus memebranceous* is the second category for different production because of they have a good performance in number of new emerging bamboo shoots, root collar diameter of the emerging shoots, culm diameter, culm height, lower internodes length, middle internodes length, upper internodes length and number of nodes, while the growth parameters of *Guadua amplexofolia* and *Oxythenantera abyssinica* are relatively the least mean value when compare with the first and second categories. Based on this we conclude that the selected bamboo species are well adapted and performed at Mechara on station. Finally we recommend further research direction on bamboo plants propagation method in order to fill the interest of wide end users.

Acknowledgements

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Reference

Baghel, L.M.S., Anjila Gupta, R.K. Verma and N.G. Totey. 1998. Socio- economic and bamboo consumption pattern in villages around Jebelbur and Mandla, Mahdhya Pradesh: A case Study. *Journal of Tropical Forestry*. 1998,14:4,252-261.

Embaye, Kassahun. 2000. The Indigenous Bamboo Forests of Ethiopia: an overview. *Ambio* 29, 518-521.

IAR, 1991. Hangzhou, China. The Chinese Academy of Forestry, China and International Development Research Centre (IDRC), Ottawa, Canada, pp 4–17.

John CK & Nadgauda RS. 2002. Bamboo Flowering and Famine. *Current Science*, 82 (3): 261–262.

Kigomo, B. N. 2007. Guidelines for Growing Bamboo. Kenya Forestry Research Institute. Guidelines Series No. 4. 58pp.

Kumar, Adarsh, Meena Dhawan and B. B. Gupta.1998. Flowering and rooting of *Bambusa tolda* culm cuttings in response to growth regulating substances. *The Indian Forester.* 1998,116:7, 574-553.

McClure, EA. 1966 The bamboos: a fresh perspective. Harvard University Press, cambridge, Mass., USA. 347 pp.

Perez, Manuel Ruiz, Zhong Maogong , Brian Belcher, Xie Chen, Fu Maoyi and Xie Jinzhong. 1998. The role of bamboo plantation in rural development: The Case of Anji Country, Zhejiang, China. Elsevier Science Ltd. *World Development* 27(1): 101-114pp.

Regassa Terefe, Dawit Samuel, Mezgebu Sanbato and Mokonin Daba. 2016. Adaptation and Growth Performance of Different Lowland Bamboo Species in Bako, West Shoa, Ethiopia. *Journal of Natural Sciences Research: ISSN; Vol.6, No.9, 2016.*

Rojo,J.P., C.A. Roxas, F.C.Pitargue, Jr and C.A. Briñas. 2000. Philippine Erect Bamboos, A Field Identification Guide. Forest Products Research and Development Institute, College, Laguna.

Sharma, Y.M.L. 1987. Inventory and resource of bamboos. In: P*roc. Int. Bamboo Workshop.*

Virtucio, F.D. and C.A. Roxas, 2003. Bamboo Production in the Philippines. Ecosystems Research and Development Bureau, Department of Environment and Natural Resources, College, Laguna.

Estimation of Optimum Water Requirement and Frequency of Watering for Different Tree Seedlings at Bako Agricultural Research Center Nursery Site

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Abstract

Determining water requirement and application frequency of tree seedlings is crucial to use available water effectively. This study estimated the Optimum water requirement and application frequency of tree seedlings: Grevillea robusta, Moringa olifera and Cordia africana at nursery site for the two consecutive years. The experiment was implemented during off-season; because of the objective of the study was to determine amount of water and frequency required for normal growth tree seedlings at nursery stage. Three different water application (1, 1.5, and 2 liters) and two irrigation frequencies (watering twice daily and watering twice after one day) and the control (Local practices) were combined with tree species. Seeds were sown directly into polythene bags in the traditional nursery site. Different growth parameters were collected and evaluated to estimate the optimum water requirement and watering frequency of different tree seedlings at nursery site. Growth parameters: root collar diameter (cm), height (cm), root depth (cm) and survival rate (%) were assessed during the nursery stage. The growth parameters measured were subjected to Analysis of Variance (ANOVA). The means were separated by Least Significant Difference (LSD; $P \leq 0.05$). The result reveals that significant difference was observed among the three tree species growth parameters; root collar diameter, height and survival rate under different watering applications and irrigation frequencies. The average potential evapotranspiration of study area over the two consecutive years were 47 mm/month. The result indicated that, the growth performance of Moringa olifera and Grevillea robusta were better when watered twice daily with 1.5 liters of per a given plot. The growth performance of Cordia africana was good performed when watered twice after one day with 2 liters of water per a given plot. Also the result showed that Moringa olifera watered twice daily with 1.5 liters had the highest height of 50.74 cm followed by Moringa olifera watered twice after one day with 2 liters had height of 45.35 cm and while Grevillea robusta watered twice after one day with 1 liters had the least height 10.73 cm. The study therefore recommends that Moringa olifera and Grevillea robusta seedlings watered twice daily with 1.5 liters and Cordia africana seedlings watered twice after one day with 2 liters per plot of water availability should be adopted in the area where warm humid climate and high potential evapotranspiration, since it ensures good growth performance of those tree seedlings species.

Key Word: Water requirement, watering frequency, tree seedling, growth parameters, nursery site

Introduction

Water is an important component of plants. Adequate amount of water is critical to successful tree nursery operation among resource-constrained smallholder farmers in Africa (Simon *et al*., 2011). Water requirements of a crop are dependent on the botanical characters of the crop, its stage of growth and the prevailing we at her conditions (Farah, 1996). Water is a significant factor in dry land forestry and it is critical to tree growth and development in the tropics (Awodola and Nwoboshi , 1993). Detection of crop water stress is critical for efficient irrigation water management, especially in the semi-arid regions. Water is an important natural resource that supports life and growth of plants, but there is a growing concern on water availability (Goyne and McIntyre, 2003). With the effects of climate change, water will become increasingly scarce in most geographical zones of the world (Morrison *et al.,* 2009). Availability of permanent water supply has been one of the major challenges in fruit tree nursery establishment and management, especially in the drier regions of the tropics and sub-tropics. Water use requirements depend on tree species, growth stage and time of the year and hence, it is necessary to establish this for each tree species as there are differences in growth rates (Bargali and Tewari, 2004). Irrigation implies the application of suitable water to plants in right amount at the right time.

Tree growth parameters are commonly studied to understand the behavior of trees under different nutrient, water or light conditions (Zahid and Nawaz, 2009). The study reported by Luvaha *et al*., (2012), mango seedlings under mild water deficit (watering once or twice in a week) promote growth rate as compared to well watered seedling (watering once or twice daily). Similarly, (Oyun et al., 2010) reported twice weekly watering is most suitable for tending the seedlings of *A.senegal* in the nursery. Establishing optimal water requirements for fruit tree seedlings in the nurseries, promotes sustainable water use (Mhango *et al*., 2008). The amount of water required by a crop depends on the local environment, the climate, the crop and its stage of growth, and the degree to which the crop may be stressed (Doorenbos *et al*., 1992). This requirement may be expressed as a uniform depth of water over the area in millimeters per day (mm/day).

In Ethiopia, although irrigation has long been practiced at different farm levels, there is no efficient and well managed irrigation water practice. Satisfying crop water requirements, although it maximizes production from the land unit, does not necessarily maximize the return per unit volume of water. Around Bako, although irrigation has long been practiced at different farm levels, there is no efficient and well managed irrigation water practice. There is no information regarding appropriate management of irrigation water and plant water requirement for the rapidly expanding small scale irrigation farms in this area.

Sufficient quantity and quality of water is extremely important for the production tree seedlings at nursery site. This need frequent irrigation and requires careful planning and management, to ensure that operations have sufficient water to maintain adequate supplies for plant production. Therefore, for effective reforestation or afforestation in degraded areas, it is crucial to understand the water requirements of different tree seedling species. This study estimated the optimal water requirement on the early growth performance of tree seedlings of three tree species commonly used in the area to overcome failuirity of these seedlings due to lack of efficient water management.

Materials and Methods

Description of the Study Area

This experiment was carried out at nursery site of Bako agricultural research center for the last two consecutive years. The center is located in the western part of Ethiopia at about 9^0 6'N latitude and 37^0 9'E longitudes and a distance of 250 km away from Addis Ababa at an altitude of 1650 m above sea level (Figure 1). It has a warm humid climate with annual mean minimum, mean maximum and average temperatures 13.7, 28.3 and 21^{o}C, respectively. The area receives an annual rain fall of 1257.66 mm with maximum precipitation in the month of June to August (Bako Agricultural Research Center meteorological data record) (Figure 2). The soil of the area is characteristically reddish brown with a pH that falls in the range of slightly acidic to very acidic (BARC soil laboratory record).

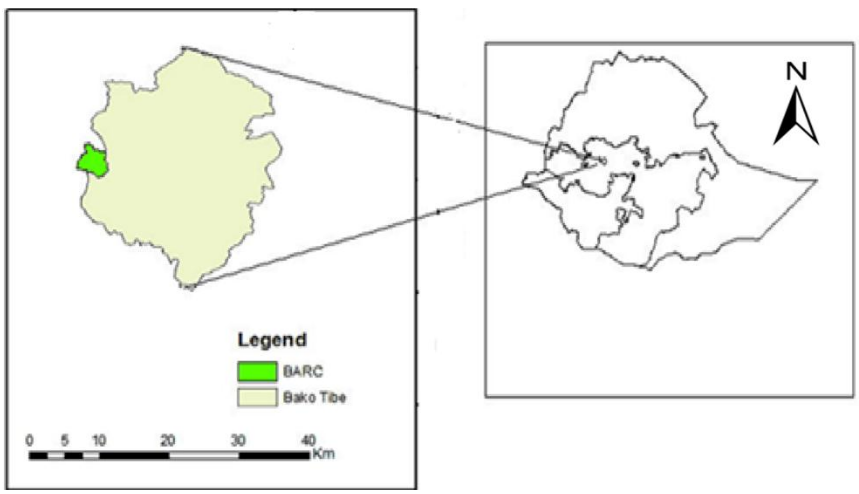

Figure 1: Study area location

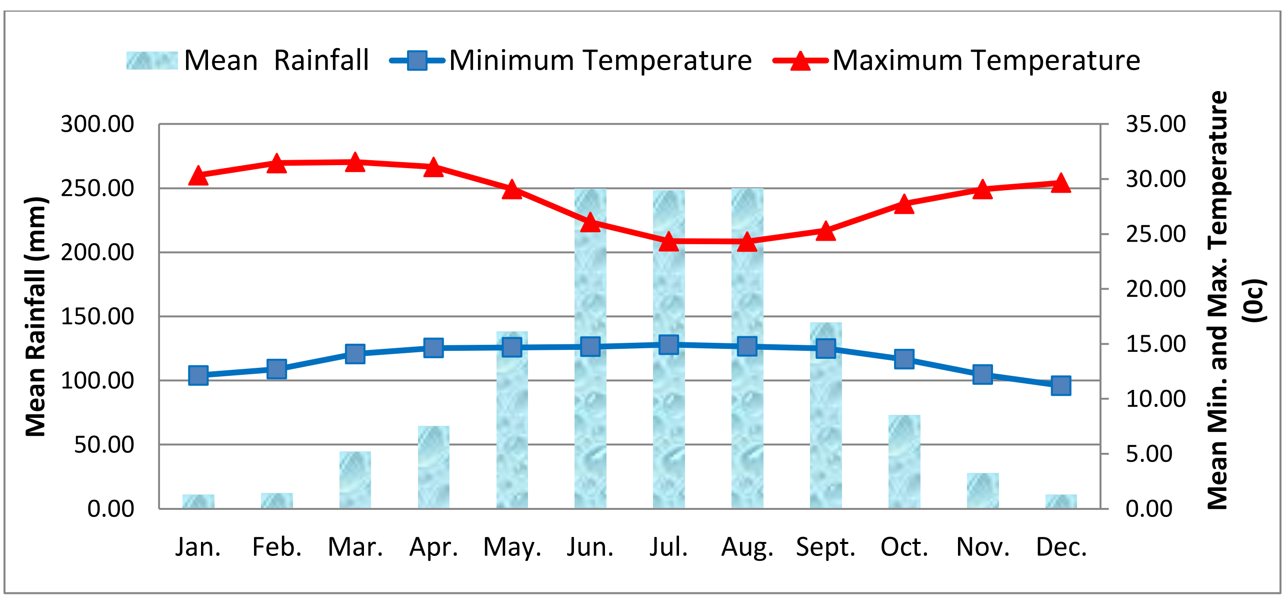

Figure 2: long-term mean monthly rainfall, minimum and maximum temperature (1990-2016)

Experimental Design and Treatments

Seeds of the three tree species: *Grevillea robusta*, *Moringa olifera* and *Cordia africana* were collected around study area. *Grevillea robusta* and *Moringa olifera* seeds were pre-treated with cold water for 24 hours before sowed while *Moringa olifera* was sowed without any pre-treatment. Pots were prepared from mixture of local soil, forest soil, sand soil, and manure. The pot size of 12cm was used for *Cordia africana* and *Moringa olifera*, while 10cm was used for *Grevillea robusta*. The nursery bed was prepared on nearly flat land, which has 0.5m width and 18.5m length including 0.5m paths between plots. Surface of bed was leveled by using available material. Each plot had an area of $1m^2$. Depending on the pot size; each plot contains 42 tree seedlings of *Grevillea robusta* and *Moringa olifera* and 36 tree seedlings of *Cordia africana*.

There were nineteen treatments with three replications. The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications and the treatments are assigned to each plot randomly. Three different water application (1, 1.5, and 2 liters) and two irrigation frequencies (watering twice daily, watering twice after one day) and the control (Local practices) were combined with three tree species (Table 1). Different growth parameters were collected and evaluated to estimate the optimum water requirement and watering frequency of different tree seedlings at nursery site. Growth parameters: root collar diameter, height, root depth and survival rate were assessed during the nursery stage. Destructive sampling was carried for growth parameters assessment.

Determination of Evapotranspiration (ET)

Crop water requirements are defined as "the depth of water needed to meet the water loss through evapotranspiration (ET)". Evaporation from an open water surface provides an index of the integrated effect of radiation, air temperature, air humidity and wind on evapotranspiration (Doorenbos *et al.*, 1992). However, differences in the water and cropped surface produce significant differences in the water loss from an open water surface and the crop. The pan has proved its practical value and has been used successfully to estimate reference evapotranspiration by observing the evaporation loss from a water surface and applying empirical coefficients to relate pan evaporation to ETo. Evapotranspiration (ETo) can be obtained from:

$$ETo = Kp*Epan$$

Where: Kp - Pan Coefficient

Epan- pan evaporation in mm/day

Table 1: Treatment arrangements

Treatments	Irrigation frequencies	Quantities of water (Lit.)	Tree species
T1	Two times per day (M and AF)	1	*Cordia Africana*
T2	Two times per day (M and AF	1	*Grevillea robusta*
T3	Two times per day (M and AF)	1	*Moringa olifera*
T4	After one day (M and AF)	1	*Cordia Africana*
T5	After one day (M and AF)	1	*Grevillea robusta*
T6	After one day (M and AF)	1	*Moringa olifera*
T7	Two times per day (M and AF)	1.5	*Cordia Africana*
T8	Two times per day (M and AF)	1.5	*Grevillea robusta*
T9	Two times per day (M and AF)	1.5	*Moringa olifera*
T10	After one day (M and AF)	1.5	*Cordia Africana*
T11	After one day (M and AF)	1.5	*Grevillea robusta*
T12	After one day (M and AF)	1.5	*Moringa olifera*
T13	Two times per day (M and AF)	2	*Cordia Africana*
T14	Two times per day (M and AF)	2	*Grevillea robus,*
T15	Two times per day (M and AF)	2	*Moringa olifera*
T16	After one day (M and AF)	2	*Cordia Africana*
T17	After one day (M and AF)	2	*Grevillea robusta*
T18	After one day (M and AF)	2	*Moringa olifera*
T19	Control (Two times per day)	Local practice	*Cordia, Gravelia and Moringa*

M-Morning; AF- Afternoon; T-Treatment

Data Collection

Determination of potential evaporation was done using a pan evaporation instrument which recorded the amount of water evaporated in a given area of $1m^2$ per day. The pan evaporation instrument was placed next to the experiment as shown in (Figure 3). Evaporation is measured daily as the depth of water (in cm) evaporates from the pan.

Figure 3: Class pan evaporation

The experiment was conducted for 12 weeks each year; after which it was terminated for destructive determination of root collar diameter, height and root depth, root collar diameter, height, root depth and survival rate were the growth parameters that were measured for the two consecutive years at its final termination. Tree seedlings in the middle (16 tree seedlings per plot) were taken as a sample for root collar diameter, height and root depth measurement to minimize the border effect, while the survival count was made for the whole trees seedlings in a plot (42 tree seedlings per plot for both *Grevillea robusta* and *Moringa olifera* and 36 tree seedlings per plot for *Cordia africana*). Root collar diameter measured by caliper and height and root depth growth was using measuring tapes as shown in (Figure 4).

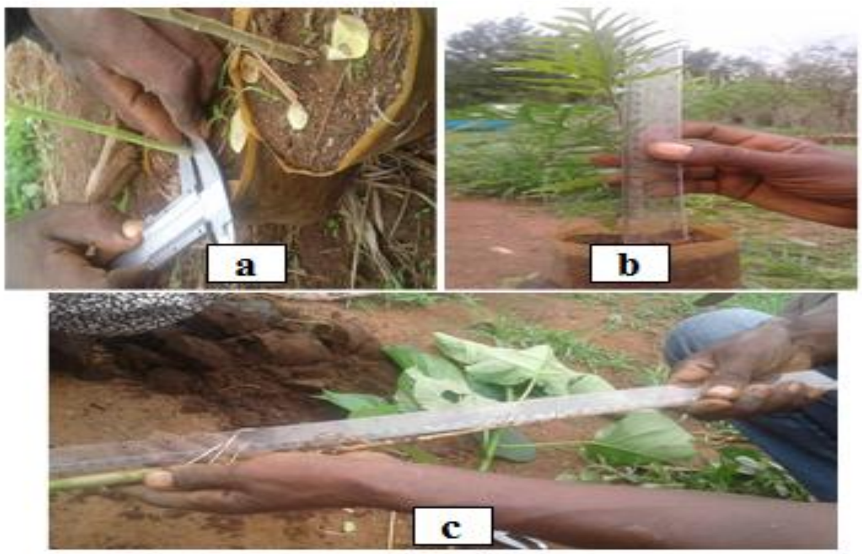

Figure 4: Growth parameters measurements (**a**-collar diameter, **b**-height and **c**-root depth)

Data Analyses

To compare the effects of the treatments statistical analysis of variance (ANOVA) and general liner model (GLM) was carried out to determine the existence of any statistical difference among the treatments. Separation of significant differences between and among treatment means was made by using statistical analysis system (SAS 9.1 versions). Means was separated using Least Significant Difference (LSD) test.

Results and Discussion

Climatic Condition during the Experimental Period

The area received minimum rainfall and high temperature during the experimental period. The mean monthly rainfall, minimum and maximum temperature were 20.97mm, 13.85^{0}C and 32.89^{0}C, respectively during the experimental period (Figure 5). Highest average temperatures of 24.20^{0}C was recorded in month of April (end of experimental period) and lowest average temperature of 22.40^{0}C was observed in the month of February (mid of experimental period). There was slightly increase in average rainfall towards the end of the experiment. This may be due to the onset of rainfall. The evapotranspiration varied with the time period depending on the atmospheric temperature and other climatic parameters. Pan evaporation was used to measure the amount of water evaporated from open pan to determine the potential evapotranspiration (ETo). The estimated average values of ETo by pan evaporation method in the first and second experimental years were 48 and 46.50 mm/month, respectively (Figure 6). Based on the collected data, the highest evapotranspiration has been occurred in March and April. This could be due to little rainfall and high temperatures during those months. The average pooled potential evapotranspiration over the two consecutive years were 47 mm/month.

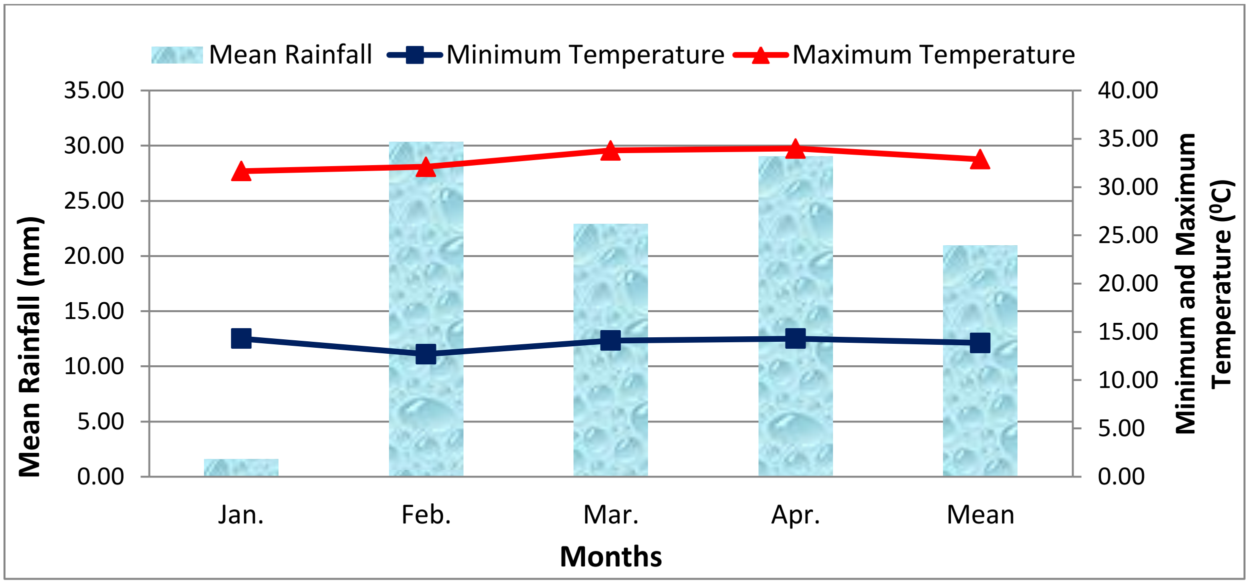

Figure 5: Mean monthly rainfall, minimum, maximum temperature during experimental period

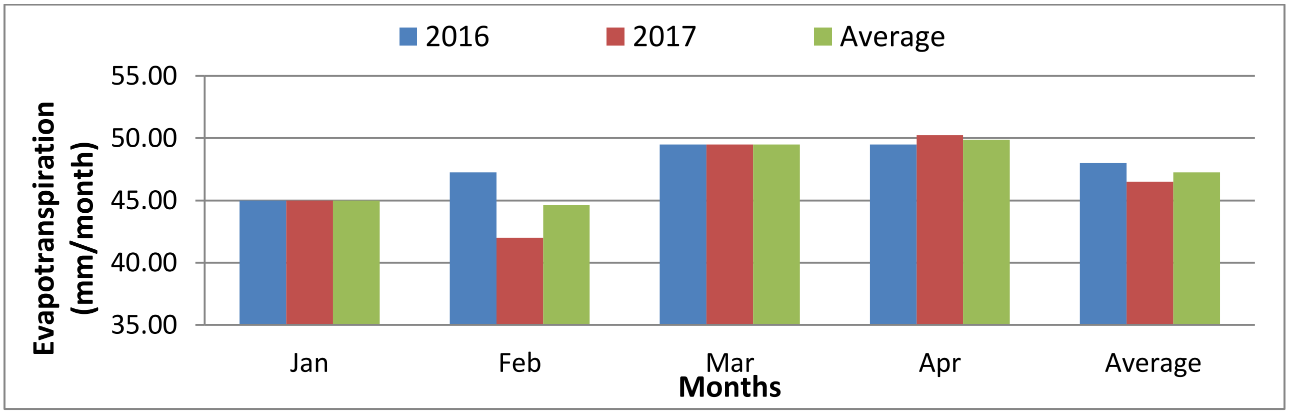

Figure 6: Mean monthly evapotranspiration during experimental period

Tree Seedlings Growth Parameters

Seedlings Height

Significant difference (P≤0.05) was observed among the tree species in seedling height due to different watering applications and irrigation frequencies (Table 3). *Moringa olifera* watered twice daily with 1, 1.5 and 2 liters was not statistically significant in height (P ≥ 0.05) (Table 2). It was observed that *Moringa olifera* watered twice daily with 1.5 liters, *Cordia africana* watered twice after one day with 2 liters and *Grevillea robusta* watered twice daily with 1.5 liters were recorded the highest height (50.74, 33.98 and 13.53 cm), respectively. *Moringa olifera* watered twice daily with 1.5 liters were produced the tallest height. *Moringa olifera* watered twice daily with 1.5 liters increased seedling height by 8.86 cm when compared with a twice after one day with 1.5 liters. *Cordia africana* watered twice after one day with 2 liters increased seedling height by 11.64 cm larger when compared with a twice after one day with 1 liter. This may shows *Cordia africana* required optimum water to survive in the humid climate area.

The influence of water quantity and irrigation frequencies were significant (P≤ 0.05) on the mean height of tree seedlings (Table 3). *Moringa olifera* and *Grevillea robusta* watered twice daily with 1.5 liters per plot had the highest mean height value of 50.74 and 13.53 cm, respectively from all irrigation frequencies and amount of water applied. *Cordia africana* seedlings watered twice after one day with 2 liters had the highest mean height value of 33.98 cm from all irrigation frequencies and water applied per plot. Similar study showed that *Parkia biglobosa* plants watered once in five days gave the highest height of the plant (Sale, F.A., 2015) and water application of 100 ml per pot at two day interval improves growth in seedling height of P. americana and V. infausta (Simon *et al*., 2011).

Therefore, *Moringa olifera* and *Grevillea robusta* seedlings watered twice daily with 1.5 liters; while *Cordia africana* seedlings watered twice after one day with 2 liters per a given plot were ensures the proper growth mean height of tree species.

Table 2: Summary of analysis of variance of tree seedlings species under different watering applications and irrigation frequencies

SV		**Root collar diameter**			**Height**			**Root depth**			**Survival rate**		
	df	MS	F	Pr>F	MS	F	Pr>F	MS	F	Pr>F	MS	F	Pr>F
TRT	18	0.27	14.41**	<.0001	1194.7	13.87**	<.0001	43.10	1.24^{ns}	0.2539	229.12	9.34**	<.0001
REP	2	0.01	0.74^{ns}	0.4828	102.4	1.19^{ns}	0.3105	8.15	0.23^{ns}	0.7916	50.61	2.06^{ns}	0.1342
YR	1	0.04	$2.32n^{s}$	0.1323	1007.78	11.7**	0.001	0.02	0^{ns}	0.9814	0.03	0^{ns}	0.9734
TRT*YR	18	0.01	0.62^{ns}	0.8705	34.50	0.4^{ns}	0.984	42.96	1.24^{ns}	0.2567	31.21	1.27^{ns}	0.2308
ERROR	74	0.02			6375.7			34.77			24.52		
Total	113												

*significantly different at 5% probability; ns- not significantly different at 5%; SV- Source of variation; MS- Mean square; F- F value.

Seedlings Root Collar Diameters

The effect of different amount of water applied and irrigation frequencies were significant ($P \leq 0.05$) on the root collar diameter of seedlings (Table 2). The mean root collar diameter of *Grevillea robusta* was not significant different in all amount of water applied and irrigation frequencies (Table 3). The highest root collar diameter (0.86 cm) was recorded in *Cordia africana* watered twice after one day with 2 liters. Similarly, *Cordia africana* watered twice daily with 1 and 1.5 liters per a given plot were recorded the mean root collar diameter 0.77 and 0.76 cm, respectively. *Cordia africana* seedlings which received 2 liters of water at irrigation frequency of twice after one day per plot had the highest mean root collar diameters value of 0.86 cm from all irrigation frequencies and amount of water applied. Treatment X year interaction were not significantly ($P \geq 0.05$) different (Table 2). This may be due to similar climate condition and potential evapotranspiration was happened over the last two seasons. Therefore, no separate analysis was required. Similarly the study by Simon *et al*., 2011, concludes that water application of 100 ml per pot at two day interval improves growth in root collar diameter of *P. americana* and *V. infausta*. A similar work carried by Isah *et al*., 2013 indicated that, *Acacia Senegal* performed better when watered once in three days and this reflects the capability of this species to cope with drought s tress and water application of 100 ml every two days was effective in promoting seedlings growth and survival of *P. americana* and *V. infausta* (Simon *et al*., 2011).

Therefore, *Moringa olifera* and *Grevillea robusta* seedlings watered twice daily with 1.5 liters while *Cordia africana* seedlings watered twice after one day with 2 liters per a given plot were ensures the proper growth mean root collar diameters of tree species.

Seedlings Root Depth

Root depth of seedlings were not significantly different ($P \geq 0.05$) under different amount of water applied and irrigation frequencies (Table 2). It was observed that *Cordia africana* watered twice after one day with 2 liters, *Moringa olifera* and *Grevillea* watered twice after one day with 1.5 liters and *Grevillea robusta* watered twice after one day with 1.5 liters per plot were recorded the highest root depth (27.08, 23.44 and 19.57 cm), respectively from all irrigation frequencies and watering application exist. The highest root depth (27.08 cm) was recorded in *Cordia africana* watered twice after one day with 2 liters of water. The mean root depth of *Grevillea robusta* watered twice daily with 1, 1.5 and 2 liters of water was not significant different (Table 3).

Seedlings Survival Rate

Similar to height and root collar diameter, significant differences ($P \leq 0.05$) was observed among species in survival rate due to different amount of water and irrigation frequencies (Table 2). The mean survival rate of *Grevillea robusta* watered twice daily with 1, 1.5 and 2 liters and *Moringa olifera* watered twice daily with 2 liters was not statistically significant ($P \geq 0.05$) (Table 3). There was no significant difference ($P \geq 0.05$) in survival rate of *Cordia africana* under all irrigation frequencies and watering applications exists.

The highest survival rate (95%) was recorded in *Grevillea robusta* watered twice daily with 2 liters of water. Similarly, *Moringa olifera* watered twice daily with 1.5 liters and *Cordia africana* watered twice after one with 1 liters per plot were recorded the highest mean survival rate 93.93% and 81.40%, respectively from all irrigation frequencies and amount of water applied.

Table 3: Means of growth parameters of tree seedlings species under different watering applications and irrigation frequencies

Treatments	**Root collar diameter(cm)**	**Height(cm)**	**Root depth (cm)**	**Survival rate %**
T1	0.77^{ab}	25.50^{efg}	23.9^{ab}	80.45^{c}
T2	0.27^{f}	12.17^{hi}	16.95^{cd}	94.25^{a}
T3	0.69^{bcd}	48.12^{a}	20.37^{abcd}	90.92^{ab}
T4	0.64^{bcde}	22.34^{fgh}	20.65^{abcd}	81.38^{c}
T5	0.25f	10.73^{i}	17.22^{bcd}	87.19^{b}
T6	0.57^{cde}	36.64^{bcd}	20.7^{abcd}	92.29^{ab}
T7	0.52^{e}	16.97^{ghi}	20.98^{abcd}	79.03^{c}
T8	0.28^{f}	13.53^{hi}	17.03^{cd}	92.97^{a}
T9	0.72^{abc}	50.74^{a}	23.44^{abc}	93.93^{a}
T10	0.71^{abcd}	25.89^{efg}	21.21^{abcd}	79.78^{c}
T11	0.26^{f}	12.4^{hi}	19.57^{bcd}	90.45^{ab}
T12	0.57^{cde}	41.88^{abc}	19.62^{bcd}	91.02^{ab}
T13	0.76^{ab}	26.91^{defg}	20.68^{abcd}	77.11^{c}
T14	0.27^{f}	12.73^{hi}	16.16^{cd}	95.08^{a}
T15	0.72^{abc}	48.04^{a}	19.59^{bcd}	92.872^{ab}
T16	0.86^{a}	33.98^{cde}	27.08^{a}	79.65^{c}
T17	0.25^{f}	11.98^{hi}	18.48^{bcd}	92.46^{ab}
T18	0.64^{bcde}	45.35^{ab}	17.93^{bcd}	91.55^{ab}
T19	0.56^{de}	29.3^{def}	19.28^{bcd}	89.73^{ab}
CV	25.13	33.66	29.12	5.70
LSD	0.16	10.7	6.71	5.77

Means within the same column followed by the same letter not significantly different at 5% probability level, CV=Coefficient of Variation; LSD=Least Significant Difference

Conclusions and Recommendation

Estimation of tree seedlings water requirement and frequency of watering is essential in irrigation scheduling and water resource management. A consistent and adequate source of water supply is essential for all tree seedling nurseries. Variation was found between the three tree seedling species with respect to growth parameters; root collar diameter, height, root depth and survival rate.

Generally, this study concludes that *Moringa olifera* watered twice daily with 1.5 liters, *Cordia africana* watered twice after one day with 2 liters and *Grevillea robusta* watered twice daily with 1.5 liters per plot were ensures good growth performance of those tree seedlings species. Such findings therefore have implications on water wastage, reduced labor costs and maximizing profitability of tree seedlings production at nursery in area where warm humid climate and high potential evapotranspiration exists.

Therefore, more study is needed for the other species to follow their optimum water requirement and frequency of watering and adaptation under different agro ecological conditions.

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References

Awodol, A .M and Nwoboshi, L.C., 1993. Effect of source of Potassium and frequency of moisture application on growth and macronutrient distribution in seedlings of *Parkia biglobosa*. Nigerian Journal of Forestry 23 (2).

Bargali K, Tewari A., 2004. Growth and water relation parameters in drought-stressed *Coriaria nepalensis* seedlings. J. Arid Environ. 58: 505-512.
Doorenbos J., Pruitt W.O., Aboukhaled A., Damagnez J., Dastane N.G., Berg C., Rijtema P.E., Ashford O.M., Frere M., 1992. Crop Water Requirements. FAO Irrigation and Drainage paper 24.

Farah, S .M., 1996. Water relations and water requirements of wheat. Gezira Research Station Report. P .O. Box 126, Wad Medani , Sudan. P p. 24-36.

Goyne PJ, McIntyre GT., 2003. Stretching water-Queensland's water use efficiency *cotton* and grains adoption program. Water SA, 48(7): 191-196.

Isah, A .D ., Bello, A .G ., Maishanu, H.M and Abdullahi , S., 2013. Effect of Watering Regime on the Early Growth of *Acacia Senegal* (LINN) Willd. Provenances. International Journal of Plant, Animal and Environmental Sciences. Vol 3: 2 -9.

Luvaha, E; Netondo, G.W. and Ouma, G., 2012. Effect of Water Deficit on the Growth of Mango (*Mangifera indica*) Rootstock Seedlings. Department of Botany and Horticulture Kisumu, Maseno University, Kenya.pp 2-4pp.

Mhango J, Akinnifesi FK, Mng'omba SA, Sileshi G., 2008. Effect of growing medium on early growth and survival of *Uapaca kirkiana Müell Arg*. seedlings in Malawi. Afr. J. Biotechnol. 7(13): 2197-2202.

Morrison J, Morikawa M, Murphy M, Schulte P., 2009. Water scarcity & climate change: Growing risks for businesses and investors. A Ceres Report, Ceres, Boston.

Oyun, M.B; Adeduntan, S. A. and Suberu, S. A., 2010. Influence of watering regime and mycorrhizae inoculations on the physiology and early growth of *Acacia senegal* (L.) Wild. African Journal of Plant Science Vol. 4(7): 210-216pp.

Sale, F.A., 2015. Evaluation of watering regimes and different pot sizes in the growth of *Parkia biglobosa* (jacq) benth seedlings under nursery conditi on. European Scientific c Journal 11(12).

Simon A., Festus K., Gudeta S., Oluyede C ., Betserai I., Ramni J. (2011). Water application rate and frequency affect seedling survival and growth of *Vangueria infausta* and *Persea Americana*. African Journal of Biotechnology Vol. 10(9), pp. 1593-1599.

Zahid MD, Nawaz A., 2009. Comparative water use efficiency of *Eucalyptus camaldulensis* and *Dalbergia sisso.* International J. Agric. Biol. 4, 540-544.

Agro meteorology Research

Assessing Local Community Perceptions on Climate Change and Variability its Effects on Crop Production in Selected Woreda of Western Oromia, Ethiopia

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Abstract

Understanding of local people's perception on environmental conditions is crucial to design and implement appropriate adaptation strategies to climate change and variability. This study looked at communities' perception of climate change impacts, barriers and effective adaptation strategies towards climate change in Western Oromia. This study examines smallholder farmers' perceptions of climate variability, climate change and their impacts on crop production, and adaptation strategies adopted over the past three 30 years. Survey data were collected from 204 respondents using both qualitative and quantitative approaches through random sampling technique. Descriptive statistics such as percentage and frequency were used in data analysis. The results of the study showed that the respondents were perceived, the occurrence of climate change in terms of increase in temperatures, decrease in rainfall and change in timing of rain, change in the onset of rains, erratic rainfall pattern. The study also indicated that due to climate change induced factors the agricultural productivity was reduced from time to time. The results show that about 80%) of farmers who participated had observed recent changes in climate. Perceptions of local communities on climate change and variability are consistent with the analyzed historical climate data. The analyzed climate data show fluctuations in onset date, cessation date and length of growing season (LGS) and rainfall is reducing. Weather related problems such as low rain, drought, flood, heat, cold, strong wind that led increased farming problems such as soil erosion, loss of soil fertility; reduction in crop yields and high rate of disease occurrence were observed. The impacts of climate change on crop production were revealed by changes in start of farming season; including: rainfall coming early or late, decrease in rainfall, increase in temperature and increase in farming problems, in particular, increase in soil erosion, loss of soil fertility and reduction in crop yields. The results showed that farmers perceived climate change in terms of changes in rainfall, in temperature, increase in drought condition, crop pests and diseases. Those changes had significant impact on farmers' households whose income depends on rain fed farming. The findings revealed that the impacts of climate in rural areas include reduced in crop yield (49%); increase in pest and disease (34%) and soil erosion (98%). Respondents perceived the main cause of climate change was human action through; intensified agriculture, deforestation, increased use of fossil fuel and use of chemical fertilizer on farms. Therefore, smallholder farmers need to adapt to the changing climate. The adaptation measures identified were soil and water conservation, crop rotation, change crop varieties, change planting dates, late planting, diversification of crop types and varieties, drought resistant varieties, building water harvesting schemes and use of irrigation. Soil and water conservation was the method commonly used by the farmers *representing of respondents. Widely used adaptation measures are soil and water conservation, crop rotation, changing planting dates and change crop varieties in the study area. Barriers to climate change adaptation included: lack of information, shortage of labor, lack of capital, black of access to water and poor potential for irrigation. There is a need to focus community dimensions such as perceptions of smallholder farmers. The study recommends enhanced knowledge of climate change and climate smart agriculture practices for their improved adoption.*

Keywords: Adaptation, Climate change, Local Community, Perception, Variability, Western Oromia

Introduction

The scientific evidence has shown that climate change is a global challenge facing humans and their socio-economic activities, livelihood, health, and food security (Mitchell and Van Aalst, 2008; Romieu *et al.*, 2010; Clarke *et al.*, 2012; Amjath-Babu *et al*., 2016). Climate change threatens various sectors of economic development including natural resources, agriculture and food security, tourism, manufacturing and health (MEADOWS, 2006; IPCC, 2007).

Climate change also imposes constraints to development especially among smallholder farmers whose livelihoods mostly depend on rain-fed agriculture (IPCC, 2007b). Negative impacts of extreme events such as floods and droughts are expected to be high in developing countries especially in rural areas (Adger *et al*. 2003; IPCC, 2007a). Adverse effects of climate change continue to be a major threat to rural livelihoods (IPCC, 2007a, 2007b; Nhemachena, 2009; Pouliotte, Smit, & Westerhoff, 2009). This poses a challenge of developing innovative technologies to improve rural livelihoods and environmental conservation and ensuring adoption of such technologies. Sub-Sahara Africa is among the most vulnerable continents or regions to climate change impacts, because the majority of the Sub-Sahara African population lives in abject poverty, and are heavily dependent on rain fed agriculture for their economic and livelihood sustenance. Therefore, variations in rainfall patterns and temperature adversely impact their economic and social survival.

Reports also indicated that climate change will cause a wide-ranging decline in most of the crops such as sorghum, maize, millet and groundnuts in several countries such as Ethiopia, Eritrea, Sudan, Zambia, Ghana, Sudan and Gambia. Yields from rain - fed crops could drop by 50% by 2020 and dwindle net revenues from crops by 90% by 2100 in some countries, worsening food insecurity and putting millions of people at risk of hunger, with Africa expected to account for the majority by 2080s particularly small scale farmers (Fischer *et al*.,2005; Boko *et al*., 2007). Because the main long-term impacts include significant changes in rainfall patterns and temperature which affect agriculture, there is a projected significant reduction in food security; worsening water security; decrease in fish resources in large lakes due to rising temperature; increase in vector-borne diseases; rising sea level affecting low-lying coastal areas with large populations; and rising water stress (African Partnership Forum (APF, 2007). Climate change is perceived to have adverse ecological, social and economic impacts (Feleke HG, 2015). Smallholder farmers face numerous risks to their agricultural production. Accordingly, 95% of respondents opine that there is frequent crop failure over the areas due to erratic distribution and dwindling rainfall quantum. According to (Menberu, 2016); increasing temperature, decreasing rainfall and abnormal precipitation distribution were observed over past 32 years.

Likewise, the livelihood vulnerability indices (LVIs) calculated for agricultural land and climatic exposure indicators revealed that households are increasingly vulnerable to climate change risks. Also the study by (Negash W., 2016) show that; farmers' perception towards rainfall variability, on average 80 % of the respondents opined that there were rainfall variability in magnitude and frequency, while 11 % perceived as no change in rainfall pattern and 4% responded that they do not know whether it exists or not over the past 20 years. Majority of the respondents (80%) agree that the rainfall variability is due to combined effect of natural and man-induced impacts. Climate change and variability has negatively affected the well-being of most rural smallholder farmers through its adverse impacts.

Similarly, according to the study in Zimbabwe; Smallholder farmers in rural areas have been experiencing low agricultural productivity, crop failure, human disease outbreak, pest and diseases, lack of water, shortages of agricultural-based food items at a household level and food insecurities (Mutekwa, 2009). Understanding of extreme weather events, their significant impacts on crop and livestock production will enable rural farmers to prepare a local response to the anticipated impacts of climate change (Zake and Hauser, 2014; Nyasimi et al., 2013; Savo et al., 2016; Adimassu and Kessler, 2016). The problem of climate change in Ethiopia has the potential of undermining sustainable development efforts; if steps are not taken to respond to its adverse consequences. This meaure depend on farming community perception and response. But there is no available information concerning perception and experiences on climatic variability.

Therefore, undertaking this research would provide important understandings; with regard to the climate change and farmers' perceptions about climate change in order to adapt and mitigate the adverse effects of climate change in western Oromia, Ethiopia.

Objective

- To assess local community 'experience of climate variability and climate change on crop production and responses made to overcome impacts of climate change and variability.

Material and Methods

Study Area Description

The study area lies between 8^0 00' to 10^0 00' N and $36^0$00' to 37^0 50'E and the elevation range from 1200 to 3200 m. The study was carried out with in six (6) selected woreda of western oromia: Diga (Lalisa Dimtu and Demeksa PAs), Jimma Arjo (Abote didessa and Hindhee PAs), Gida Ayana (Anger Gutin PA), Sibu-sire (Cari PA), Bako Tibe (Sedan kite and Biqiltu Leku PAs) and Cheliya (Jarso Dire and Tulu kosoru PAs).

The annual precipitation over western oromia ranges from 1000 mm to 2100mm. The study area experiences annual temperature ranging from 10^0C to 30^0C, with mean annual temperature of 19^0C, where the highlands and mountainous areas in the region receive lowest mean annual temperature, while lowlands and valley bottoms get highest mean annual temperature records (BoFED, 2008; ORHB, 2010). Western oromia wet season runs from May/June to August/September; this is also regarded as the main agricultural summer growing season. Most rainfall occurs in June, July and August. The least rainfall is in September when the summer agricultural crops are mostly at maturity stage.

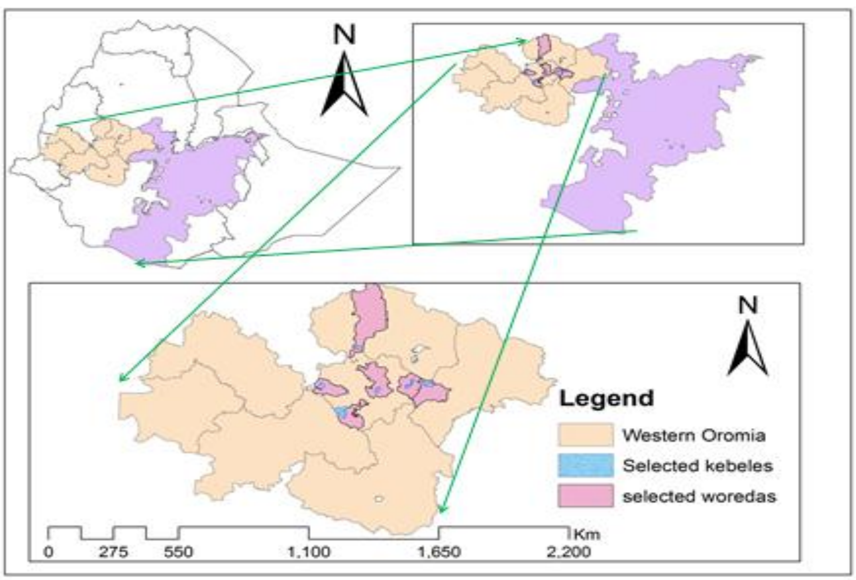

Figure 1: Location of Study area

Data Sources

The studies on local community's perceptions, responses and knowledge of climate variability, impact on crop farming and adaptive strategies at the household levels were gathered through key informants interviews, personal interviews and field observations. Data was collected from smallholder farmers, combined with historical climate data to assess farmers' perception of climate change and variability, and compare the perceptions of historical trends from meteorological data. Meteorological data were collected from meteorological stations available in the study area. Two types of data were used in this study, primary and secondary data. The data was described and summarized quantitatively and qualitatively, which was collected from the National Meteorological Agency (NMA). The primary data were collected from the household's survey through two complementary approaches, namely (i) Key informant interviews) and (ii) Farmer interviews using semi-structured household questionnaires. Meteorological stations were purposively selected, based on the availability of daily rainfall, minimum temperature and maximum temperature data in the study area.

The people selected for interview were those individuals living in the sample peasant association (PA), who are knowledgeable and elderly people who likely represent the opinion of the community. A total of 204 randomly sampled farmers were interviewed using a structured questionnaire with closed and open ended questions.

Purposive sampling techniques were used in the selection of study site and sample households. At the first stage, Digga & Gida Ayana from *kola* (lowland), Sibu sire & Bako Tibe from *woinadeg*a (midland) and Jimma Arjo & Cheliya from highland agro-ecologies were selected. The criteria considered for the selection of study area were: representativeness, prevalence of the problem, availability of relevant data and proximity to meteorology station. Most of the people in the area are engaged in mixed agriculture. Crop cultivation and livestock production is practiced. Crop production is entirely rain fed, except in very specific and small areas where vegetables are cultivated based on traditional and small-scale irrigation. To ascertain if farmers' perceptions of climate change and variability correspond to actual long term climatic records, climatic data for the selected stations of western Oromia were analyzed and compared with the survey results. Available historical climate data on precipitation and temperature of western oromia, covering the period from 1980 to 2014 were obtained from National Meteorology Agency of Ethiopia.

Methods of Data Analysis

Climate Variability

The study integrated both qualitative and quantitative methods to build on their complementarities for cross-checking information received from the respondents and analyzed available historical climate data covering the period 1980 to 2014 from National Meteorology Agency (NMA). Coefficient of variation (CV) was calculated as the ratio of standard deviation to the mean (NMSA, 1996) and in order to study the monthly variability of rainfall in the study area, a modified version of (Oliver, 1980) Precipitation Concentration Index (PCI) was used. This index described as:

$$PCI = 100 * \frac{\sum_{i=1}^{12}(Pi)^2}{\left(\sum_{i=1}^{12}(Pi)\right)^2} P$$

Where: Pi is the rainfall amount of the i[th] month; and Σ is summation over the 12 months PCI values of less than 10 indicate uniform monthly distribution of rainfall, values between 11 and 20 indicate high concentration, and values above 21 indicate very high concentration (Oliver, 1980). Standardized anomalies of rainfall were calculated and used to assess frequency and severity of drought, as in (Mulugojjam and Ferede, 2012; Woldeamlak, 2009). Further, as indicated in (Agnew and Chappel, 1999) the standardized rainfall anomalies were calculated and graphically presented to evaluate inter annual fluctuations of rainfall in the study area over the period of observation, described as:

$$S = \frac{(Pt-Pm)}{\delta}$$

Where: SRA is standardized rainfall anomaly, Pt is an annual rainfall in year t,
Pm is long term mean annual rainfall over a period of observation and
σ is the standard deviation of annual rainfall over the period of observation.

The drought severity classes are extreme drought (SRA < -1.65), severe drought (-1.28>SRA> 1.65), moderate drought (-0.84>SRA>-1.28), and no drought (SRA>-0.84). Survey data were analyzed using the statistical package for social sciences (SPSS). Descriptive statistical tools such as, mean, percentages, frequencies and standard deviations were used to summarize and categorize the information gathered. Crosstabs, F-test, chi-square test and a one-way ANOVA tests were employed to compare group means.

In order to observe the trend of temperature and rainfall, a time series data for temperature and rainfall were used for the analysis. A common statistical tool for detecting trend of climatic data is the trend analysis. Mann-Kendall test is one of these techniques used to detect a monotonic increase or decrease trend in the time series of climate such as temperature and rainfall (Bose *et al*., 2014).

Results and Discussion

Characteristics of Respondents

From the total 204 respondents included in the survey, 79.4% were male and the rest 20.6% were female. The ages of household head respondents were ranges from 30 to 75 years old. Around 44.1% of the respondents were below 40 years old and about 55.9 % were above 50 years old. Marital statuses of respondents were; 91.7% married, 2.9% single, 2.4% widowed and 2% divorced from the sampled households. From the total respondents around 23% can read and write and 36.8% household heads respondents were illiterate with no formal education (Table 1).

Local Community Response to Climate Change

The communities' perception on climate variables such as temperature and precipitation behavior of the area in past times was investigated. The results reveal that a slightly higher proportion of farmers claimed that temperature is increasing and rainfall is decreasing, and noted change in the frequency of floods and droughts. In the last 20 years majority of the local communities (more than 80.4% of the respondant) were responded that they had experiences in climate change with an increasing temperature (Figure 2) in their respective area.

Table 1: Characteristics of the respondents (N=204)

Characteristics of the respondents		Frequency	% respondents
Sex of households	Male	162	79.4
	Female	41	20.1
Marital status of households	Single	6	2.9
	Married	187	91.7
	Widowed	5	2.4
	Divorced	4	2.0
Educational levels	Illiterate	75	36.8
	Read & Write	47	23.0
	First cycle complete	54	26.5
	Secondary education complete	15	7.4
	High school complete	10	4.9
	Higher education	2	1.0
Ages of households	19-30	14	6.9
	31-40	76	37.3
	41-50	62	30.4
	51-60	29	14.2
	61-70	23	11.3

Results showed that 100% of the respondents perceived that the existaance of change rainfall in western Oromia in the last 20 years. Local communities have been experiencing decrease in precipitation and change in timing of precipitation over the past 20 years. Almost 49% and 39.2% respondents confirmed that the decrease in precipitation and change in timing of precipitation, respectively in the study area, western Oromia. Most of local communities (81%) also perceived the increasing tendency of temperature (Figure 3).

In this survey, local community were asked to tell what indicators they have been using to perceive changes in rainfall over the last 20 years. Their responses revealed that decline of agricultural yields (27%), rainfall comes early or lately (26%), loss of some animal and plant species (20%), decreased available water (11%), Increased drought and flood frequency (10%) and short growing period (6%) (Figure. 4). These results showed clearly that the main climate attributes that had changed in this area were rainfall and temperature. These findings were in agreement with several studies that had shown farmers perception with regard to climate variability and change (Bose et al., 2014; Zake and Hauser, 2014; Feleke, 2015; Adimassu and Kessler, 2016; Menberu, 2016; Negash, 2016).

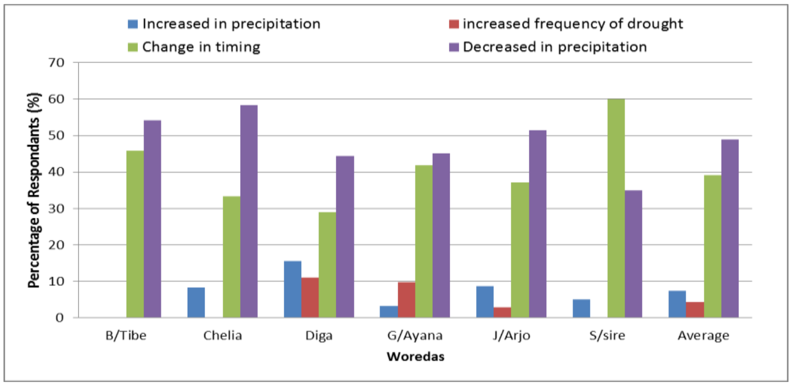

Figure 2: Community's response on rainfall variability

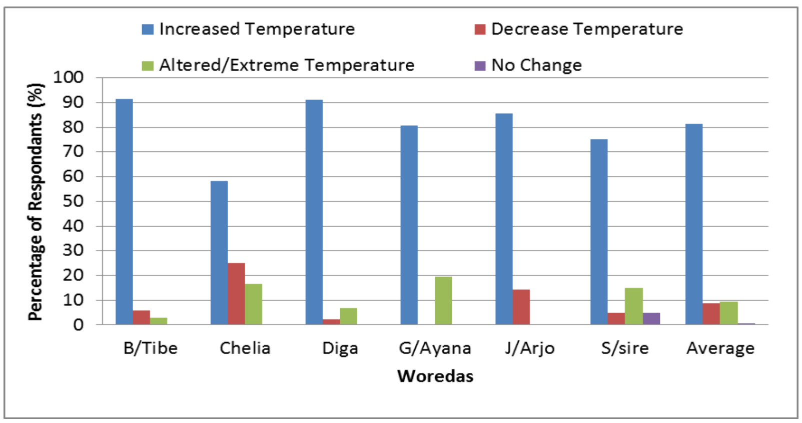

Figure 3: Community's response on temperature variability

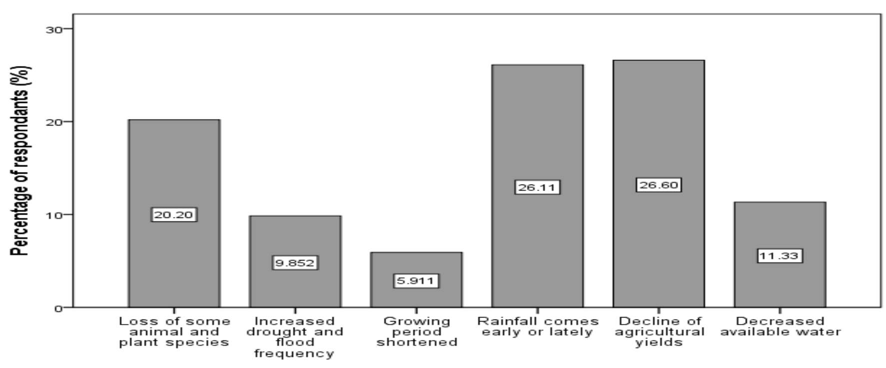

Figure 4: The perceived local indicators to evaluate the rainfall trends

Changes from Historical Climate Data Analysis

Climate Variability

To ascertain if farmers' perceptions of climate change and variability correspond to actual long term climatic records, climatic data for western Oromia was analyzed. The mean annual, maximum and minimum temperature generally shows a warming trend ranging from 0.25 to 0.86°C and 0.05 to 0.46°C per decade respectively over the last 30 years (Figure 5). The precipitation concentration index (PCI) value is more than 12% for most of the stations and highlights the seasonality in rainfall distribution. The PCI of the area indicated that the area have strong rainfall seasonality. Based on the results of the study, annual and seasonal rainfall variability for selected stations ranged between 12% and 25%. This shows high annual and seasonal rainfall variability (Figure 6). *Belg* rainfall showed higher variability compared to annual and *Kirmet*. Generally, the PCI of the area indicated that *kiremt* season was more uniform than both Belg and Bega seasons. A plot of the three climate variables (precipitation, maximum temperature, and minimum temperature) shows that temperature has been increasing while average annual rainfall has been decreasing (Figure 7).

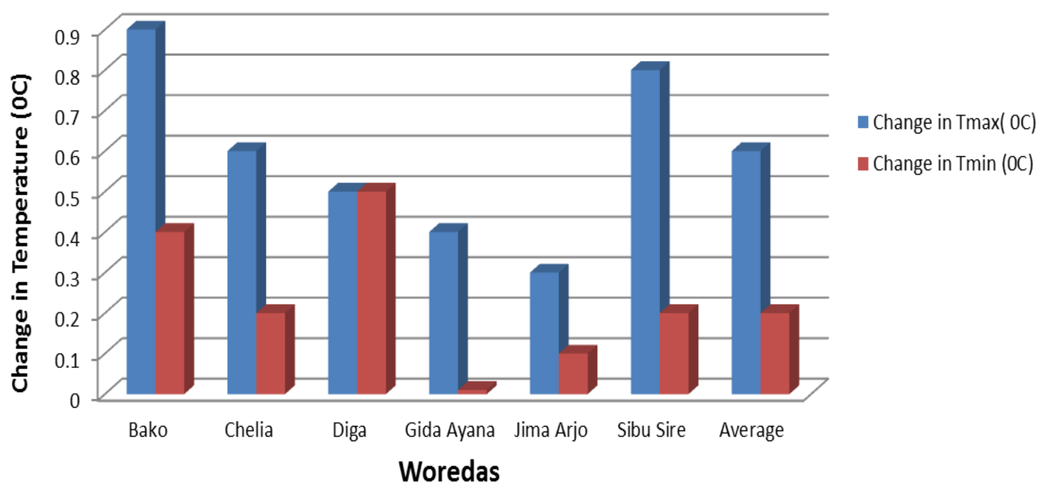

Figure 5: Change in observed temperature per decade over the last 20 years

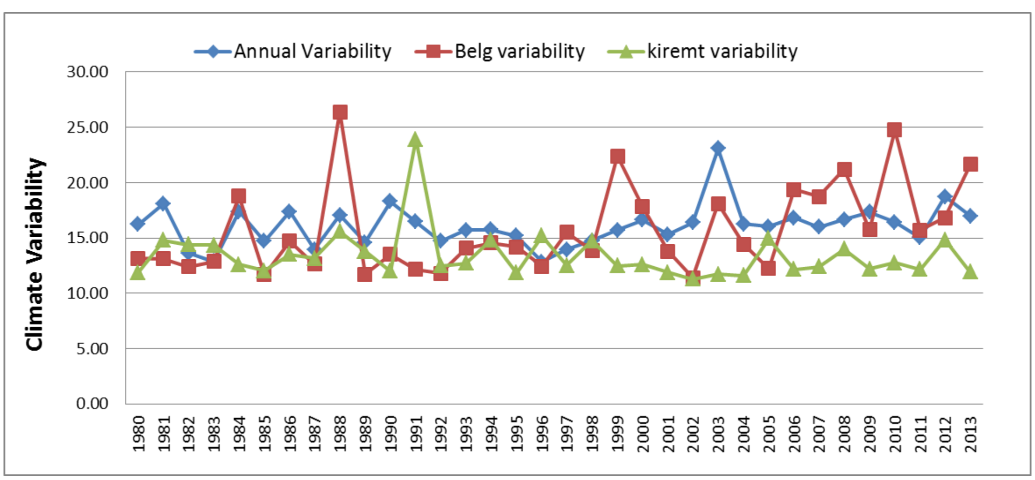

Figure 6: Annual, Belg and kiremt rainfall variabilty (PCI)

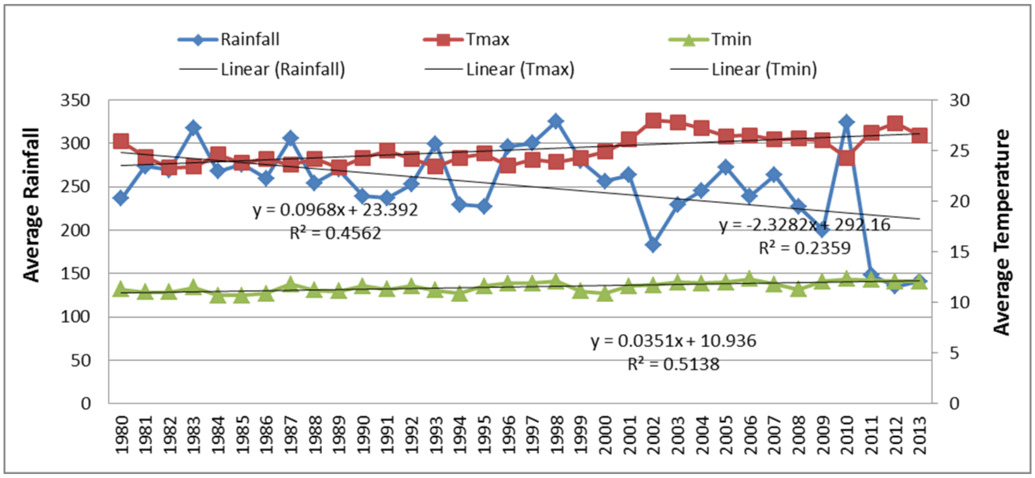

Figure 7: Time series and trends for precipitation, minimum and maximum temperatures

Drought Assessment

Agricultural drought is a situation when rainfall and soil moisture are inadequate during the crop growing season to support healthy crop growth to maturity, causing crop stress and wilting. Drought is directly a response to the shortage of rainfall. Standardized Rainfall Anomaly index calculated for a period of (1980-2013) for the selected stations also indicate that the annual rainfall of selected woreda of western Oromia, exhibit cyclic wet and dry conditions with positive and negative anomalies. By using Standardized Rainfall Anomaly (SRA) time series against drought index gives a good indication of the temporal drought history for the selected station. It was noted that the major drought years were identified as 1980, 1984, 1985, 1986, 1988, 1989, 1990, 1991, 1994, 1995, 1999, 2000, 2002, 2003, 2004, 2006, 2008, 2009, 2011, 2012 and 2013 in the study area (Figure 8). This shows selected woredas of western Oromia were mostly affected by drought. The result reveals that almost all station indicted that there was drought index in the study area even though the drought severity degree was different. In this study the dry and wet periods for selected woredas of western Oromia were identified. Accordingly, the average dry periods identified were 1980, 1984, 1986, 1988, 1989, 1990, 1991, 1994, 1995, 1999, 2000, 2001, 2002, 2003, 2009, 2011, 2012, 2013 and the wet periods were 1981, 1982, 1983, 1985, 1987, 1992, 1993, 1996, 1997, 1998, 2004, 2005, 2006, 2007, 2008 and 2010. As indicated in the figure. 8 blew; drought will occur once every one to four years with the extent of moderate to very severe. Therefore, drought prediction and assessment are important, mainly for farmers to prepare and establish a good agricultural plan to tackle the effect of drought.

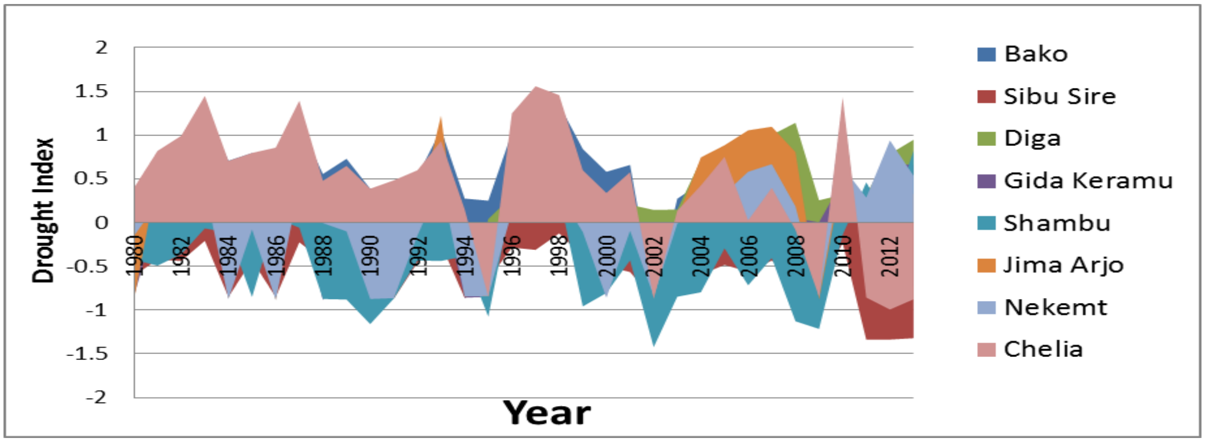

Figure 8. Drought index for the selected woredas of western Oromia

Perceived Impacts of Climate Change on Agricultural production

Results revealed decline in crop yield, increase in pest and disease, reduced seedling, delayed in seedling and delayed in maturity as the major impacts of climate change on crop production in the Western Oromia. The dominant crops for subsistence and cash for the communities in Western Oromia are maize, wheat, teff, barley, finger millet, sorghum beans, peas and potatoes. However, crop yields in all areas is on a declining trend due to climate change, land degradation, pests and diseases, high cost of inputs and decreasing land sizes. Survey results revealed that the farmers perceived various impacts of climate change. For example about 98% of respondents were perceived soil erosion problem during the last 10 years. The types of soil erosion persist in the study area were include: Sheet erosion (58.71%), created rills in the farm (22.40%), sediments formed in ditches (11.44%) and furrows and gullies created in their farm land (7.46%), while major one was sheet erosion (58.71%) according to respondents perception.

Deforestation and minimal practices of soil and water conservation give the impression to cause more serious problems in soil erosion. However, recently, larger number (43%) of respondents started to adopt soil and water conservation measures through soil bunds. That means, different soil and water conservation measure options have been undertaken to minimize the problem of soil erosion, which include ditches/trenches (22%), contour planting (19%), terraces (10%), stone dams (3%) and check dams(2%). Some of the adaptations induced by perceptions of rainfall pattern chang seem to differ from those induced by perceptions of changing temperature. About 100% of respondents were perceived soil fertility problem in over the last 10 years.

The indicators of soil fertility problem in the study area include: yield decline and increased in input demand. The major indicator of soil fertility problem was decline in crop yield 58% respondents were perceived. Different management practices were undertaken to minimize the problem of soil fertility.

These include crop rotation (34%), manure application (23%), fertilizer (14%), intercropping (12%), fallowing (11%), Legume trees (4%) and mulching (2%).

Respondents mentioned various aspects of climate change induced-vulnerabilities' in the past 15-20 years such as increase in pest and disease, soil erosion, drought, flood and landslide. A more quantitative analysis on perceived climate change induced-vulnerabilities' showed that increase in pest and disease by 34% and soil erosion by 30% was the most prevalent induced problem mentioned by the respondents. When respondents were asked about the adverse impacts of climate change on agriculture (Table 2), they pointed out several things. For example: 45% of the respondents claimed that, one of the impact of the climate change among other was decrease in crop yields due to changes in temperature and rainfall over the last 20 years. While many of respondents (21%) claimed crop failure due to climate change. Based on survey data/findings, we suggest that climate change impacts negatively upon crop production in selected districts of Western Oromia whereas climate adaptation and mitigation measures are a practice to be required to reduce the long term vulnerability and food security of the area (Table 3)

Table 2: Perceived adverse impacts of climate change on agriculture (n=204)

Areas of Assessment	**Frequency**	**Percent**
Crops are sometimes failing	43	21.10
Crops are totally failing	5	2.5
Production per ha is decreasing	92	45.10
Production per ha is increasing	3	1.50
Crop disease and weeds are increasing	30	14.70
Increased problem of livestock disease	20	9.80
Increased problem of seasonal flooding	11	5.40

Table 3: Perceived impacts of climate change on crop production (n=204)

Areas of Assessment	**Frequency**	**Percent**
Total Crop loss	14	6.9
Reduced yield	99	48.5
Reduced seeding area	23	11.3
Delayed seeding	7	3.4
Delayed maturity	15	7.4
pest/ disease	46	22.5

Coping and Adaptation measure to Climate Change and Variability

Climate adaptation measures are crucial if the long term impacts of climate change on crop production and livelihoods of farmers are not to be compromised. In an attempt to investigate the extent of adaptation to climate change, farmers were questioned on their adaptation measures. All the farmers interviewed used one or more methods of adaptation. Most respondents (93%) in the study area have adjusted their farming practices to long-term climate change. Only 7% have not adjusted (Figure 9). The adaptation measures identified were soil and water conservation, crop rotation, crop varieties selection, adusting planting dates, diversification of crop types and varieties, building water harvesting schemes and use of irrigation.

Similarly, descriptive statistics results have shown that communities in Western Oromia have adapted to the impact of climate variability and change through a number of mechanisms. Particularly, sample respondents in the study area have multiple strategies for adapting to the impacts of climate variability and change. Majority of sample households adapting to impacts of climate change and variability through soil and water conservation (57%) and the rest adapting through crop rotation, crop variety seelection, adjusting planting dates, diversification of crop types and varieties, build water harvesting schemes, irrigation and intercropping. (Figure 10).

Most respondents in the study area point out that climate change can be mitigated through afforestation practice on the degraded land, farm land and home garden. Respondents also explained the advantage of afforestation in terms of moisture conservation, protecting soil erosion and improve soil fertility, availability of enough rainfall and optimal temperature for agriculture. Accordingly adaptation strategies proposed by the respondents to resist climate change impact on agriculture were:

1. Changing/adjusting planting date rain patern change
2. Use drought resistant and short maturity crop variety
3. Tree planting
4. Stop burning trees for charcoal

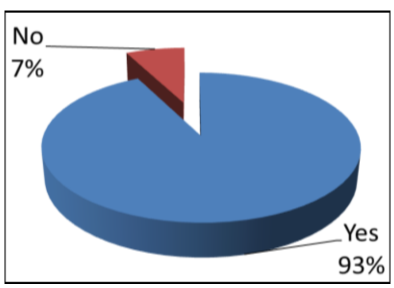

Figure 9: Adaptation measure to Climate Change and Variability

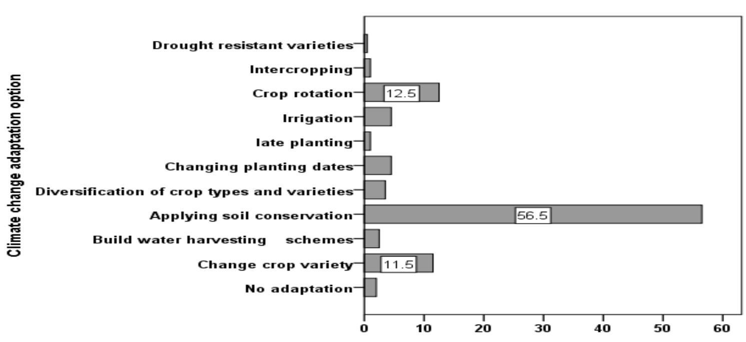

Figure 10: Distribution of households by coping and adaptation measures

Barriers to Climate Change Adaptation

Communities were facing various barriers that can make the adaptation strategies ineffective at the local level. The sample households listed a number of interrelated serious barriers associated with adaptation strategies that made their lives very difficult besides the presence of unpredictable rainfall and other climate related impacts. These were lack of information (43.59%), shortage of labor (22.05%), and lack of capital (21.54%) and others (Figure. 10). These barriers act interdependently to restrict the ability of communities to adapt/resist climate change and variability. The government could build the capacity of agricultural extension systems (Morton, 2017) and make available climate change education scheme (Ayanlade and Jegede, 2016) with ICT innovations such as cell phone applications. Therefore, policy makers need to plan a holistic and coordinated approach in dealing with these barriers. This studies providing empirical evidence to deepen our understanding of the barriers that challenge small-scale farmers in their attempt to implement appropriate adaptation strategies to manage the negative impacts of climate change and variability.

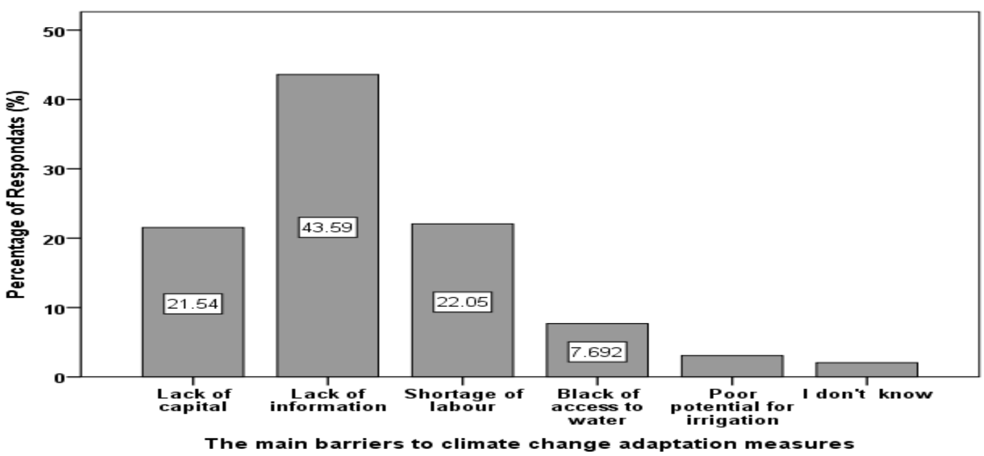

Figure 10: The main Barriers to climate change adaptation measures

Conclusion and Recommendations

This study draws upon both quantitative and qualitative approaches to investigate the smallholder farmers' perception of climate change impacts on crop production in western Oromia and compare their perceptions to historical meteorological data. Smallholder farmers' perception of climate change impacts and effective climate change adaptation methods and local knowledge were used in combination with scientific knowledge systems from meteorological data analysis. The study revealed that perception of most farmers was an existence of increase pattern in temperature and decrease pattern in precipitation in study area for past 20 years. Similarly perceived indicators of major impacts of climate change were decline in crop yield, increased flood and drought problem, livestock diseases, increase in crop pest and disease, reduced seedling, delayed in seedling and delayed in maturity.

Generally, from this findings we concluded that the impacts of climate change on crop production in Western Oromia is negative whereas farming community practiced some adaptation measure that include soil and water conservation, crop rotation, adjusting planting dates and variety selection to overcome impact imposed by climatic change. On the other hand this finding identified some serious barriers including lack of information, shortage of labor, lack of capital, lack water potential for irrigation that affect level of adaptation measure to climate change.

Therefore based on this conclusion we draw the following recommendation to strengthen local skill to ward climate change adoption and to introduce new adoption measure.

- Capacity building and awareness creation is vital to support climate change adaptation process especially in rural communities.
- Development of participatory adaptation strategy that encompass local community in decision making and planning stage.
- Reforming policies regarding issues that strengthen climate change adaptation and mitigation practices through different anticipatory adaptation strategies like Soil and water conservation practices, crop varieties selection, water harvesting techniques and others.
- Improving access for varieties and other agricultural inputs
- Developing network for easy metheorolgiacl and other information transfer for communities those affected by climate change impact.

Acknowledgements

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References

Adger, W. N., Hug, S., Brown, K., Conway, D., & Hume, M. 2003. Adaptation to Climate Change in Developing World. Progress in Development Studies, 3(3), 179-195. Doi: 10.1191/1464993403ps060oa, http://dx.doi.org/10.1191/1464993403ps060oa.

Adimassu, Z., Kessler, A., 2016. Factors affecting farmers' coping and adaptation strategies to perceived trends of declining rainfall and crop productivity in the central Rift valley of Ethiopia. Environ. Syst. Res. 5, 1.

AFP. 2007. Climate Change and Africa. 8th Meeting of African Partnership Forum, Berlin, Germany, 22-23 May, 2007.

Agnew CT, Chappel A., 1999. Drought in the Sahel. Geo J., 48: 299-311.

Amjath-Babu T., Krupnik, T.J., Aravindakshan, S., Arshad, M., Kaechele, H., 2016. Climate change and indicators of probable shifts in the consumption portfolios of dry land farmers in Sub-Saharan Africa: implications for policy. Ecol. Indic. 67, 830 – 838.

Ayanlade, A., Jegede, M.O., 2016. Climate change education and knowledge among Nigerian University Graduates. Weather Clim. Soc. 8, 465– 473.

BoFED, 2008. Oromia Atlas. Oromia Finance and Economic Development Bureau. Addis Ababa.

Boko, M., I. Niang, A. Nyong, Vogel, C., A.Githeko, M. Medany, et al. 2007. Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. In M. Parry, J. P. O.F. Canziani, P. v. Linden, and C. Hanson (Ed.), .Contribution of Working Group 11 to the Fourth Assesment Report of the Intergovernmental Panel on Climate Change (pp. 433 -467. Cambridge.UK: Cambridge University Press.

Bose, M. M., Abdullah, A. M., R, H., Jamalani, M.A., R.E, E., & M., F. (2014). Perception of and adaptation to climate change by farmers in the semi - arid zone of North - eastern Nigeria. IOSR Journal of Environmental Science, Toxicology and Food Technology. Retrieved November 24, 2014, from http://www.iosrjournals.org/iosr-jestft/papers/vol8-issue11/Version-1/I081115257.pdf.

Clarke, C., Shackleton, S., Powell, M., 2012. Climate change perceptions, drought responses and views on carbon farming amongst commercial livestock and game farmers in the semiarid Great Fish River Valley, Eastern Cape province, South Africa. Afr. J. Range Forage Sci. 29, 13–23.

Feleke HG. 2015. Assessing Weather Forecasting Needs of Smallholder Farmers for Climate Change Adaptation in the Central Rift Valley of Ethiopia. J Earth Sci Clim Change. 6: 312. doi: 10.4172/2157-7617.1000312.

Fischer, G., Shah, M., Tubiello, F., and Van Velhuizen, H . 2005. Socio-economic and Climate Change Impacts on Agriculture:An Intergrated Assesment,1990 -2080.
Philosophical Transaction Son Royal Society, 360 (1463), 2067-2083.

IPCC. (2007). Summary for Policymakers. In: Climate Change: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate. Cambridge. UK. Cambridge University Press, 2007.

IPCC. 2007a. Climate Change 2007: Impacts, Adaptation and Vulnerability. Cambridge: Cambridge University press.

IPCC. 2007b. Climate Change: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: Intergovernmental Panel on Climate Change.

MEADOWS, M.E. (2006). Global change and Southern Africa. Geographical Research, 44:135-145.

Menberu. 2016. Rural households' agricultural land vulnerability to climate change in Dembia woreda, Northwest Ethiopia. Environmental Systems Research20165:14 DOI: 10.1186/s40068-016-0064-3.

Mitchell, T., Van Aalst, M., 2008. Convergence of Disaster Risk Reduction and Climate Change Adaptation. A review for DFID – 31st October.

Morton, J., 2017. Climate change and African agriculture: unlocking the potential of research and advisory services. In: Nunan, F. (Ed.), In Making Climate Compatible Development Happen. Wiley.

Mutekwa, V.T. (2009). Climate change impacts and adaptation in the agricultural sector: The case of smallholder farmers in Zimbabwe. Journal of Sustainable Development in Africa, 11: 237-256.

Negash W. 2016. Analysis of Rainfall Variability and Farmers' Perception towards it in Agrarian Community of Southern Ethiopia. Journal of Environment and Earth Science; ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online), Vol.6, No.4, 2016.

Nhemachena, C. 2009. Agriculture and Future Climate Dynamics in Africa: Impacts and Adaptation Options. Pretoria: University of Pretoria.

Nyasimi, M., Radeny, M., Kinyangi, J., 2013. Climate Change Adaptation and Mitigation Initiatives for Agriculture in East Africa.

Zake, J., Hauser, M., 2014. Farmers' perceptions of implementation of climate variability disaster preparedness strategies in Central Uganda. Environ. Hazards 13, 248 –266.

Oliver JE, 1980. Monthly Precipitation Distribution: a comparative index. Professional Geographer 32: 300-309.

ORHB, 2010. Oromia Regional Health Bureau. Five year health performance report. Addis Ababa.

Pouliotte, J., Smit, B., & Westerhoff, L. 2009. Adaptation and development: Livelihoods and climate change in Subarnabad, Bangladesh. Climate Change and Development, 1, 31-46. doi:10.3763/cdev.2009.0001, http://dx.doi.org/10.3763/cdev.2009.0001.

Romieu, E., Welle, T., Schneiderbauer, S., Pelling, M.,Vinchon, C., 2010. Vulnerability assessment within climate change and natural hazard contexts: revealing gaps and synergies through coastal applications. Sustain. Sci. 5, 159–170.

Savo, V., Lepofsky, D., Benner, J., Kohfeld, K., Bailey, J., Lertzman, K., 2016.Observations of climate change among subsistence-oriented communities around the world. Nat. Clim. Change 6, 462– 473

Agro Climatic Characterization in the Selected Woredas of Western Oromia, Ethiopia

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Abstract

Agro-climatic characterization of western Oromia was performed using indigenous knowledge and historical meteorological data indices in a statistical software. Rainfall and temperature of selected meteorological stations representing different Agro-ecological zones (lowland, midland and highland) of western Oromia were analyzed on annual, seasonal and monthly time scales using long period data. Quantitative data were analyzed through SPSS and qualitative data through content analysis. Instant Statistical Packages for Agro-climatological data was used in analyzing the 30 years meteorological data of western Oromia meteorological stations. This study looks at growing season dates in terms of dry spell lengths, onset, cessation and length of growing season among others using INSTAT software. The spatial distributions of different annual and seasonal rainfall variables were mapped. A survey research design was used and data collected through focus group discussions, questionnaires and key informant interviews. Simple random and purposive sampling methods were used, where 210 small scale farmers and 30 key informants from western Oromia participated. The study conducted surveys of 210 households in the selected woredas of Western Oromia to characterize the agro climate of smallholder farmers. Rainfall, minimum temperature and maximum temperature data of western Oromia (1980-2014) were analyzed to assess agro-climatic characterization and climatic trend of the area. The rainfall and temperature data over the western Oromia are analyzed on an annual basis using historical datasets. Over western Oromia, the observed average total annual rainfall showed a significant decreasing trend (43.67mm per decade) in the last 30 years analysis period, with a relatively large inter-annual variability, while the maximum, mean and minimum temperatures have increased at a rate of 0.22 and 0.21 8°C per decade, respectively. The study revealed that most significant change has been unpredictable rains (60.48%), very hot season (20.95%) and prolonged drought (14.29%). The historical climate results across the selected stations shown that a late start has an early end of rainfall hence a short growing season observed. Farmers' perceived late on set of rain, poor distribution within the season, and sometimes early cessation. Local community perceived the onset date of Kiremt (Ganna) rainfall of study area was on the first week of May and the cessation date of Kiremt rainfall starting from the last week of November over the last 20 years. But, the historical climate results shows the onset date of the growing season was in the early June and the cessation date of Kiremt rainfall on the mid October. Therefore, Knowledge on the date of onset and cessation rains and length of growing period (LGP) will help to plan the agricultural operations better, particularly, land preparation and sowing.

Key Word: Agro climate; Characterization; Indigenous knowledge; Growing season; Historical climate

Introduction

Agriculture is the back bone in the Ethiopia economic development. Agricultural activities are totally dependent on weather and climate that will have a serious implication on the food security efforts which is currently strained by the ever increasing human population and increased demand and the growth of natural resources use (Rosenzweig and Parry, 1994). Crop production in Ethiopia is highly dependent on the long rainy season, which accounts for about 70% of total annual rainfall. Inter-annual variability in rainfall was higher than annual rainfall amounts (Suryabhagavan, 2017). Climate characterization is very use full for understanding the current occurrence of the climate in the area for agricultural planning (Niguse and Aleme, 2015). Ethiopia is highly vulnerable to climate change due to dependence on climate sensitive sectors such as agriculture. Agriculture plays a dominant role in the economy of Ethiopia, contributing 41% GDP, 80% of the employment and the majority of foreign exchange earnings (Gebreegziabher Z., Stage J *et al*. 2011). In Ethiopia, rainfall and temperature is the most important factor that determine crop growth, crop variety choice and grain yield (Sinebo, Lakew *et al*. 2010). The rising temperature and fluctuating rainfall patterns could adversely affect the productivity of crops (Berger and Turner, 2007).

In Oromia, agriculture is influenced by a wide range of climatic, topography and socio-economic diversities (NMSA, 1996, Engida, 1992). More over the majority of its population depend on subsistence agriculture. The dependency of most of farmers are on rain fed agriculture has made the countries crop production potential extremely vulnerable to the effect of weather and climate (Reddy and Kidane, 1993). Characterizing the long term climate data and providing climate information for agricultural planning to minimize the yield reduction and economical loss caused by climate change and variability is crucial (Shiferaw *et al*, 2015). Such analyses are very important for the future planning and decision-making process in the development and implementation of agricultural systems.

Some of the important type of information that is very important in this respect is to understand the rain fall climatology, the frequency occurrences of extreme temperature, different characteristics of growing season. Proper agro climatic characterization and seasonally climate forecasts are crucial elements in minimizing climatic risk. The determination of start, end and length of the growing season and the patterns of dry and wet spells during the season is useful information for the agricultural planning and farm management operations including land preparation, crop planting, weeding, fertilizer and other agro-chemical applications, harvesting and post-harvest handling activities (Amukono CL et al., 2016). The characteristics determined for the growing season will assist the farmers, agricultural extension agents and other actors along the agricultural value chain to determine sowing dates, enterprise selection, type and variety of crops to plant depending on the length of the season (Amukono CL et al., 2016). Therefore, understanding of historical observed climatic change is essential in order to provide framework for climate risk forecasting, agricultural planning and climate change projections, as well as a convincing basis for climate change adaptations. But there is no information for the area concerning agro climate characteristics. So to fill the existing gap this project was designed having an objective to characterize the agro climates of selected woredas of Western Oromia by Using local community perception and historical climate data.

Materials and Methods

Description of the Study Area

The study area lies between 8^0 00' to 10^0 00' N and $36^0$00' to 37^0 50'E and the elevation range from 1200 to 3200m. The east Wollega zone stratified into three agro ecological zones based on agro-climatic conditions namely: low land 56.4% (1200-1799 m), mid land 28.2 % (1800 -2450 m) , and high land 15.4% (2460- 3178 m) (Fita, 2014). Oromia is mainly characterized by the diversity in altitude occupying climate and ecological variation generally western oromia is characterized by the dry and the wet season with over nine moths wet period (Tesfaye, 1970). The annual precipitation over western oromia ranges from 1000 to 2100 mm. The study area experiences annual temperature ranging from 10^0C to 30^0C, with mean annual temperature of 19^0C, where the highlands and mountainous areas in the region receive lowest mean annual temperature, while lowlands and valley bottoms get highest mean annual temperature records (BoFED, 2008; ORHB, 2010). Western oromia wet season runs from May/June to August/September; this is also regarded as the main agricultural summer growing season. Most rainfall occurs in June, July and August. The least rainfall is in September when the summer agricultural crops are mostly at maturity stage.

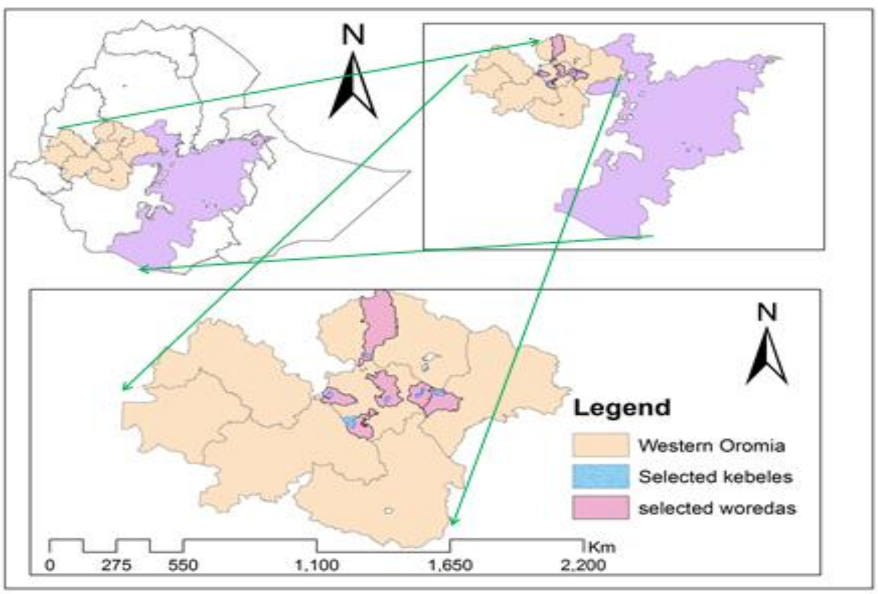


Figure 1: Location of Study area

Data Sources

The study was carried out with in six (6) selected woreda of western oromia: Diga (Lalisa Dimtu and Demeksa PAs), Jimma Arjo (Abote didessa and Hindhee PAs), Gida Ayana (Anger Gutin PA), Sibu-sire (Cari PA), Bako Tibe (Sedan kite and Biqiltu Leku PAs) and Cheliya (Jarso Dire and Tulu kosoru PAs). Two types of data were used in this study, primary and secondary data. The primary data were collected from the households' survey through two complementary approaches, namely (i) Key informant interviews) and (ii) farmer interviews using semi-structured household questionnaires.

Purposive sampling was used in determining individuals for administration of questionnaires, identifying key informants and focus group. In eastern Wollega; Sibu-sire, Diga, Jima Arjo, Gida Keremu, and from West Shewa Bako-Tibe and Chaliya Woredas were selected. The data used for the study was a long-term (historical) rainfall and temperature climate records. To assess the farmers' perception on agro climate (mainly rainfall and temperature) about 210 farmers were interviewed using a semi-structured questionnaire that elicited information on dry spell lengths, onset, cessation and length of growing season to plan the agricultural operations better, particularly land preparation and sowing. Available historical climate data on precipitation and temperature of western Oromia, for the period from 1980 to 2014 were obtained from National Meteorology Agency of Ethiopia

Method of Data Analysis

The collected data was analyzed by use of both quantitative and qualitative approaches. The quantitative data collected through household survey method were analyzed using Statistical Package for Social Sciences (SPSS); while qualitative data from focus group discussions, questionnaires and key informant interviews was analyzed by establishing the categories and themes, relationships/patterns and conclusions in line with the study objectives (Gray, 2004). INSTAT plus (v3.6) Software was used to characterize the climate of the study area. Mainly, historical meteorological data (rainfall and temperature data) were used to characterize the climate of the study area. Daily mean rainfall was calculated and cumulative mean daily rainfall curve was used to estimate possible late start and early end of growing season. Total rainfalls, number of wet days and dry spell within 30-day periods in each season were computed and hence simple linear trend analysis for each characteristic was carried out. To ascertain if farmers' perceptions of agro climatic characterization correspond to actual long term climatic records, climatic data for western Oromia were analyzed and compared with the survey results. The precipitation analyses were done using monthly rainfall from more than 30 stations distributed around western Oromia. The monthly totals were computed using Microsft Excel and Instat+ software. The computed monthly, annual, and seasonal were mapped using ArcMap 9.3. The average values at the stations were used in the interpolation using the ordinary kriging method to obtain a surface. Kriging method was chosen ahead of the other interpolation method because it tends to recognize the trend of the data to be interpolated.

Results and Discussion

Characteristics of Respondents

From 210 respondents included in the sample, 70.48% were male and the rest 29.52% were female. The ages of household head respondents were ranged from 20 to 70 years old. Around 44.3% of the respondents were below 40 years old and about 55.7% were above 40 years old. Marital statuses of respondents were; 93.33% married from the sampled households. From the total respondents around 66.2% can read and write and 33.8% household heads respondents were illiterate (Table 1).

Local Community Response to Rainfall Onset and Cessation date

The onset date of *Kiremt (Ganna)* rainfall of study area over the last 10 years shown that on the mid of May and the cessation date of *Kirem*, rainfall was last week of November (Figure 2). Farmers perceived late onset of rain, poor distribution within the season, and sometimes early cessation. In particular, they noted that the season had shifted from a start in Late April to mid May and ended in late November. During the past 15 years, farmers highlighted the existance of problems specifically concerning variability in duration, time and intensity of the rains. Information on the date of onset and cessation date of rains will help to plan the agricultural farming better, particularly land preparation, sowing and harvesting.

Table 1: Characteristics of the respondents

Characteristics of the respondents		Frequency	% respondents
Sex of HHs	Male	148	70.5
	Female	62	29.5
Marital status of HHs	Single	5	2.4
	Married	196	93.3
	Widowed	6	2.9
	Divorced	3	1.4
Educational levels	Illiterate	71	33.8
	Read & Write	53	25.2
	First cycle complete	59	28.1
	Secondary education complete	19	9.0
	High school complete	8	3.8
Ages of household	19-30	13	6.2
	31-40	80	38.1
	41-50	64	30.5
	51-60	28	13.3
	61-70	25	11.9
Current occupation	Farmer	201	95.7
	Trader	3	1.4
	Farmer and Trader	5	2.4
	Daily laborer	1	.5

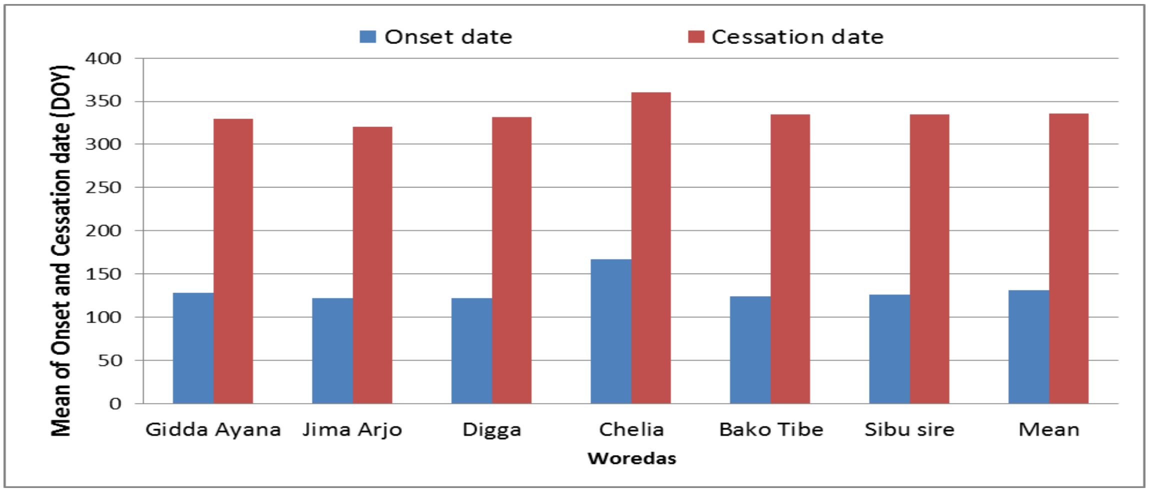


Figure 2: Local community perception on onset and cessation date

Response to Dry Spell

The average length of dry spell during the *Kiremt* season over the study area was too long. The probability of dry spells lengths of 5, 7, 14 and 21 days observed in *Kiremt* season during the growing season. The probability of being 14, 7, 21, and 5 days dry spell was about 41%, 27%, 13% and 11% in the *kiremt* seasons, respectively (Figure 3). For this reason, cropping needs a great attention in selecting the appropriate sowing date in order to avoid the long dry spells during the flowering stage to reduce the possible negative impacts.

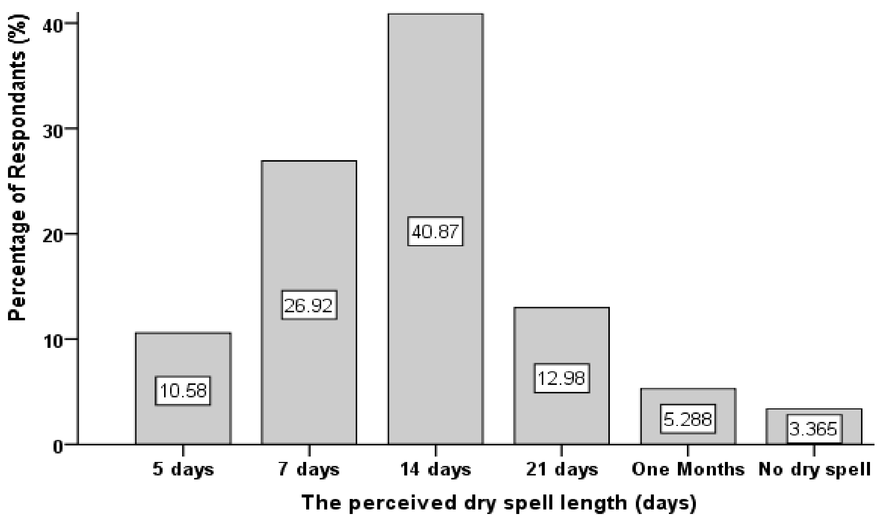


Figure 3: The perceived probability of dry spells

Perception of Respondents on Agro Climate

Both women and men commonly share the same observations on climatic conditions. In the study area farmers perceived an increase in temperature and changing rainfall patterns.Due to this reason the growing season became shorter, because of the onset rain shifting from late May to early June and rainfall cessation shifting from early December to early November. Even some of the respondant explained that their observation as onset of the rainy season has become less predictable. Several changes have been perceived in climate conditions over the past 20 years, according to the respondat. While identified most significant changes have been unpredictable rains (60.48% of the respondants), very hot season (20.95% of the respondants) and prolonged drought (14.29% of the respondants) (Figure 4).

According to most respondents, the observed changes in climate have resulted in crop faille and reduction in productivity (43.8% of the respondants). Other impacts of weather changes include livestock disease, increased crop diseases and weeds and increased in seasonal flooding. According to respondants the major factors that negatively influence livestock farming in Western Oromia are lack of pasture (28.10% of the respondants), inadequate grazing land (28.10% of the respondants), and livestock diseases (20% of the respondants), water scarcity (19.05% of the respondants), lack of market (4.3% of the respondants) and pest (1.2% of the respondants) (Figure 5). Despite 100% of respondents perceived temperature change, out of these respondents, about 76% of the informants took responses to increased number of hot days over the last 20 years.

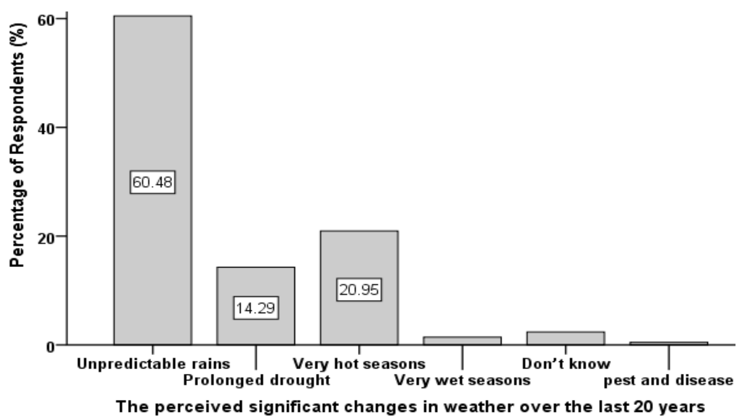


Figure 4: Indicators of weather change

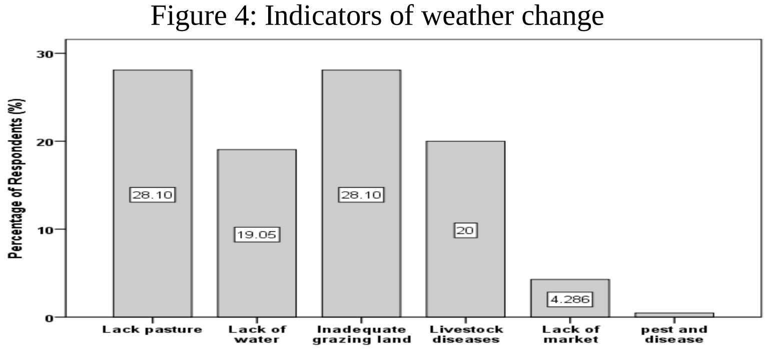


Figure 5: Major livestock farming problems

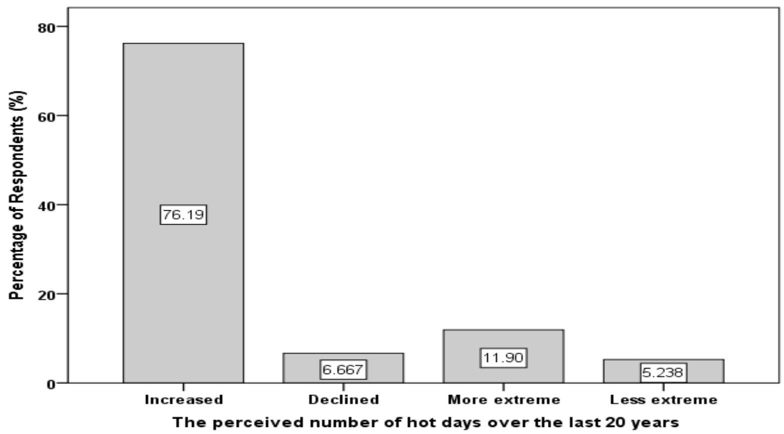


Figure 6: Farmers' Response to Perceived Change to Temperature

Changes in Crop Calendar

During the assessment, farmers were asked to report beginning of growing season and end of growing season of major crops in the area in the past 20 years and now. Their response indicated that the present crop calendar is shorter than it was before. As a result the cropping trend shifted towards selection of different crop varieties that adopt shorter planting season. Because of this problem most crops are planted today during mid-last May to early of July wheras maturity time is during last October. Hence, the growing period of major crop has shortened by almost one month duration as compared to before. This could indicate a demand shifting towards faster-growing/early maturing varieties with higher drought resistance. The reduction in the growing period of crops more likely resulted from increase in temperature and erratic rainfall.

Climate Impacts on Natural Resources

Assessment made on households at major areas of environmental resources in the study area in Table 2 shows. According to the assessment made, 82% of the respondant agree the decreasing trend of drinking water availability for animals. More over, 73% of them even agree the decreasing pattern of water availability in general. Similarly, about 92% of the household's respondent, in the study area, perceived a reduction of forest coverage whereas about 85% of the respondents were assured an increament of the problems of soil erosion in Western Oromia.

Table 2: Households‟ assessment on major areas of environmental resources

Major areas of Assessment		Frequency	% of respondents
Availability of water for animals	Increasing	11	5.2
	Decreasing	172	81.9
	No change	27	12.9
Change in forest cover	Increased	11	5.2
	Decreased	193	91.9
	No change	6	2.9
Problem of soil erosion over time	Increased	178	84.8
	Decreased	26	12.4
	No change	6	2.9
Change in water availability	Increased	21	10.0
	Decreased	153	72.9
	No change	36	17.1

Historical Climate Data Characterization

To characterize the agro-climatic, as a first step, the climatic data was classified according to the seasons i.e. *Bega* (DJF), *Kiremt* (JJA), *Belg* (MAM) and *Tseday* (SON). The area characterized as mono modal type of rainfall. The longest rainy season was from June to August locally called "*Kiremt*" had received the highest amount of rainfall from 1000 to 2100 mm, especially on the month of July and August. The "*Bega*" (dry) season from December to February had received from 63 to 360 mm. "*Kiremt*" is the main rainfall season for the region which is very useful for agricultural production. As seen from the seasonal map, less than 1000mm is received over the west Shewa and Qelem wellega in *kirem*t. The mean seasonal rainfall varies quite a lot throughout the area with the minimum of 63 mm recorded at Gore (in *Bega*), and the maximum of 1440 mm recorded at Nekemt (in *Kiremt*). Monthly rainfall varies with both space and time.

The spatial distribution shows high monthly rainfall over the central parts of the western oromia. The least rainfall is in Bega (December-February) when the agricultural crops are mostly at maturity stage and harvest. The lowest mean Belg (March-April) seasonal amounts of rainfall were observed at West Shewa, Horro Guduru Wellega, West and Qelem Wellega. In contrast, the highest Belg (March-April) seasonal amounts are recorded at Ilu Aba Bor and Jimma. The mean seasonal rainfall distribution quite varies throughout the study area with low recorded in West Shewa, some parts of West and Qelem Wellega, and the highest amounts registered in Ilu Aba Bora, Jimma and East Wellega (Figure 7). West Shewa received relatively low amount of rainfall during Bega (December-February) season with less than 150 mm.

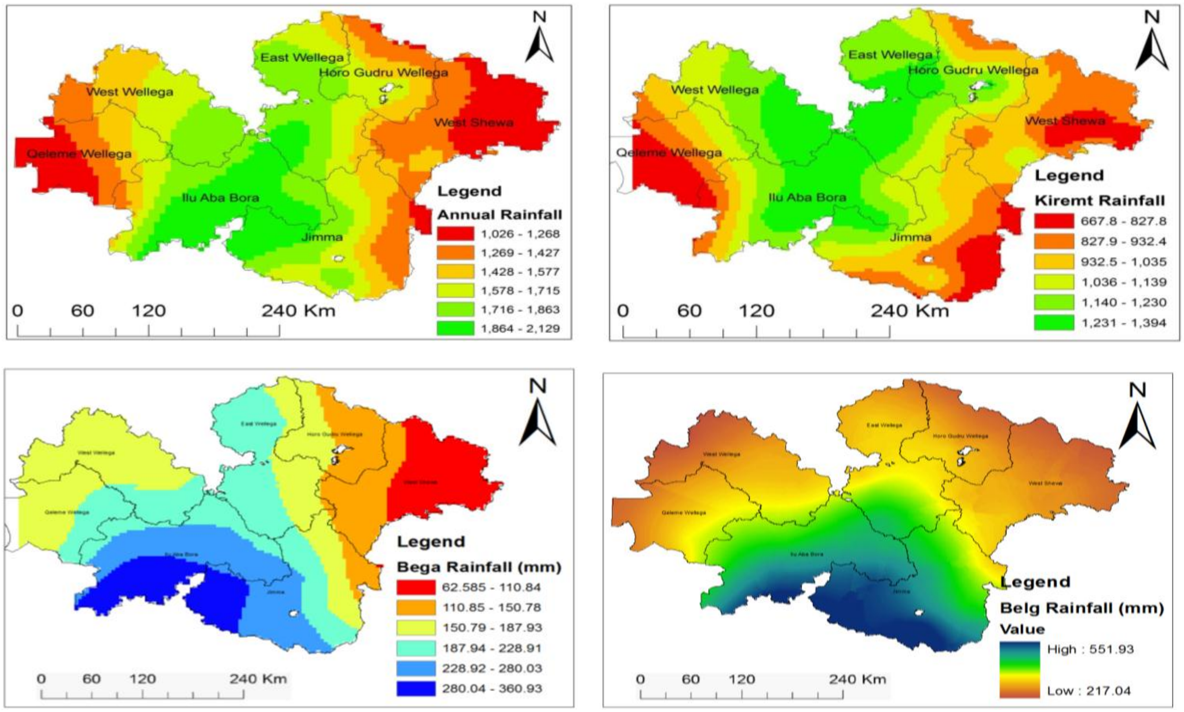


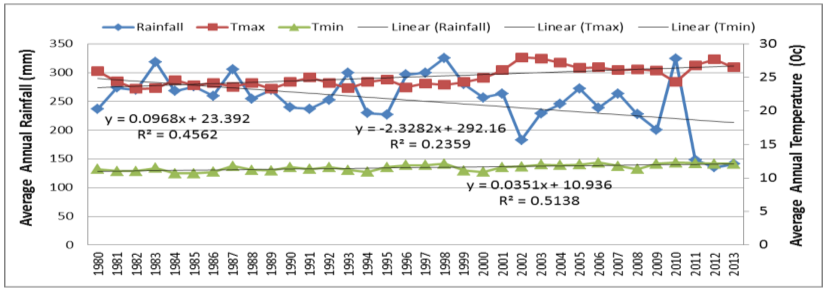
Figure 7: Annual and seasonal distribution of rainfall

Annual Rainfall and Temperature Trends

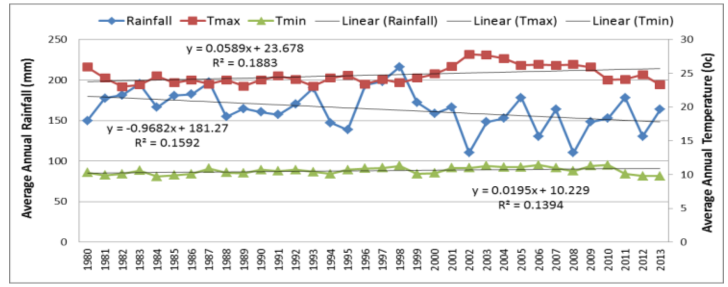
Results showed that the average annual minimum and maximum temperature of Bako had an increasing trend which was statistically significant (Figure 8a). But the average annual rainfall of Bako had decreasing trend which was statistically significant (Figure 8a). This means that the woreda has been experiencing significantly reducing rainfall and increasing temperature through time and this confirms the farmer's perception.

The average annual rainfall of Chelia district shows decreasing trend which was statistically not significant (Figure 8b). However, average annual minimum and maximum temperatures in Chelia had an increasing trend which was not statistically significant (Figure 8c). Similar to Chelia district, in Sibu-sire, Jima Arjo, Gida Keremu and Diga, the average minimum and maximum temperatures had an increasing trend that was not statistically significant (Figures 8c-2f). On the other hand the average annual rainfall had decreasing trend for Sibu-sire, Gida Keremu and Diga (Figure 8c, 8e and 8f) but increasing trend for Jima Arjo (Figure 8d) which was statistically significant. The average minimum and maximum temperature of Bako has risen by an average of 0.35 and 0.91 °C per decade, respectively between 1980 and 2013; while the average annual rainfall had decreasing by an average of 23 mm per decade (Figure 8).

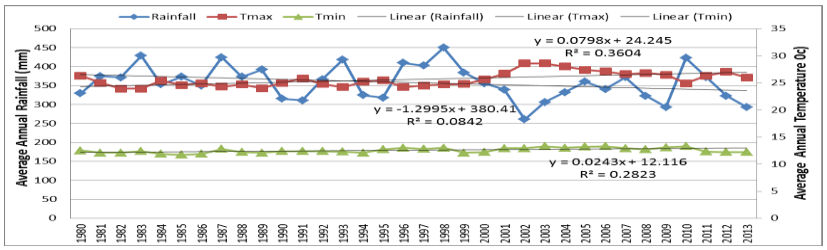
In Chelia, Sibu-sire, Jima Arjo, Gida Keremu and Diga, the average minimum temperatures had an increasing trend at a rate of 0.20, 0.24, 0.07, 0.22 and 0.28^{0}C per decade, respectively that was not statistically significant. Similarly, the average maximum temperatures showed an increasing trend at a rate of 0.59, 0.80, 0.35, 0.38 and 0.54^0C per decade, respectively but not statistically significant (Figure 8(c-f)). Contrarily, average annual rainfall showed a significant decreasing trend (9.68, 13, 7.15 and 18.98 mm per decade) in Chelia, Sibu-sire and Gida keremu, respectively with a relatively large inter-annual variability, while increasing trend in average annual rainfall of Diga at rate of 2.95 mm per decade.

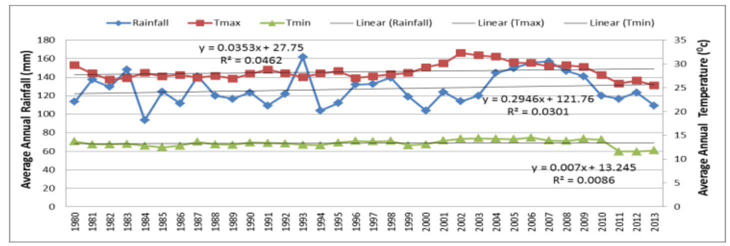


(a) Bako



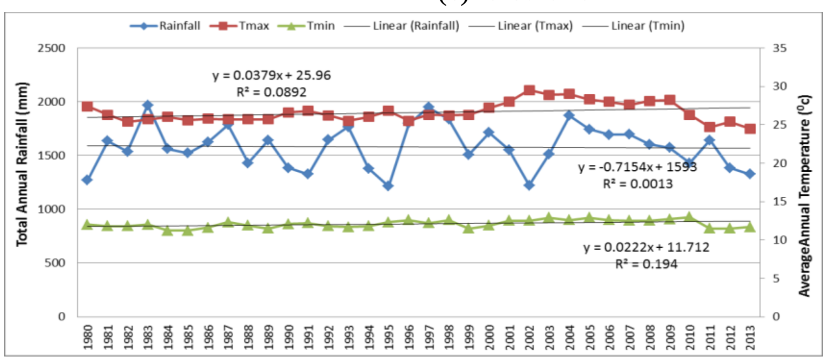
(b) Chelia

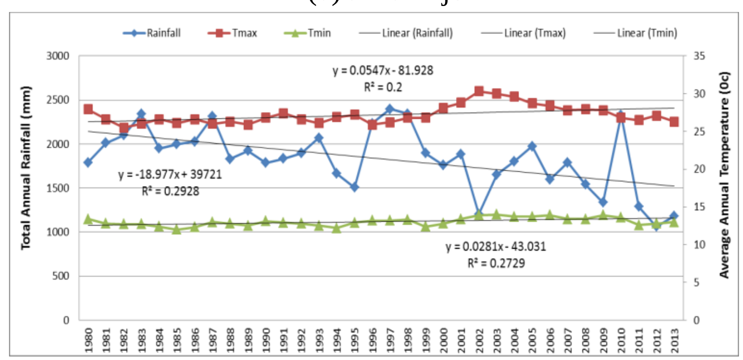




(c) Sibu-sire

(d) Jima Arjo





(e) Gida Keremu

(f) Diga

Figure 8a-f: Trends of annual rainfall, minimum and maximum temperature for Bako (2a), Chelia (2b), Sibu-sire (2c), Jima Arjo (2d), Gida Keremu (2e) and Diga (2f)

Onset and Cessation date from Historical Climate Data Analysis

The onset date of the growing season in the western Oromia ranged mid-May to early June) with the mean onset of first June. The end date of the growing season (EOS) for the study area ranged from mid-September to last November with the mean end date of the growing season (EOS) mid-October (Figure 9). This Onset and cessation date from historical climate data where different from the farmer's perceptions. The community perceptions on onset date lags from historical climate by three weeks and exceed cessation date by almost one month. For this reason, the crop needs a great attention in selecting the appropriate sowing date in order to avoid the long dry spells during the flowering stage and reduce the possible negative impacts. Therefore, knowledge on the date of onset of rains will help to plan the agricultural operations better, particularly, land preparation, sowing and harvesting.

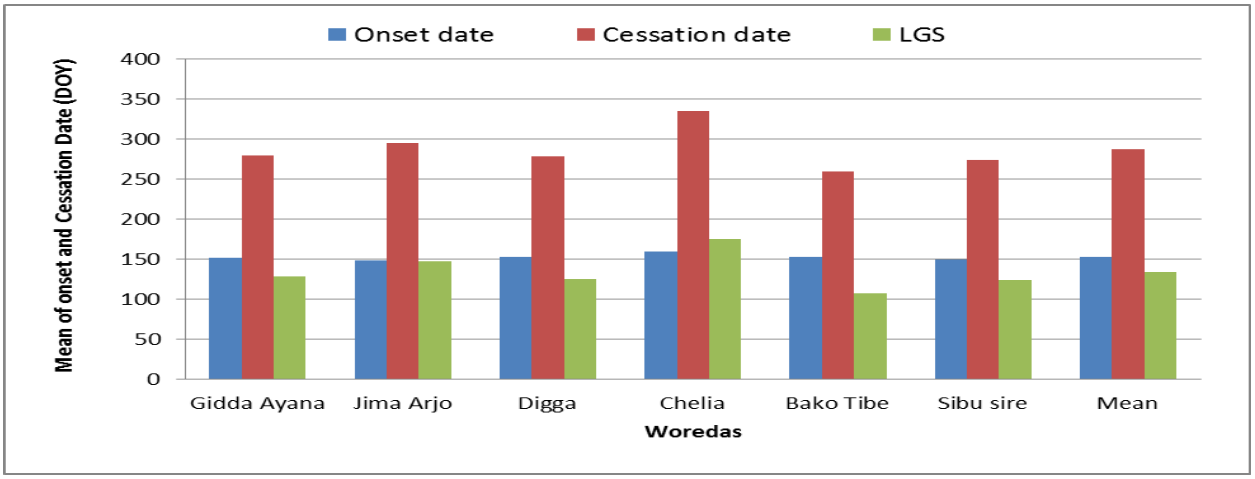


Figure 9: Onset and cessation date from historical climate data

Dry Spell Length from Historical Climate Data

Probability of different dry spells longer than 5, 7, 14 and 21 days were analyzed. The mean probability of dry spells to be 5 days was 40% during the early June and the probability of dry spells of 5 days is 60% during last of -August. All dry spell probability curves converge to their minimum during the peak rain season. The mean probability of dry spells of 7 days is 20% during early June and August (Figure 10). This also confirm with the community perception where the dry spell length occurred during rainy season.

Dry season causes high probability occurrence of long dry spell while low probability of dry spell happens during rainy seasons. As it was presented in (Figure 10) the probability of occurrence of 5, 7, 14, 21 day dry spells is not more than 20% during pick rainy season.

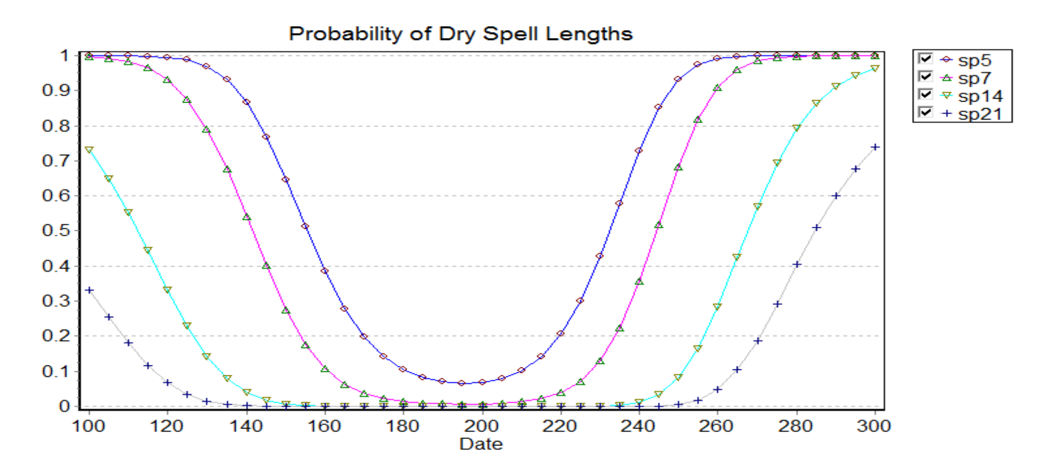


Figure 10: Probability of dry spell lengths

Conclusions and Recommendation

The result of the study illustrated that integrating indigenous and scientific knowledge would provide an insight in designing proper agricultural practices and identification of optimum sowing date as a strategy to minimize crop failure and yield reduction. In areas where communities dependent on rainfall; providing information about the distribution, onset date, end date and duration of rainfall is crucial for agricultural activities. This approach could be very useful in obtaining valuable climate and agronomic information for different decisions.

Climate trends over western Oromia have shown an increasing trend in minimum and maximum temperatures and reducing trend in rainfall over the past few decades. Seasonally, amount of rainfall were quite varies with relatively higher rainfall recorded during *kiremt* months than Bega and Belg months. Hence, in the majority of the rainfall stations of West Oromia, June to August (kiremt) is the period in which highest rainfall has been recorded whereas December-February (Bega) is the period of low rainfall were recorded. Annual rainfall is highest over the Ilu Aba Bora, Jimma and Easts Wellega while the West Shewa and the Qelem Wellega receives less rainfall.

From the respondents view point and climatic data analysis, it is concluded that frequent drought, flood, diseases and pests, variability of rainfall (onset and cessation date as well as distribution) and temperature, significant reduction in length of growing as a result of temperature increment and erratic rainfall, increased dry spells and other had been the main problem of the region that caused due to climatic change. These all problems have got negative impact on production and productivity that highly affected the livelihood of the community.

Generally, except for onset and cessation date difference, the community perceptions and historical climate data analysis results basically conceded or suppot each other. Therefore, integrating indigenous and scientific knowledge would provide good skill and information that contribute for appropriate agricultural planning in order to avoid agro climatic risks.

References

Amukono CL., Bosire E., Lukorito C., (2016). Agro climatic Characterization of Makueni County using Rainfall Data. BACHELOR OF SCIENCE (BSc) thesis. University of Nairobi, Kenya.

Berger, J., and Turner, N. (2007). Chickpea breeding and management. (W. C. The ecology of chickpea in: R. R. Eds SS Yadav, B Sharma (Ed.), ed.), pp. Pg, 47-71. CAB International, Wallingford, UK.

BoFED, 2008. Oromia Atlas. Oromia Finance and Economic Development Bureau. Addis Ababa.

Engida Mersha, (1992). Agro climatic analysis for sustainable development agricultural, planning in Ethiopia. WMO/UNDP Project Eth/86/021. AddisAbeba, Ethiopia. 172 p.

Fita T., (2014). White Mango Scale, *Aulacaspis tubercularis*, Distribution and Severity Status in East and West Wollega Zones, Western Ethiopia. Sci. Technol. Arts Res. J., July-Sep 2014, 3(3): 01-10. http://www.starjournal.org/.

Gebreegziabher, Z., J. Stage, A. Mekonnen, A. Alemu. Climate change and the Ethiopian economy: A computable general equilibrium analysis. Environment for Development Discussion Paper Series, 2011. 24 p.

Gray, D. 2004. Doing Research in the Real World, London. Oxford: Sage Publications.

National meteorological service agency (NMSA), (1996). Climate and agro climatic resources of Ethiopia. Meteorological research report no.1. Addis Abeba Ethiopia no. 137p.

Niguse and Aleme, (2015). Agro Climatic Characterization of the Western Zone of Tigray Region, Humera. Journal of Environment and Earth Science: 5(17); 24-29.

ORHB, 2010. Oromia Regional Health Bureau. Five year health performance report. Addis Ababa.

Reddy M.S and Kidane Giorgis, (1993). Dry land farming research in Ethiopia, a review of the past and trust in the nineties institutes of agricultural research. Addis Abeba 107 p.

Rosenzweig, C. and Parry, M.L. (1994) Potential Impact of Climate Change on Food Supply. Nature, 367, 133-138. http://dx.doi.org/10.1038/367133a0.

Partal T, & Kahya E (2006). Trend analysis in Turkish precipitation data. Hydrol. Processes, 20: 2011-2026.

Shiferaw H., Gebremedhin A., Tsehaye Y., Gebresamuel G., Zenebe A., Girmay G., Tesfaye S., 2015. Characterizing Climate for Agricultural Production and Best Sowing Dates to Minimize Crop Failure: The Case of Kelte-Awelalo Woreda, Tigray, Int. J. of Multidisciplinary and Current research: 3(6); 558-563.

Sinebo, W., Lakew, *et al.* 2010. "Bi plot analysis of grain yield in barley grown under differing management levels in years of contrasting season-end drought. Plant Breeding and Crop Science."152-164.

Suryabhagavan, 2017. GIS-based climate variability and drought characterization in Ethiopia over three decades. Weather and Climate Extremes 15 (2017) 11–23.