Regional Review Workshop on Completed Research Activities

Proceeding of Review Workshop on Completed Research Activities of Natural Resource

Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Oromia, Ethiopia. 07-12 October 2019

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Correct citation: Kefyalew assefa, Tilahun Chibsa, Bikila Mengistu and Tilahun Geleto,(eds) Proceeding of Review Workshop on Completed Research Activities of Natural Resource Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Oromia, Ethiopia. 07-12 October 2019

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Soil Resource Survey Research

Soil Fertility Assessment and Mapping at Negele Arsi District, West Arsi Zone, Oromia Region, Ethiopia.

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Abstract

Information on soil fertility assessment and mapping of arable land helps to design appropriate Soil fertility management practices. The study was conducted during 2015/2016 at Arsi Negele District to assess and map soil fertility status of the district for selected Soil fertility parameters (N, P, K, Ca, Mg, OM, CEC and PH). Accordingly, based on the soil forming factors such as; parent material, climate, topography and geomorphology Arsi Negele District was divided into land units. Then, a total of 236 composite soil samples were collected and analyzed at Batu soil Research Center. Finally, based on laboratory soil analysis result and GPS points, ArcGIS10.3 Software through Ordinary Kriging was used to predict values for un-sampled locations and mapped for whole district. From the study done the Geostatistical analysis revealed that available Phosphorus, Organic matter and Cation exchange capacity were classified into low, medium, high and dominated by medium class with an area coverage of 78.24%,74.60% and 79.77% respectively . However, Nitrogen was classified only into low and medium and also the largest area was grouped into medium class with area coverage 78.24%. pH was classified into neutral, slightly acidic to slightly alkaline. Moreover, potassium and magnesium were classified into medium, high and very high and the largest area was covered by very high and high respectively.

Key words: - ArcGIS, Soil fertility assessment, Soil fertility assessment Map.

Introduction

Soil is the most vital resource for the sustained quality of human life and the foundation of agricultural development. The development and survival of civilizations has been based on the performance of soils on this land to provide food and further essential goods for humans (Hillel, 2009). Efficient management of soil resource is a major challenge for the scientists, planners, administrators and farmers to ensure food security for the present and future generation.

Soil fertility is the inherent capacity of soil that enables it to provide essential plant elements in quantities and proportions for the growth of specified plant when other factors are favorable. Continued removal of nutrients, with little or no replacement will increase the potential for the future nutrient related plant stress and yield loss (Tisdale *et.al*., 2003). Both over dose and under application of chemical fertilizer to soil has negative impact on crop productivity and over dose additionally pollute the environment, so that soil fertility evaluation is the most basic decision making tool in order to efficient plan of a particular land use system (Havlin *et al*., 2010). There are several techniques for the evaluation of soil fertility status. Among them soil testing is a most popular and appropriate. Soil testing provides information about their property, problems and nutrient availability (status) in soils which forms the basis for the fertilizer recommendations. Soil properties vary spatially from a small to larger area might be due to effect of intrinsic and extrinsic factors (Gambardella and Karlen, 1999). Describing the spatial variability of soil fertility across a field has been difficult until new technologies such as Global Positioning Systems (GPS) and Geographic Information Systems (GIS) were introduced. Collection of soil samples by using GPS is very important for preparing thematic soil fertility maps (Mishra *et al.*, 2013).

Similarly, Geographical Information System (GIS) is a potential tool used for easy access, retrieval and manipulation of voluminous data of natural resources often difficult to handle manually. It facilitates manipulation of spatial and attributes data useful for handling multiple data of diverse origin (Mandal and Sharma, 2009). Based on the geo-statistical analysis, several studies have been conducted to characterize the spatial variability of different soil properties (Huang *et al*., 2007; Weindorf and Zhu, 2010; Liu *et al*., 2013). Among the different geo-statistical methods, ordinary kriging is widely used to map spatial variation of soil fertility because it provides a higher level of prediction accuracy (Song *et al.*, 2013). Therefore, it is important to investigate the soil fertility status and mapping their spatial distribution, thus may provide valuable information for agricultural development. However soil of Arsi Negele district were not accessed and mapped at semi detailed level survey. Hence these activities were initiated with the following objectives:-

- To identify and classify soil nutrient status of the study area
- To map soil fertility parameters and avail information on fertilizer application

Materials and Method

Description of the Study Area

The study was conducted at Arsi Negele district, which is located in West Arsi zone of the Oromia Regional State, Ethiopia. The district is located between 7.15°N to 7.75°N latitudes and 38.35°E to 38.95° E longitudes. Total area coverage of the study area is128095.82 hectare (Figure 1).

Soils Types

In Arsi Negele district , there are nine dominant soil types, namely EutricVertisols, Mollic Andosols, ,Eutric Cambisols ,Chromic luvisols, Haplic solonchaks, Vitric Andosols ,Haplic Luvisols ,Lithic Leptosols and Humic Nitisols.

Topography

Topography is one of the soil forming factors influencing the characteristics of soil in the given area. Both slope and elevation of the study area are generated from digital elevation model by using ArcGIS10.3spatial analyst of surface analysis.

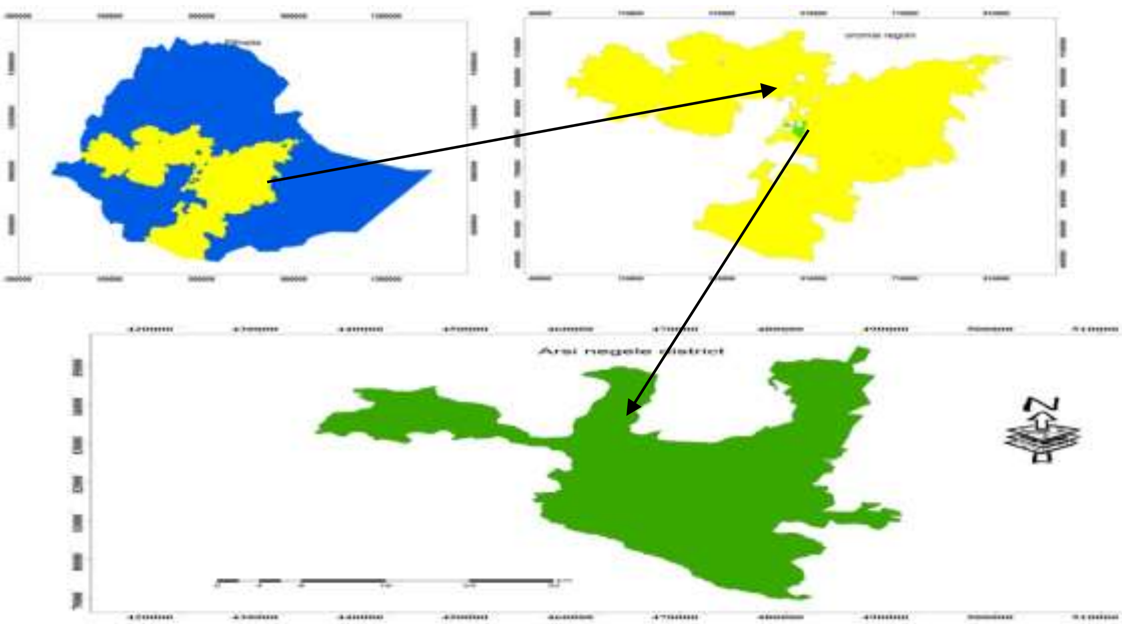

Figure 1: Location map of Arsi Negele District

Mapping Unit Preparation and Soil Sampling

In order to delineate mapping units, the soil forming factors such as parent material, topography, climate, geomorphology and land use were considered digitally by spatial tools to categorize areas having similarly properties. Based on these factors 236 mapping units was prepared and 236 soil samples (one composite sample from each land unit) (at 0-20cm depth) were collected from developed mapping units (land units) during 2015/2016, registering their geographical location of each sampling point using GPS (Figure 2).

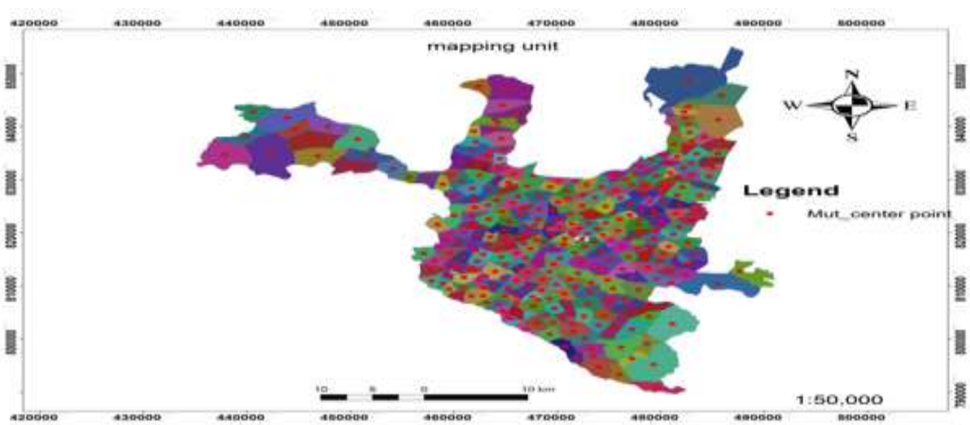

Figure 2: mapping units and soil sampling points.

Method Followed

Both statistical evaluation and geospatial evaluation were conducted. Then at the end of the activities fertility map was prepared for total nitrogen, organic matter, available phosphorous, exchangeable sodium, magnesium, potassium, and CEC and soil pH. The analysis of these parameters was done in Batu Soil Research Center soil laboratory following the methods listed in the table below (Table 1).

Table 1: Tested Soil parameters

No	Soil parameters	Method of Analysis
1	Texture	Hydro meter
2	Bulk density	Gravimetric(oven dry)
3	pH	pH-meter
4	CEC	By Ammonium Acetete
5	EC	EC-meter
6	TN	Kjeldhal Method
7	K,Na	Flame Photometer
8	Ca, Mg	spectrophotometer
9	Av.P	Olsen et al (1954)
10	Organic carbon(OC)	Walkey & Blank method

Having soil composite sample laboratory analysis results, rating(very low, low, medium , high and very high) of parameters determined values were made based on rating standard sated by Booker(1991) ,Tekilign(1991), FAO (2006) and Hazelton and Murphy(2007). Likewise, ARC map10.1 with geostatical analyst extension of ARC GIS software was used to prepare spatial distribution map of soil parameters, while interpolation method employed was ordinary king stable.

Results and Discussions

The soil fertility distribution of the district was assessed with respect to soil texture, pH, exchangeable sodium, potassium, Cation exchange capacity, available phosphorous, total nitrogen and organic matter content. The results obtained are presented and discussed in the following headings.

Soil Texture

Soil texture plays important role for drainage, water holding capacity, aeration, and susceptibility to erosion, organic matter content, cation exchange capacity and pH buffering capacity (Berry *et al*., 2007). The sand content of samples ranged from 35 to 74% with a mean of 54.5% and that of silt content were 18 to 46% with a mean of 32%, while the range of clay content was 5 to 27% with a mean of 16% (Table 1).

The study area was dominated by loam and sandy loam soil texture, with an-area coverage of 40.25% and 58.05% respectively. Whereas, the remaining 1.70% covered by clay loam. Among the observed soil texture (loam) had proper water and nutrient holding capacity; hence suitable for most of the crops. Panda (2010) reported medium textured soils like loam and silt loam are considered suitable among all the soil texture for most of the crop.

Table 2: soil texture status of study area

Descriptive statistics	Soil separates		
	Sand %	*silt%*	*clay%*
Maxim	*74*	*46*	*27*
Minimum	*35*	*18*	*5*
Mean	*54.5*	*32*	*16*
Class	*sandy loam*	*loam*	*clay loam*
Area coverage (%)	*58.05*	*40.25*	*1.70*

Soil pH

Soil pH is one of the most important characteristics of soil fertility, because it has a direct impact on nutrient availability and plant growth (Brady and Weil, 2002). The soil pH varied from 6.1 to 7.8. The distribution of soil pH varied from slightly acidic to slightly alkaline according to Booker 1991 classification system.

Accordingly 67.30% and 29.40 5 of the study area classified as neutral and slightly acidic respectively, which is appropriate to major crops. The result in part with Amacher *et.,al* (2007)finding which state that optimum pH for many plant species is 5.5 to 6.8 and absence of exchangeable AL in this range also suits for crop production.

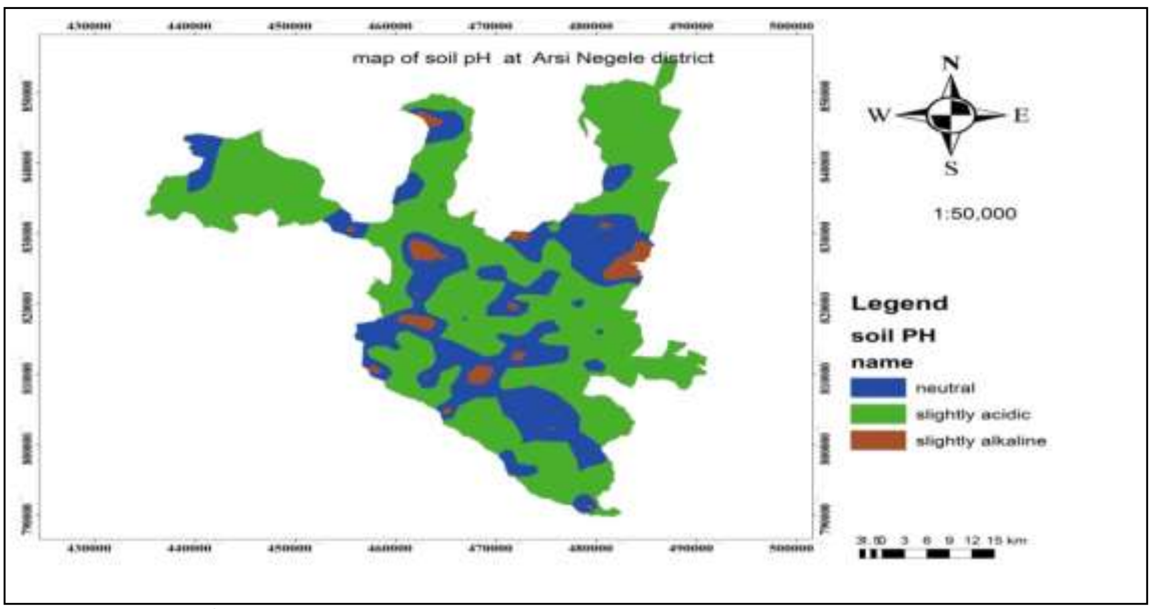

Figure 3: map of soil pH at Negele Arsi district

Available Phosphorus

Phosphorus is the second most limiting nutrient after nitrogen, and has negative impacts on crop yield if found to be deficient (Sharma *et al*., 2017). The available phosphorus varied from 3.04 ppm to 30.08 ppm. According to Booker (1991) soil rating system, study area has three classes of available phosphorous namely low, medium and high, with an area coverage of 0.85%, 92.49% and 6.70% respectively. Phosphorus deficiency in Ethiopian soils is well documented in various research works (Melese *et al*., 2015; Daniel and Tefera, 2016; Kebede *et al*., 2017). On top of the inherent low occurrence of P, its availability is limited by strongly acid characteristics of the soils in the high land part of the country.

The higher content of available phosphorus in the some part of study area might be due to the continuous application of phosphates' fertilizers namely di-ammonium phosphate (DAP) and Recently NPS for every crop without knowing phosphorus supplying capacity of soil. The result was in agreement with Taddesse *et al*., 2012) finding who reported that high concentration of available phosphorous is due continuous usage of phosphate fertilizer without knowing capacity of soil to supply nutrient (phosphorous).

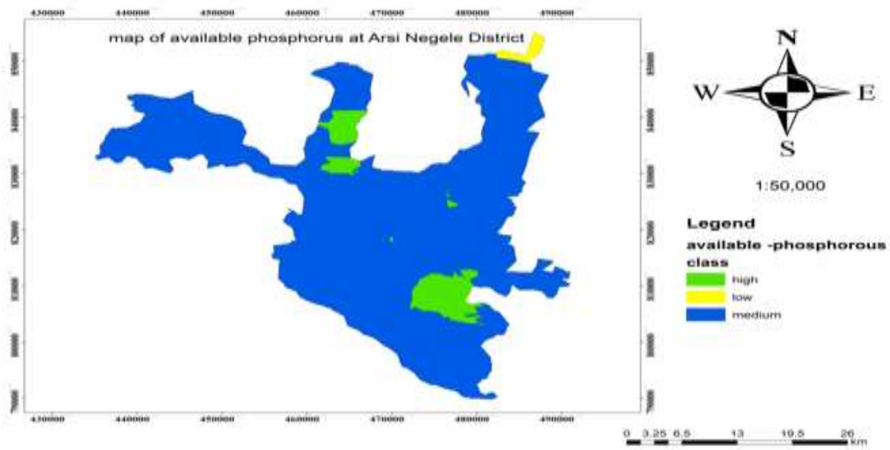

Figure 4: map of available phosphorous at Arsi Negele district.

Organic matter

Organic matter is a vital parameter for making soil alive, because it improves different physical, biological and chemical properties (Hoyle *et al*., 2011, Alabandan *et al*., 2009) .The value of organic matter of analyzed representative soil sample ranges from 1.17 to 8.09. According to Booker (1991) soil rating system the study area has low, medium and high organic matter (Figure 5). Accordingly 74.60 % of the study area has medium organic matter, however low organic matter in the study area might be due low incorporation of organic matter such as organic manure, green manure ,animal dung ,excessive tillage, low biomass availability, compost, as well as removal crop residue for livestock feed and fuel. The result was in line with Tegenu *et al*., 2009 finding who reported that low organic matter content North –West Ethiopia. The adequate incorporation of organic manure, vermin-compost, green manure and adoption of resource conservation technology during cultivation is important for organic matter improvement in the study area.

Cation Exchange Capacity of Soil (CEC)

Cation exchange capacity (CEC) is a measure of the soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilizers and other ameliorants (Hazleton and Murphy 2007). Soil with a higher clay fraction and organic matter tend to have a higher CEC.

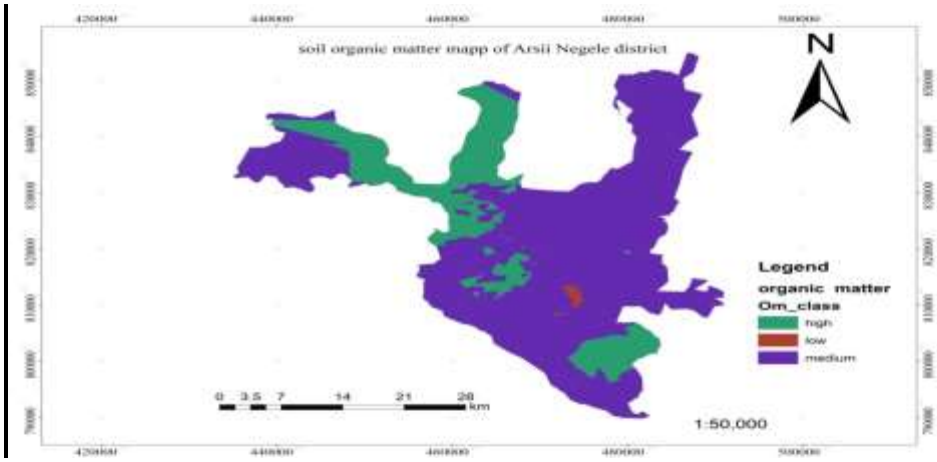

Figure 5.:map of organic matter content at Arsi Negele district

According FAO, (2006) soil rating system study area has very low, low, medium and high CEC. More than 98.10% of the study area has low to medium CEC (Figur 6). These might be due poor soil fertility management including: continuous cultivation, mono cropping, intensive cultivation, low clay fraction (Table 2) and medium organic matter (Figure 5) in the study area. The result in line with Alemayehu (2007) who reported that depletion of organic matter as a result of intensive cultivation contributed to lower CEC of the soils.

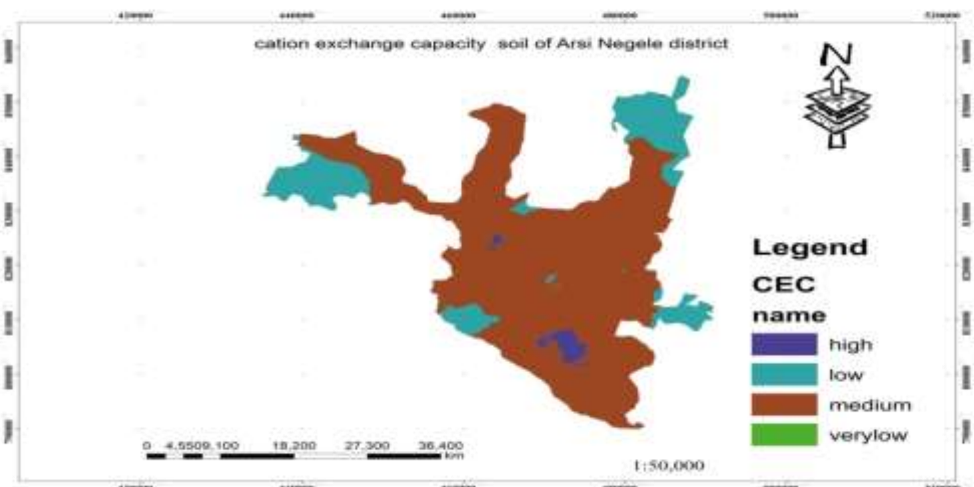

Figure 6: Cation exchange capacity of soil at Arsi Negele district

Total Nitrogen

The total nitrogen ranged from 0.10 to 0.23% with a mean of 0.12%. Based on the rating set by Tekalign (1991) total nitrogen varied from low to medium (Figur 7). More than 77.85% of the study area has medium total nitrogen; whereas remaining 21.84% has low total nitrogen. There is a strong relation between organic matter and total nitrogen in the soil system; hence medium organic matter content (Figure 5) in the study area can cause medium total nitrogen in this area. Low total nitrogen in the study area might be due to inadequate supply of respective inorganic as well organic fertilizer. Moreover, the low organic matter status in some part of study area might also the of cause low total nitrogen.

In agreement with this result, Meysner *et al*. (2006) indicated that as much as 93 to 97% of the total nitrogen in soils is closely associated with organic matter.

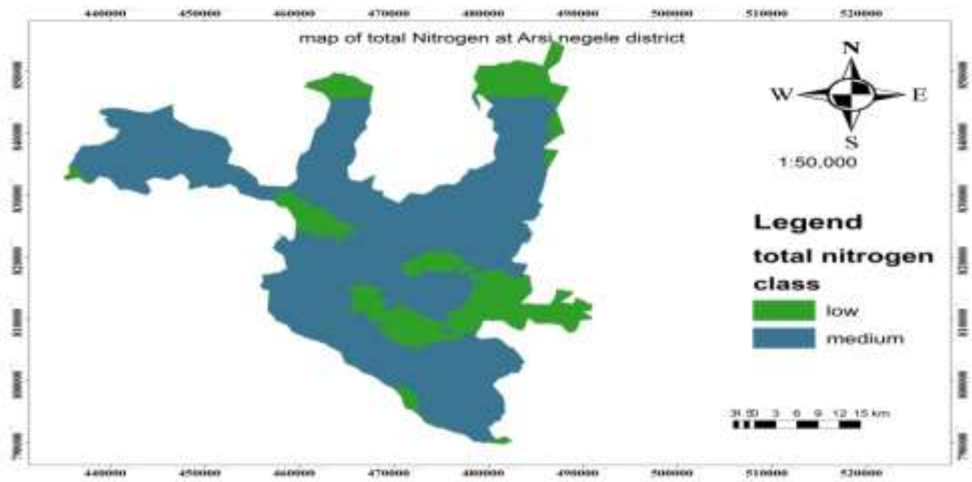

Figure 7: map of soil total nitrogen at Arsi Negele district.

Exchangeable Potassium

After nitrogen and phosphorus, it is the third most likely element to limit plant productivity. It is an activator of the various enzymes responsible for various which is nitrate reduction, protein synthesis, breakdown of carbohydrates, photosynthesis (Wang, 2013). According to Hazelton and Murphy (2007) rating system, study area has medium, high and very high exchangeable potassium (Figure 8). More than 92.3% of the study area belongs to very high exchangeable potassium; this might be due parent material from which soil is developed and leaching of basic cation from high altitude low altitude and their subsequent accumulation in lower part. The result in line with finding of Lawal *et al*., (2013), which states that, the high content exchangeable potassium on the surface horizons across the landscape may be due to the lateral movement of the ion from the upper slope to the toe slope.

Exchengable Magnisium

Magnesium is the central core of the chlorophyll molecule in plant tissue. Magnesium is held on the surface of clay and organic matter particles. Exchangeable form of magnesium is available to plants; this nutrient will not readily leach from soils, which contributes high concretion in soil. According to Hazelton and Murphy (2007) rating system study area has medium, high and very high exchangeable magnesium (Figure 9). About 90.16% of the study area belongs to high exchangeable magnesium, these might due parent material from soil is developed and leaching of basic cation from high altitude low altitude and their subsequent accumulation in lower part. The result in line with T Lawal *et al*., (2013) finding which states that, the high content Exchangeable magnesium on the surface horizons across the landscape may be due to the lateral movement of the ion from the upper slope to the toe slope.

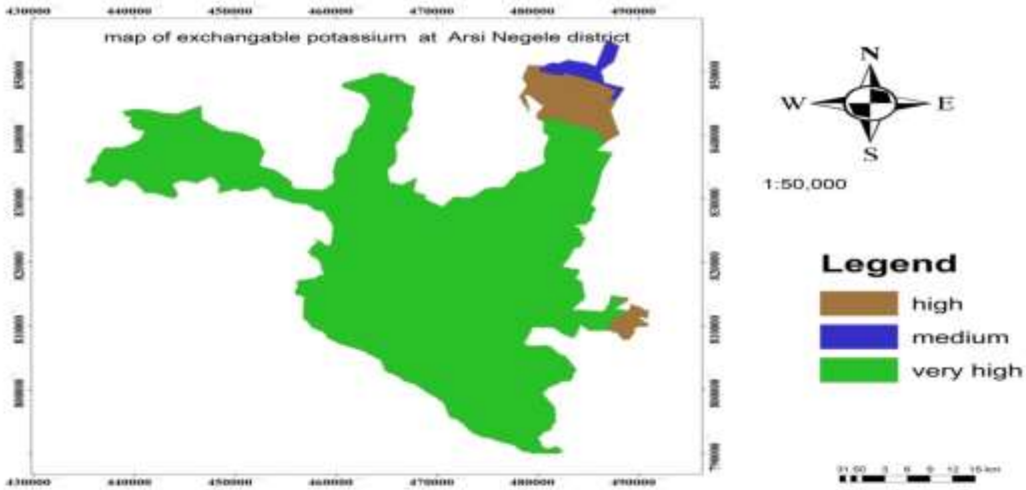

Figure 8: map of Exchangeable Potassium at Arsi Negele District.

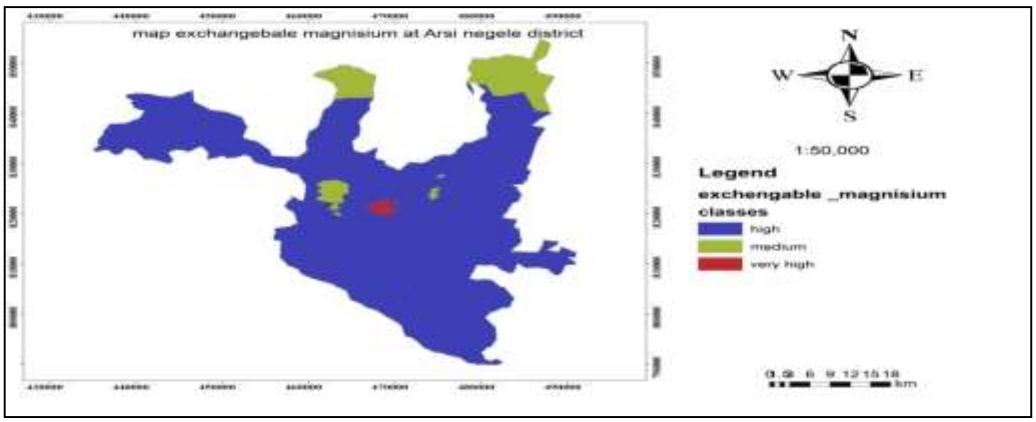

Figure 9: Map of Exchangeable magnesium at Arsi Negele District.

Conclusion and Recommendation

Soil fertility map shows plant nutrient status in the soil and useful for decision making on, fertilizer type and rate, as well as for designing appropriate soil fertility management practices. Based on the study has been done on soil fertility assessment and mapping, eight soil fertility parameters were accessed and mapped for Arsi Negele district. Accordingly 92.44% of study area has medium available phosphorus (5-15ppm) ,about 74.60% of study area has medium (1-3%)organic matter and 67.30% soil of the district was slightly acidic(pH=6.1-6.5) . More over study area has four classes of CEC, namely very low, low, medium and high, were as exchangeable magnesium and potassium categorized as medium, high and very high based on Hazelton and Murphy (2007) soil rating system(appendix table).

From this study we conclude that soil fertility parameters, within a district shows heterogeneity for all nutrient assessed. Finally based on these results, the following recommendation is given for decision makers, researchers and other stake holders that this soil fertility map can be used as information source regarding soil fertility management in the district. Moreover, further correlation and calibration of soil test data with plant response is recommended for site–soil–crop specific fertilizer recommendation with appropriate rate.

Acknowledgment

The authors would like to thanks Oromia agricultural research institute(IQQO) for financial, logistic , and material support during activity implementation, I provide special thanks to all researchers, field assistance ,laboratory technicians and support staff of Batu soil research center for their contribution.

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Soil Fertility Assessment and Mapping at Adami Tulu Jidoo Kombolcha District, East Shewa Zone, Oromia Region, Ethiopia

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Key words: - *ArcGIS, Soil fertility assessment, Soil fertility assessment Map*.

Introduction

Soil is most vital resource for the sustained quality of human life and the foundation of agricultural development. The development and survival of civilizations has been based on the performance of soils on this land to provide food and further essential goods for humans (Hillel, 2009). Efficient management of soil resource is a major challenge for the scientists, planners, administrators and farmers to ensure food security for the present and future generation. Soil fertility is the inherent capacity of soil that enables it to provide essential plant elements in quantities and proportions for the growth of specified plant when other factors are favorable. Continued removal of nutrients, with little or no replacement will increase the potential for the future nutrient related plant stress and yield loss (Tisdale *et.al.*, 2003). Both over dose and under application of chemical fertilizer to soil has negative impact on crop productivity and over dose additionally pollute the environment, so that soil fertility evaluation is the most basic decision making tool in order to efficient plan of a particular land use system (Havlin *et al.*, 2010).

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- To identify and classify soil nutrient status of the study area
- To map soil fertility parameter and avail information on fertilizer application

Materials and Method

Description of the Study Area

The activity was conducted in Adami tullu jidoo Kombolcha district, East shewa Zone, Oromia, Ethiopia (Figure 1). The district located at 150 km from Addis Ababa in the South direction on 38°00'E to 39° 30' E longitude ,7° 00' N to 8° 30' N latitude with an altitude 1500- 2300 masl .The district receive annual rainfall from 500 to 900 mm and its map is indicated below.

Soil Type

In Adami tuluu jidoo kombolcha district there are six dominant soil types namely, Mollic Andosols ,Eutric Vertisols, Eutric Cambisols , Haplic Solonchaks, Vitricandosols and Lithic Leptosols .

Topography

Topography is one of the soil forming factors influencing the characteristics of soil in the given area. Both slope and elevation of the study area are generated from digital elevation model by using ArcGIS10.3spatial analyst of surface analysis.

Mapping Unit Preparation and Soil Sampling

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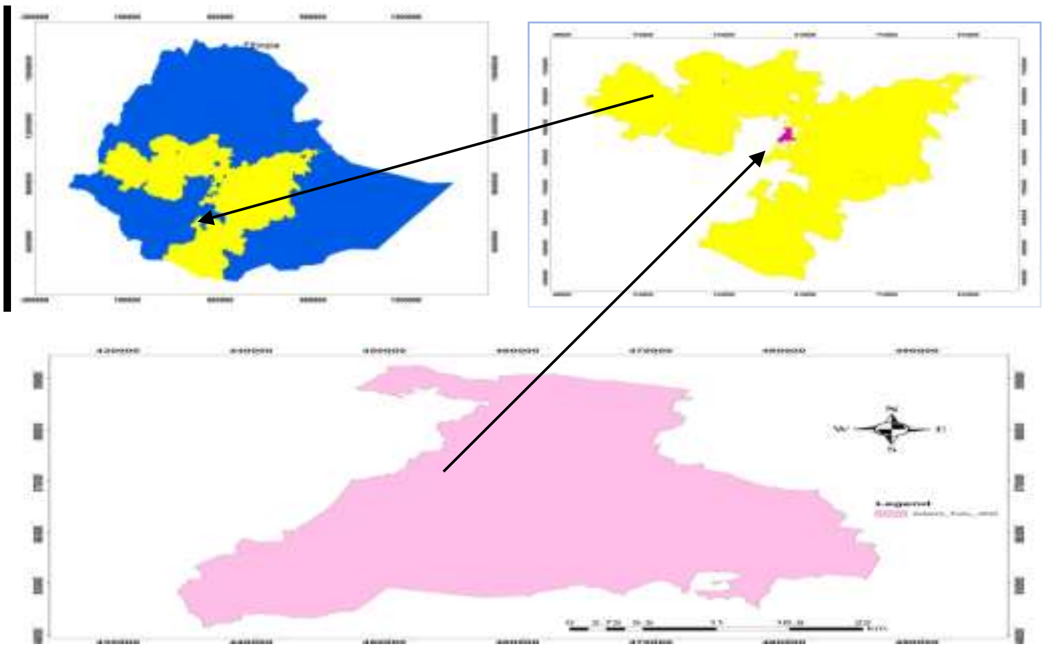

Figure : loction map of Adami tuluu jidoo kombolcha district

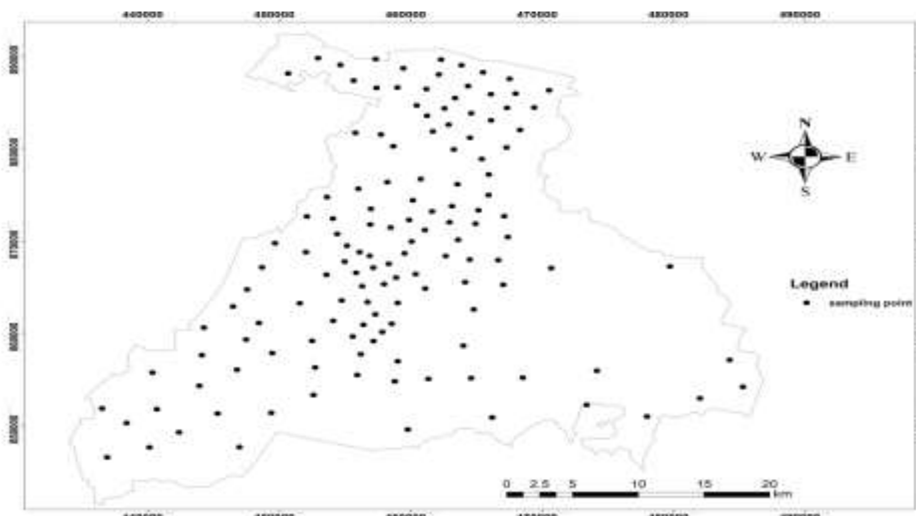

Figure 2: map of soil sampling points

Method Followed

Both statistical evaluation and geospatial evaluation were conducted. Then at the end of the activities fertility map was prepared for total nitrogen, organic matter, available phosphorous, exchangeable sodium, magnesium, potassium, and CEC and soil pH. The analyses of these parameters were done in Batu soi research center soil laboratory following methods listed in the table below (Table1).

Table 1: tested soil parameters

No	Soil parameters	Method of Analysis
1	Texture	Hydro meter
2	Bulk density	Gravimetric(oven dry)
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4	CEC	By Ammonium Acetete
5	EC	EC-meter
6	TN	Kjeldhal Method
7	K, Na	Flame Photometer
8	Ca, Mg	spectrophotometer
9	Av.P	Olsen et al (1954)
10	Organic carbon(OC)	Walkey & Blank method

Having soil composite sample laboratory analysis results, rating(very low, low, medium , high and very high) of parameters determined values were made based on rating standard sated by Booker (1991) ,Tekilign (1991), FAO (2006) and Hazelton and Murphy (2007). Likewise, ARC map10.1 with geostatical analyst extension of ARC GIS software was used to prepare spatial distribution map of soil parameters, while interpolation method employed was ordinary king stable.

Results and Discussions

The soil fertility distribution of the district was assessed with respect to soil texture, pH, exchangeable magnesium, sodium, Cation exchange capacity, available Phosphorous, total nitrogen and organic matter content .A results obtained are presented and discussed in the following headings.

Soil Texture

Soil texture plays important role for drainage, water holding capacity, aeration, susceptibility to erosion, organic matter content, cation exchange capacity, pH buffering capacity and soil tilth (Berry *et al.*, 2007). The sand content of samples ranged from 24 to 84% with a mean of 56% and that of silt content were 6 to 42% with a mean of 24%, while the range of clay content was 6to 30% with a mean of 18% (Table 2). The study area dominated by loam and sandy loam soil texture, with an area coverage of 49.64% and 46.04% respectively, where as reaming 4.31% covered by clay loam. Among the observed soil texture (loam) had proper water and nutrient holding capacity; hence suitable for most of the crops. Panda (2010) reported medium textured soils like loam and silt loam are considered suitable among all the soil texture for most of the crop

Table 2: Soil texture status of the study area

Descriptive statics	Soil separates		
	Sand %	*silt%*	*clay%*
Maxim mum	*88*	*42*	*30*
Minimum	*24*	*6*	*6*
Mean	*56*	*24*	*18*
Class	*sandy loam*	*Loam*	*clay loam*
Area coverage (%)	*46.04*	*49.64*	*4.32*

Soil pH

Soil pH is one of the most important characteristics of soil fertility, because it has a direct impact on nutrient availability and plant growth (Brady and Weil, 2002). The soil pH varied from 6.05 to 8.07. The distribution of soil pH varied from slightly acidic to strongly alkaline (Figure 3). Most of the study area dominated by neutral and slightly acidic soil reaction (with area coverage of 68.72 %), which is more suitable for major crops. The result in part with Amacher *et.al.,* (2007) finding which state that optimum pH for many plant species is 5.5 to 6.8 and absence of exchangeable AL in this range also suits for crop production

Available Phosphorus

Phosphorus is the second most limiting nutrient after nitrogen, and has negative impacts on crop yield if found to be deficient *(Sharma et al.,* 2017). The available phosphorus varied from 0.69 ppm to 36.044ppm. According to rating sated by booker (1991) study area has three class of available phosphorous namely, low, medium and high (Figure 4). It is dominated by medium available phosphorous with an area coverage of 72.71%. Phosphorus deficiency in Ethiopian soils is well documented in various research works (Melese *et al.,* 2015; Daniel and Tefera, 2016; Kebede *et al.,* 2017). On top of the inherent low occurrence of P, its availability is limited by strongly acid characteristics of the soils in the high land part of the country.

However, Medium available phosphorous in the study area might be attributed by medium organic matter (figure 5) in the study area as well as existence of soil disturbance for cultivation in the area. Similarly, Tekilign and Haque (1991) reported that organic matter as main source available phosphorous and its availability decline by impacts of fixation, intensity of disturbance, soil erosion and crop harvest.

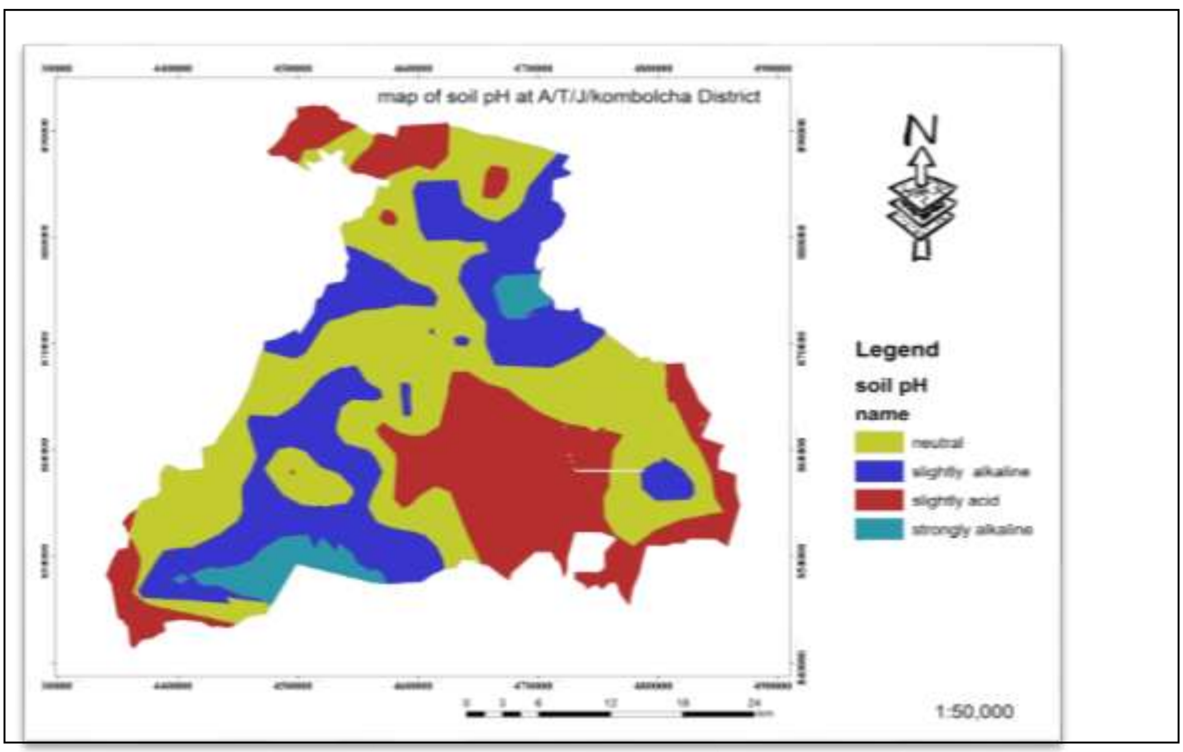

Figure 3: map of soil pH att Adami tuluu jidoo kombolcha district

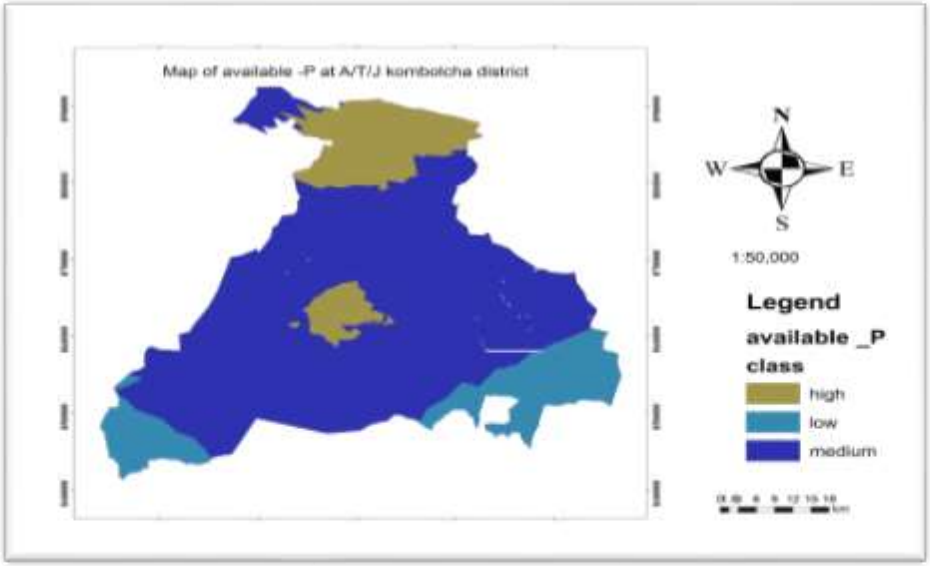

Figure 4 : map of available phosphorous at Adami tuluu jidoo kombolcha district

Organic matter

Organic matter is a vital parameter for making soil alive, because it improves different physical, biological and chemical properties (Hoyle *et al*., 2011, Alabandan *et a*l., 2009) .The value of organic matter of analyzed representative soil sample ranges from 0.89 to 6.306. According to rating sated Booker (1991) the study area has low, medium and high organic matter (Figure 5). Its dominated with medium organic matter with an area coverage of 78.77% , however low organic matter in some part of study area might be due low incorporation of organic matter such as : organic manure, green manure ,compost ,animal dung, excessive tillage, low biomass availability, as well as removal crop residue for livestock feed and fuel .

The result was in line with Tegenu .,*et.al* (2009) finding who reported that low organic matter content in North - West Ethiopia. The adequate incorporation of organic manure, vermin-compost, green manure and adoption of resource conservation technology during cultivation is important for organic matter improvement in the study area.

Cation Exchange Capacity of Soil (CEC)

Cation exchange capacity (CEC) is a measure of the soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilizers and other ameliorants (Hazleton and Murphy 2007). According rating sated FAO (2006) soil of study area has low, medium and high CEC (Figure 6). More than 68% of the study area has low to medium CEC. This might be due poor soil fertility management including: continuous cultivation, mono cropping, intensive cultivation as well as low clay fraction (Table 2) and medium organic matter (Figure 4) in the study area. The result in line with Alemayehu (2007) reported that depletion of organic matter as a result of intensive cultivation contributed to lower CEC of the soils

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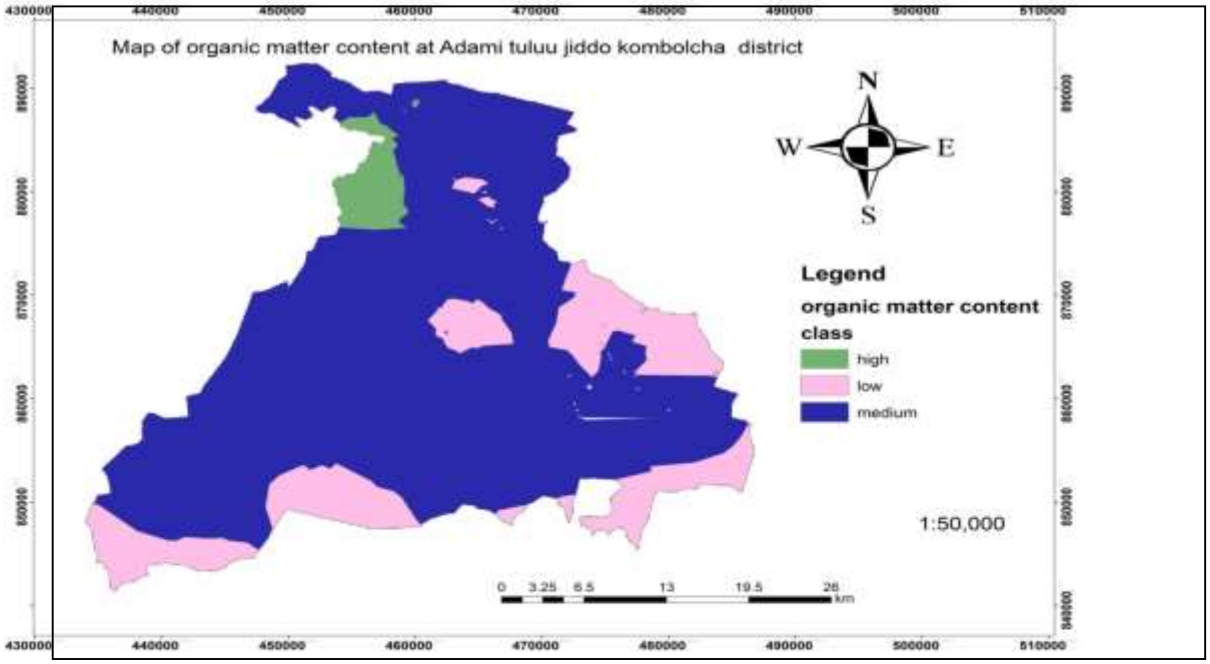

Figure 5. map of organic matter content at Adami tuluu jidoo kombolcha district

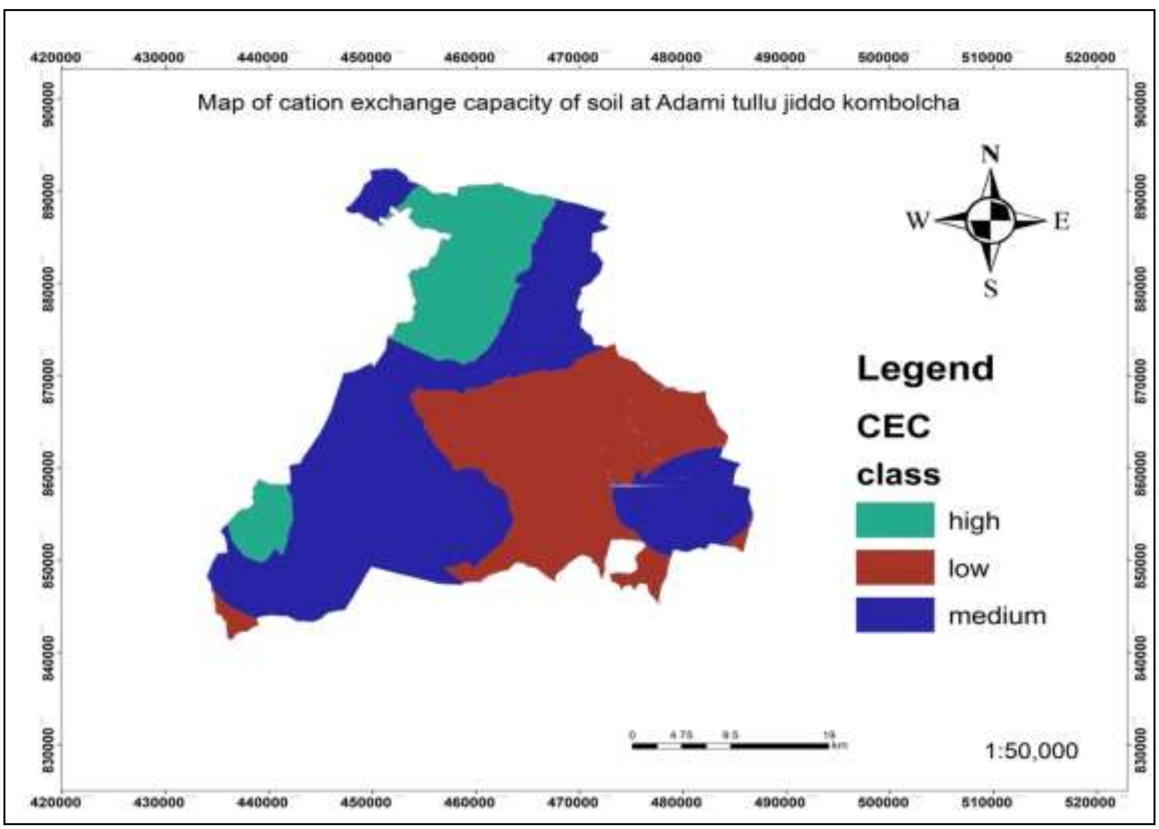

Figure 6: Cation exchange capacityof soil at Adami tuluu jidoo kombolcha district

Total Nitrogen

The total nitrogen ranged from 0.10 to 0.28% with a mean of 0.17%. Based on the rating set by Tekalign (1991), total nitrogen varied from low to medium. More than 77.85% of the study area has medium total nitrogen; whereas remaining 21.84% has low total nitrogen (Figure 7). There is a strong relation between organic matter and total nitrogen in the soil system, hence medium organic matte content (Figure 5) in the study area can cause medium total nitrogen in this area. Were as, low total nitrogen in some part study area might be due to inadequate supply of respective inorganic as well organic fertilizer .Moreover, the low organic matter status in the study area might also be the cause of low total nitrogen.

In agreement with this result, Meysner *et al*. (2006) indicated that as much as 93% to 97% of the total nitrogen in soils is closely associated with organic matter. The optimum total nitrogen should have to maintain through application of compost, crop rotation and use of nitrogenous fertilizer as well plantation of leguminous crops in the study area.

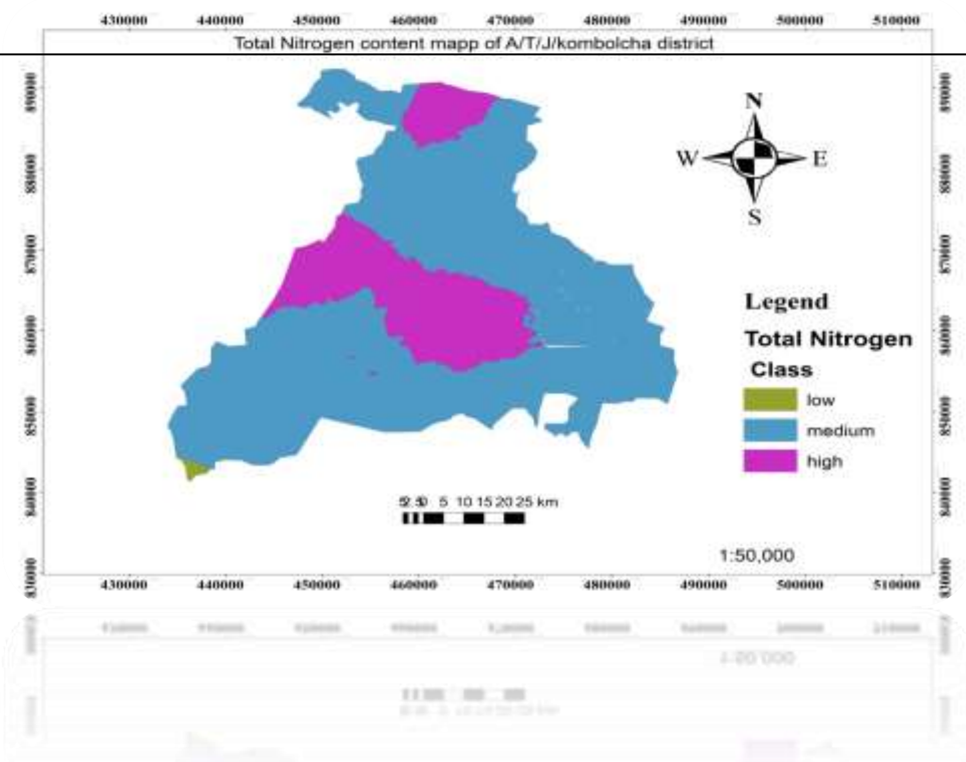

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Figure 7: Map of soil total nitrogen at Adami tuluu jidoo kombolcha district

Exchangeable Potassium

After nitrogen and phosphorus, it is the third most likely element to limit plant productivity. It is an activator of the various enzymes responsible for various which is nitrate reduction, protein synthesis, breakdown of carbohydrates, photosynthesis (Wang.2013).

Potassium is also recognized as assisting plants adapt to stresses such as drought conditions and colder temperatures. According to rating sated by Hazelton and Murphy (2007) more than 99% of the study area belongs to high and very high exchangeable potassium (Figure 8). This might be due to nature of parent material from which soil is developed and leaching of basic cation from high altitude low altitude and their subsequent accumulation at lower part. The result in line with finding (T Lawal *et al*., 2013) which states the high content of exchangeable potassium on the surface horizons across the landscape may be due to the lateral movement of the ion from the upper slope to the toe slope.

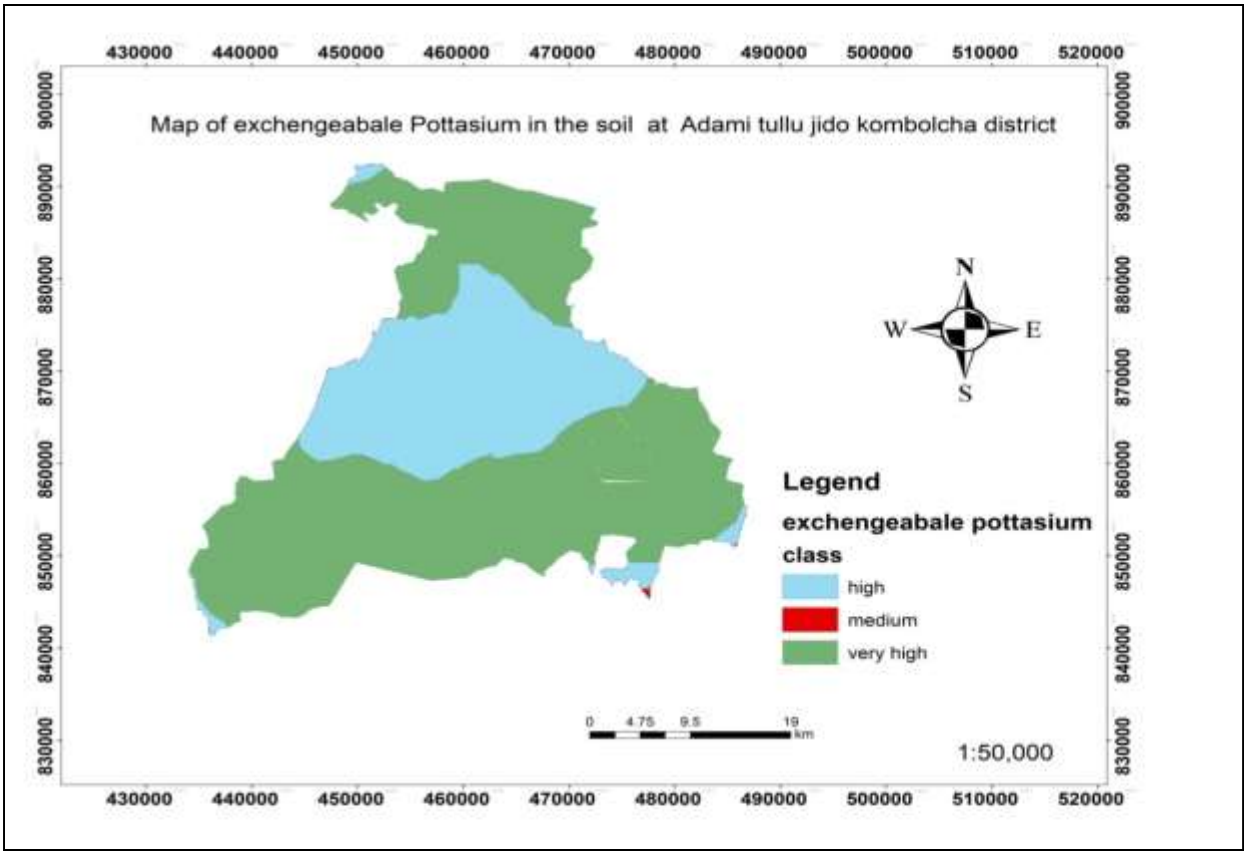

Figure 8 : map exchengable pottasium at Adami tuluu jido kombolcha district

Exchengable magnisium

Magnesium is the central core of the chlorophyll molecule in plant tissue. Magnesium is held on the surface of clay and organic matter particles. Exchangeable form of Mg is available to plants; this nutrient will not readily leach from soils and its availability increase with increase in soil pH. According to rating sated by Hazelton and Murphy (2007) about 84.41% of the study area has medium magnesium exchangeable magnesium (Figure 9).

High exchangeable magnesium in the study area might be due, lateral flow of basic cation from high altitude to low altitude in the study area and their subsequent accumulation at lower part. The result in line with finding (T Lawal *et a*l., 2013) which states the high content of exchangeable potassiumon the surface horizons across the landscape may be due to the lateral movement of the ion from the upper slope to the toe slope.

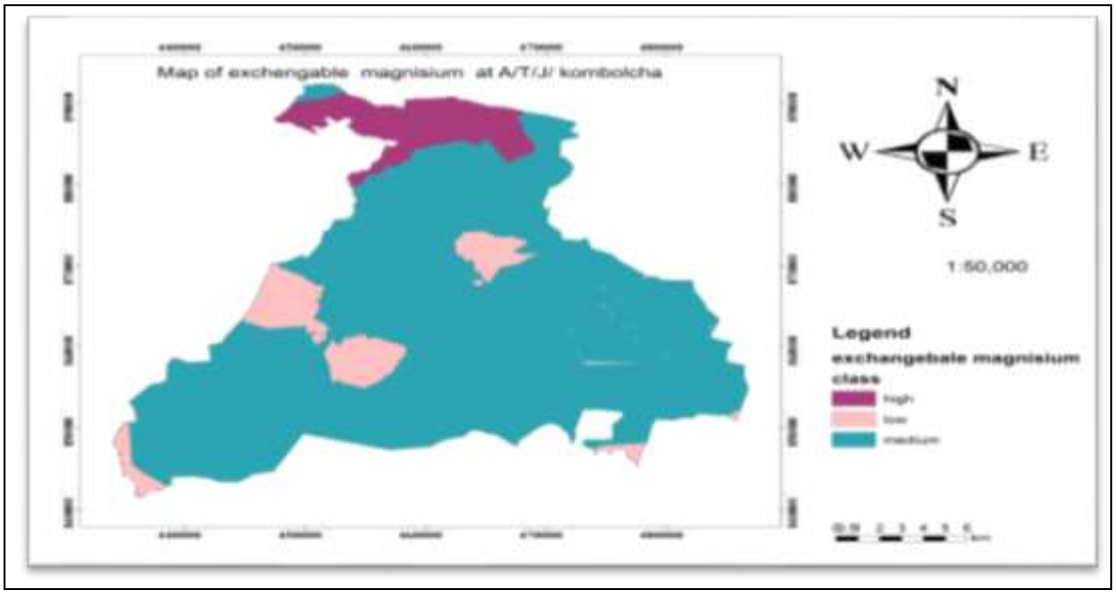

Figure 9: map exchangeable magnesium at Adami tuluu jidoo kombolcha district

Exchangeable sodium

The exchangeable sodium ranged from 0.05 to 2.02cmol$_c$ kg-^{1}with a mean of 2.0702cmol$_c$ kg-^{1} . Based on the rating set by Hazelton and Murphy (2007), exchangeable sodium classified as very low, low, medium and high with an-area coverage of 22.58%, 22.73%, 46.96%, 7.71% respectively (Figure 10).

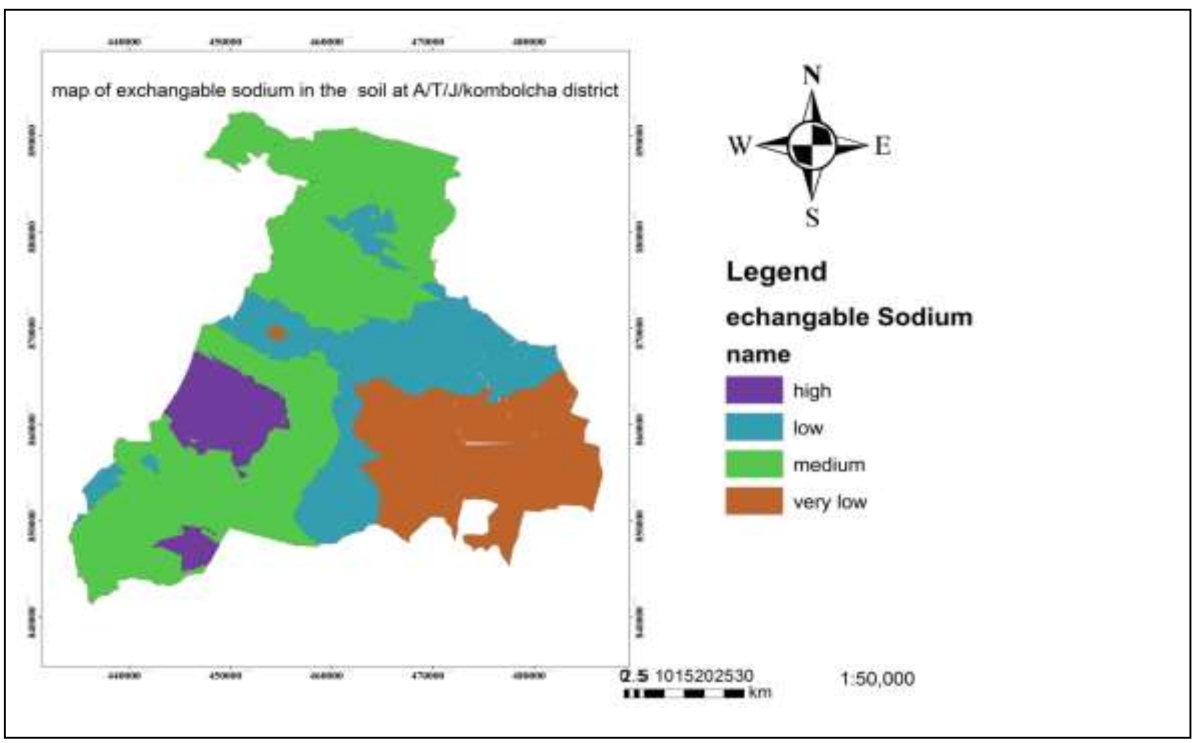

Figure10: map exchangeable sodium at Adami tuluu jidoo kombolcha district

Conclusion and Recommendation

Soil fertility map shows plant nutrient status in the soil and useful for decision making on, fertilizer type and rate, as well as for designing appropriate soil fertility management practices. Based on the study has been done on soil fertility assessment and mapping, nine soil fertility parameters were accessed and mapped for Adami tuluu jidoo kombolcha district. Accordingly 72.71% of study area has medium available phosphorus (5-15ppm), about 78.77% of study area has medium (1-3%) organic matter and 42.72% soil of the district was neutral (pH=6.6 - 7.3). More over study area has three classes of CEC, namely, low, medium and high, were as exchangeable magnesium and potassium categorized as medium, high and very high based on Hazelton and Murphy (2007) soil rating system.

From this study we conclude that soil fertility parameters, within the district shows heterogeneity for all nutrients assessed. Finally based on these results, the following recommendation is given for decision makers, researchers and other stake holders that this soil fertility map can be used as information source regarding soil fertility management in the district. Moreover, further correlation and calibration of soil test data with plant response is recommended for site–soil–crop specific fertilizer recommendation with appropriate rate.

Acknowledgment

The authors would like to thanks Oromia agricultural research institute (IQQO) for financial, logistic and material support during activity implementation, I provide special thanks to all researchers, field assistance ,laboratory technicians and support staff of Batu soil research center for their contribution .

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Soil Fertility Assessment and Mapping of Dugda District, East Shewa Zone, Oromia Region, Ethiopia

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Abstract

Information on soil fertility assessment and mapping of arable land helps to design appropriate Soil fertility management practices. The study was conducted during 2014/2015 at Dugda District to assess and map soil fertility status of the district for selected soil fertility parameters (N, P, K, Ca, Mg, OM, CEC and PH). Accordingly, based on the soil forming factors such as; parent material, climate, topography and geomorphology Dugda District was divided into land units. Then, a total of 124 composite soil samples were collected and analyzed at Batu soil Research Center. Finally, based on laboratory soil analysis result and GPS points, ArcGIS10.3 Software through Ordinary Kriging was used to predict values for un-sampled locations and mapped for whole district. From the study done the Geostatistical analysis revealed that, Organic matter, total nitrogen and Cation exchange capacity were classified into low, medium, high and dominated by medium class with an area coverage of 47.67%,72.38% and 45.11% respectively . However, available phosphorous was classified only into medium and high, also the largest area was grouped into medium class with area coverage 63.10%. pH was classified into slightly acidic , neutral, slightly alkaline, strongly alkaline and very strongly alkaline . Moreover, sodium were classified into very low, low, medium, high and very high ,where as calcium classified as very low, low, medium and high . Finally magnesium classified into low, medium, high, very high and dominated by medium class with area coverage 70.73%.

Key words: - ArcGIS, Soil fertility assessment, Soil fertility assessment Map.

Introduction

Soil is most vital resource for the sustained quality of human life and the foundation of agricultural development. The development and survival of civilizations has been based on the performance of soils on this land to provide food and further essential goods for humans (Hillel, 2009). Efficient management of soil resource is a major challenge for the scientists, planners, administrators and farmers to ensure food security for the present and future generation.

Soil fertility is the inherent capacity of soil that enables it to provide essential plant elements in quantities and proportions for the growth of specified plant when other factors are favorable. Continued removal of nutrients, with little or no replacement will increase the potential for the future nutrient related plant stress and yield loss (Tisdale et.al., 2003). Both over dose and under application of chemical fertilizer to soil has negative impact on crop productivity and over dose additionally pollute the environment, so that soil fertility evaluation is the most basic decision making tool in order to efficient plan of a particular land use system (Havlin et al., 2010).

There are several techniques for the evaluation of soil fertility status. Among them soil testing is a most popular and appropriate. Soil testing provides information about their property, problems and nutrient availability (status) in soils which forms the basis for the fertilizer recommendation. Soil properties vary spatially from a small to larger area might be due to effect of intrinsic and extrinsic factors (Gambardella and Karlen, 1999). Describing the spatial variability of soil fertility across a field has been difficult until new technologies such as Global Positioning Systems

(GPS) and Geographic Information Systems (GIS) were introduced. Collection of soil samples by using GPS is very important for preparing thematic soil fertility maps (Mishra et al., 2013). Similarly, Geographical Information System (GIS) is a potential tool used for easy access, retrieval and manipulation of voluminous data of natural resources often difficult to handle manually. It facilitates manipulation of spatial and attributes data useful for handling multiple data of diverse origin (Mandal and Sharma, 2009). Based on the geo-statistical analysis, several studies have been conducted to characterize the spatial variability of different soil properties (Huang et al., 2007; Weindorf and Zhu, 2010; Liu et al., 2013). Among the different geo-statistical methods, ordinary kriging is widely used to map spatial variation of soil fertility because it provides a higher level of prediction accuracy (Song et al., 2013).

Therefore, it is important to investigate the soil fertility status and mapping their spatial distribution, thus may provide valuable information for agricultural development. However soil of Dugda were not assessed and mapped at semi detailed level survey. Hence this activity was initiated with the following objective:

- To identify and classify soil nutrient status of the study area
- To map soil fertility parameters and avail information on fertilizer application

Materials and Method

Description of the Sudy Area

The study was conducted at Dugda district, which is located in East shewa zone of the Oromia Regional State, Ethiopia, 134 km from Addis Ababa to the South direction. its geographical position is 38°- 31‘ E to 38° 57' E longitude ,8° 01' N to 8° 10' N latitude. And its altitude was 1600- 2020 masl, its map is indicated below.

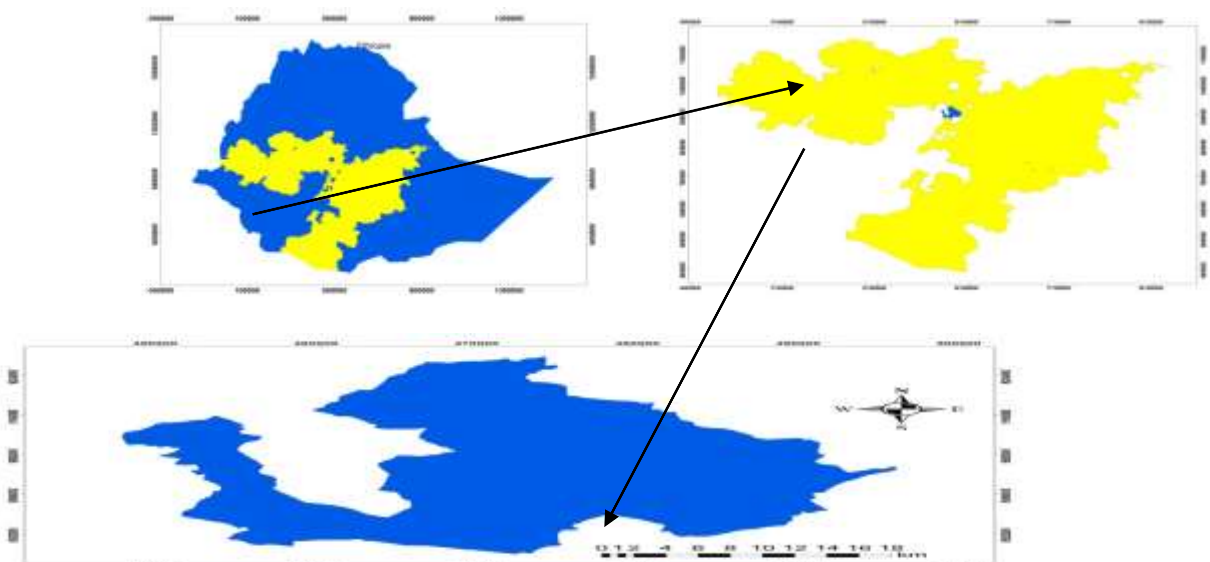

Figure1: location map of Dugda district

Soils Types

In Dugda district ,about seven dominant soil types exist, namely Luvic Phaezomes , Chromic Verticsols , Vitric Andosols , Lithosols , Eutric Fluvisols , Vertic Cambisols, and Eutric Cambisols,.

Topography

Topography is one of the soil forming factors influencing the characteristics of soil in the given area. Both slope and elevation of the study area are generated from digital elevation model by using ArcGIS10.3spatial analyst of surface analysis. And its elevation ranges from 1601 to 3170 m above sea level.

Mapping Unit Preparation and Soil Sampling

In order to delineate mapping units, the soil forming factors such as parent material, topography, climate, geomorphology and land use were considered digitally by spatial tools to categorize areas having similarly properties. Based on these factors 124 mapping units were prepared and 124 soil samples (one composite soil sample from each mapping units) (at 0-20cm depth) were collected during 2014/2015, registering their geographical location of each sampling point using GPS.

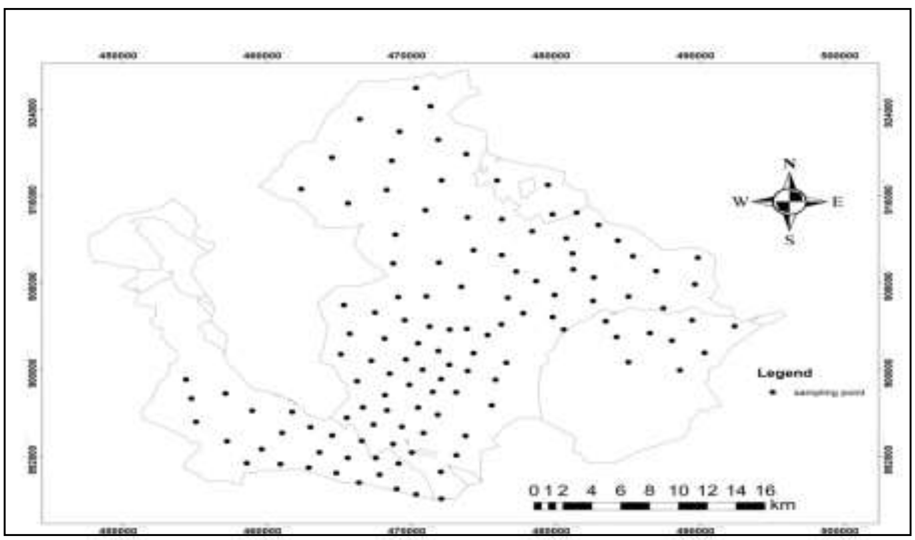

Figure 2: map of soil sampling points

Method Followed

Both statistical evaluation and geospatial evaluation were conducted. Then at the end of the activities fertility map was prepared for total nitrogen, organic matter, available phosphorous, exchangeable sodium, magnesium, potassium, CEC and soil pH. The analyses of these parameters were done in Batu soil research center soil laboratory the following methods listed in the table below (Table 1).

Table: tested parameters

No	Soil parameters	Method of Analysis
1	Texture	Hydro meter
2	Bulk density	Gravimetric(oven dry)
3	pH	pH-meter
4	CEC	By Ammonium Acetete
5	EC	EC-meter
6	TN	Kjeldhal Method
7	K, Na	Flame Photometer
8	Ca, Mg	spectrophotometer
9	Av.P	Olsen et al (1954)
10	Organic carbon(OC)	Walkey & Blank method

Having soil composite sample laboratory analysis results, rating(very low, low, medium , high and very high) of parameters determined values were made based on rating standard sated by Booker(1991) ,Tekilign(1991), FAO (2006) and Hazelton and Murphy(2007). Likewise, ARC map10.1 with geostatical analyst extension of ARC GIS software was used to prepare spatial distribution map of soil parameters, while interpolation method employed was ordinary king stable.

Result and Discussions

The soil fertility distribution of the district was assessed with respect to soil texture, pH, organic matter, exchangeable sodium, potassium, Cation exchange capacity (CEC), available Phosphorous, total nitrogen and organic matter content .The results obtained are presented and discussed in the following headings.

Soil Texture

Soil texture plays important role for drainage, water holding capacity, aeration, susceptibility to erosion, organic matter content, cation exchange capacity, pH buffering capacity and soil tilth (Berry et al., 2007). The sand content of samples ranged from 82 to 26% with a mean of 54% and that of silt content were 52to 12% with a mean of 32%, while the range of clay content was 6to 44% with a mean of 25% (Table 1). The study area dominated by loam and sandy loam soil texture, with an area of 68.55%and 25.80% respectively ,where as reaming 5.65% covered by clay loam and silt loam . Among the observed soil texture (loam, silt loam) had proper water and nutrient holding capacity; hence suitable for most of the crops. Panda (2010) reported medium textured soils like loam and silt loam are considered suitable among all the soil texture for most of the crop.

Table 2. Soil texture status of the study area

Discriptive satatistic	Soil separates		
	Sand %	Silt %	Clay %
Maximum	82	52	44
Minimum	26	12	6
Mean	54	32	25
Class	sandy loam	loam, silt loam	clay loam
Area coverage %	25.80	70.17	3.3

Soil pH

Soil pH is one of the most important characteristics of soil fertility, because it has a direct impact on nutrient availability and plant growth (Brady and Weil, 2002). The soil pH varied from 6.23 to 9.10. According to FAO,(2006) soil rating study area are classified into slightly acidic ,neutral, slightly alkaline , strongly alkaline and very strongly alkaline, with an area coverage of 5%, 13.64%, 20.18%, 24.24%, and 36.93% respectively. Most of plant species prefer pH range from 5.5 to 6.8 (Amacher., 2007) absence of free exchangeable AL in this range ,only 18.64 % of the pH of the soils in the study area could be considered as suitable for most of crop production (Figure 3).

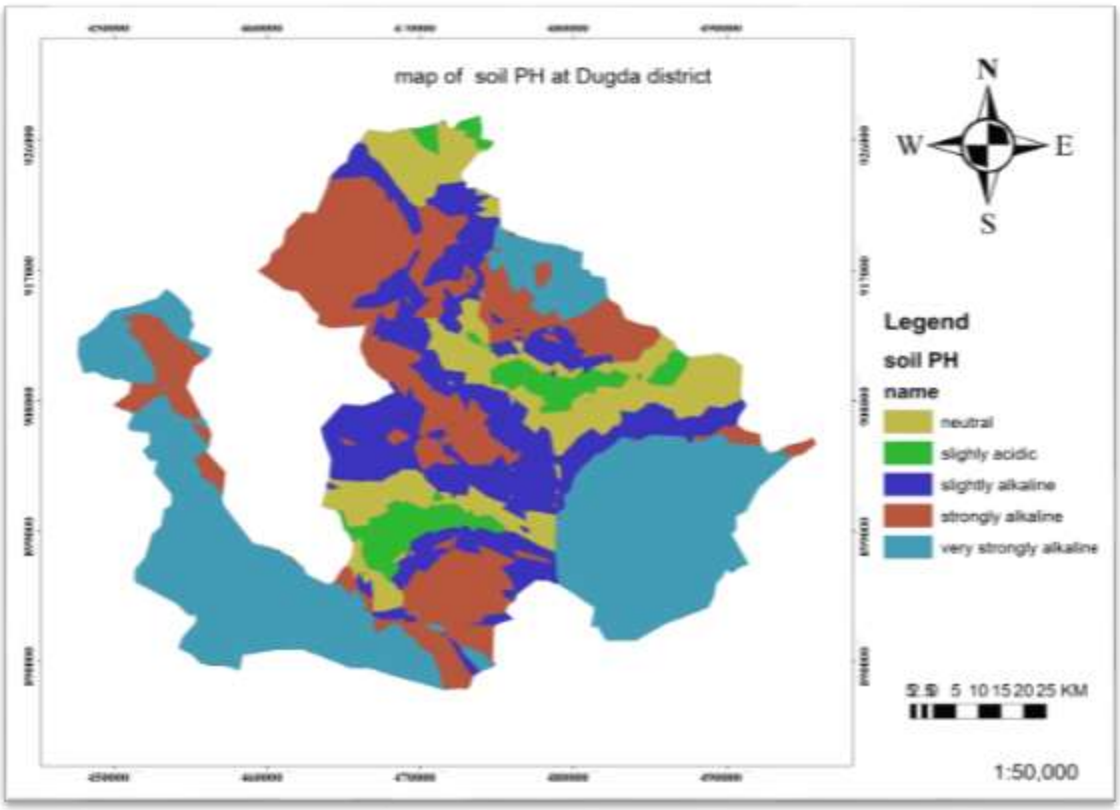

Figure 3: map of soil pH at Dugda district

Available Phosphorus

Phosphorus is the second most limiting nutrient after nitrogen, and has negative impacts on crop yield if found to be deficient (Sharma et al., 2017). The available phosphorus varied from 5.10 ppm to 26.98ppm. According to booker (1991) soil rating system, study area has two classes of available phosphorous namely, medium and high available phosphorous. Accordingly 65% study area has medium available phosphorus, were as reaming 35% classified as high available phosphorous (Figure 4). Phosphorus deficiency in Ethiopian soils is well documented in various research works (Melese et al., 2015; Daniel and Tefera, 2016; Kebede et al., 2017). On top of the inherent low occurrence of P, its availability is limited by strongly acid characteristics of the soils in the high land part of the country.

Medium available phosphorous in the study area might be attributed by medium organic matter content (figure 5)in the study area as well as existence of soil disturbance for cultivation in the area .Similarly,Tekilign and Haque (1987) reported that organic matter as main source available phosphorous and its availability decline by impacts of fixation ,intensity of disturbance ,soil erosion and crop harvest . Howe ever higher content of available phosphorus in some part of study area might be due to the continuous application of phosphates' fertilizers namely di-ammonium phosphate (DAP) and Recently NPS for every crop without knowing phosphorus supplying capacity of soil ammonium. The result was in agreement with Taddesse et.al (2012) finding who reported that high concentration of available phosphorous is due continuous use phosphate fertilizer without knowing capacity of soil to supply nutrient (phosphorous).

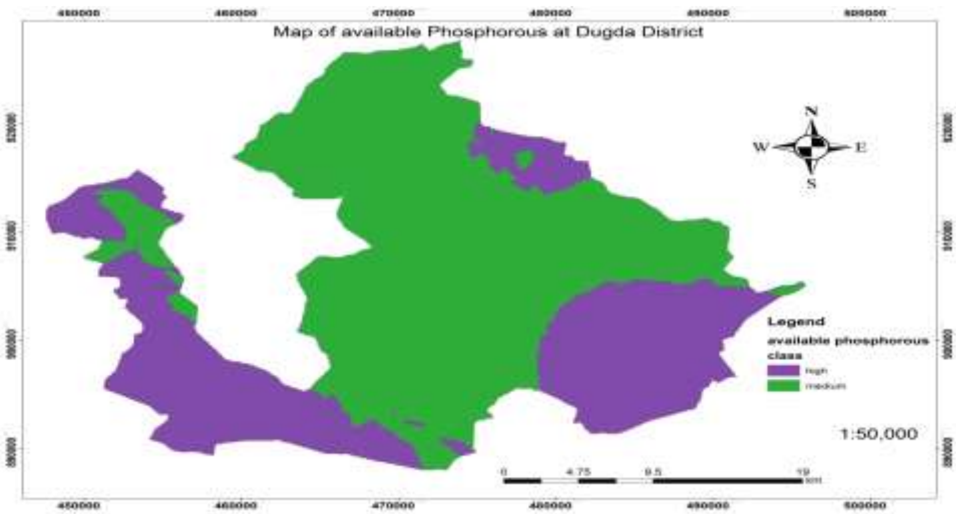

Figure 4: map of available phosphorous at Dugda district

Organic matter

Organic matter is a vital parameter for making soil alive, because it improves different physical, biological and chemical properties (Hoyle et al., 2011; Alabandan et al .,2009) .The value of organic matter of analyzed representative soil sample ranges from 0.92% to 7.89% . According to rating sated Tekalign (1991) the study area has low, medium and high organic matter (Figure 5). It's dominated with medium organic matter with area coverage of 47.67% and the remaining covered by low and high organic matter with area coverage of 35.74 % and 16.53 % respectively. low organic matter in some part of study area might be due low incorporation of organic matter such as : organic manure, green manure ,compost ,animal dung, excessive tillage, low biomass availability, as well as removal crop residue for livestock feed and fuel . The result was in line with Tegenu .,et.al (2009) finding who reported that low organic matter content in North - West Ethiopia. The adequate incorporation of organic manure, vermin-compost, green manure and adoption of resource conservation technology during cultivation is important for organic matter improvement in the study area.

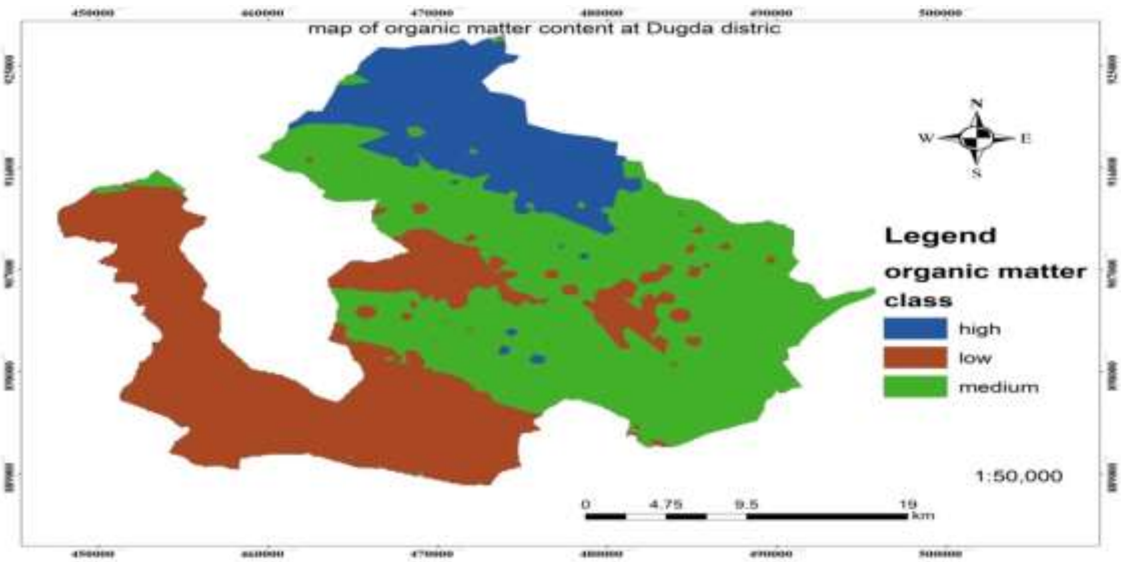

Figure 5: map of organic matter content at Dugda district.

Cation Exchange Capacity(CEC) of Soil

CEC is a measure of the soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilizers and other ameliorants (Hazleton and Murphy 2007). Soils with a higher clay fraction and organic matter tend to have a higher CEC. According FAO (2006) soil rating system study area has low, medium and high CEC, with area coverage of 11.48%, 45.11% and 43.40 % respectively (Figure 6). Relatively medium organic matter (Figure 4) the study area may attributed medium CEC. Soils with Low CEC are more likely develop defiency in basic cation, mainly K^+ , Mg^{++} and other cations ,which are susceptible to leaching ,while soils with high CEC less susceptible to leaching (CUCE,2007). Were as, low CEC in the study are might due to intensive cultivation, low clay fraction (table2) and nature of soil in the study area. The result in line with Alemayehu (2007) reported that depletion of OM as a result of intensive cultivation contributed to lower CEC of the soils.

Total Nitrogen

The total nitrogen ranged from 0.04% to 0.24% with a mean of 0.14%. Based on the rating set by Tekalign (1991), study area has low, medium and high total nitrogen, with an-area coverage of 9.88%, 72.38% and 17.74% respectively (Figure 7). There is a strong relation between organic matter and total nitrogen in the soil system; hence domination of medium organic matter content (Figure 4) in the study area can cause medium total nitrogen in this area. Were as low total nitrogen in some part of study area might be due to inadequate supply of respective inorganic as well organic fertilizer .Moreover, the low organic matter status in some part of study area might also be the cause of low total nitrogen. In agreement with this result, Meysner et al. (2006) indicated that as much as 93% to 97% of the total nitrogen in soils is closely associated with organic matter.

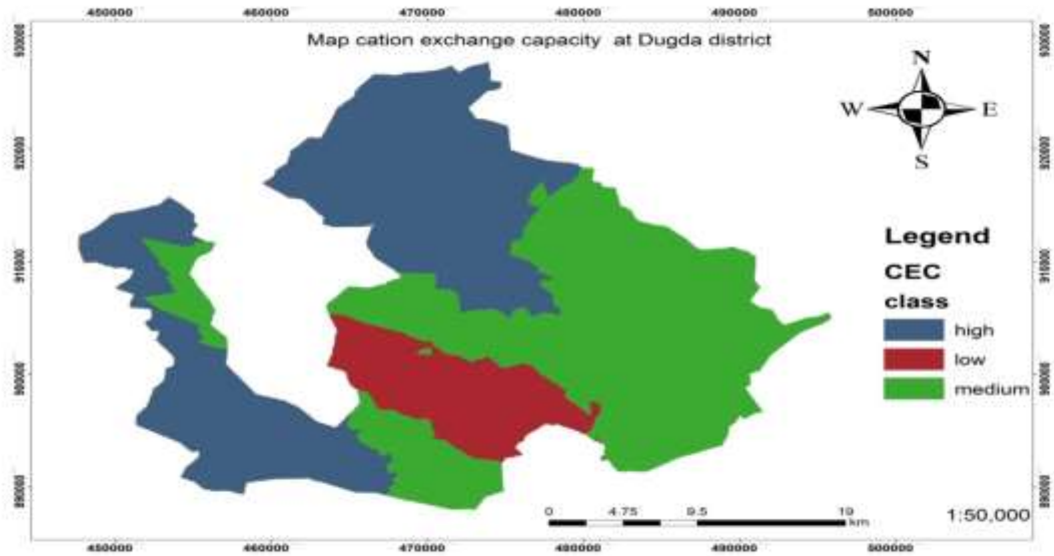

Figure 6: map of CEC at Dugda district

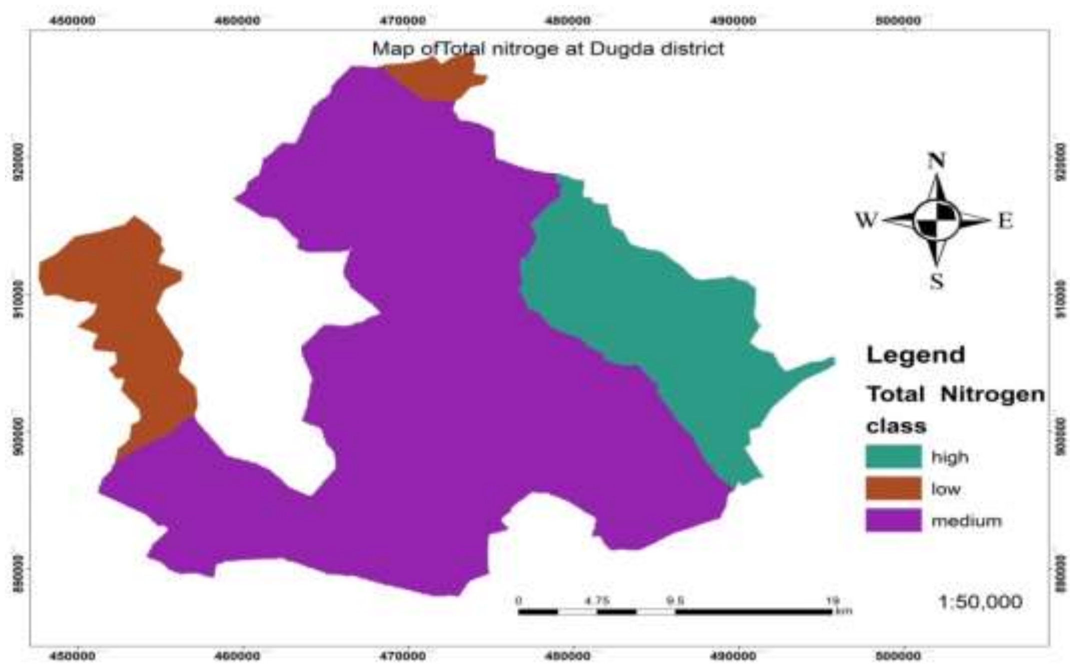

Figure 7: Map of soil total nitrogen at Dugda district

Exchengable Magnisium

Magnesium is the central core of the chlorophyll molecule in plant tissue. Magnesium is held on the surface of clay and organic matter particles. Exchangeable form of magnesium is available to plants; this nutrient will not readily leach from soils, which contributes high concretion in soil. According to Hazleton and Murphy (2008) soil rating system study area has low, medium, high and very high exchangeable magnesium. About 70.73% of the study area belongs to medium exchangeable magnesium. This might due nature of soil, medium organic matter content (figure 4) and medium CEC (figure 5) in the study area. Soils with Low CEC are more likely develop defiency in basic cation, mainly K^{+} , Mg^{++} and other cations ,which are susceptible to leaching ,while soils with high CEC less susceptible to leaching (CUCE,2007). Were as high exchangeable magnesium in some part of study area might be, due to leaching of basic cation from high altitude low altitude and their subsequent accumulation at lower part. The result in line with fiding T Lawal et al.,(2013) which states that the high content exchangeable magnesium on the surface horizons across the landscape may be due to the lateral movement of the ion from the upper slope to the toe slope .

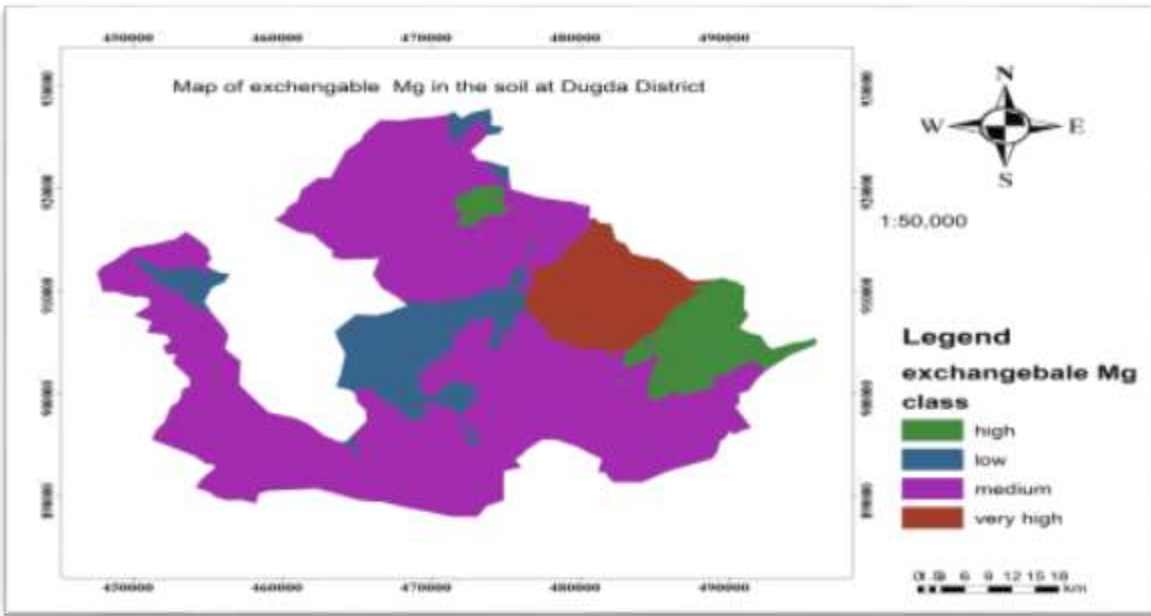

Figure 8: map exchangeable magnesium at Dugda district

Exchangeable Sodium

The exchangeable sodium ranged from 0.015 to 2.32cmol$_c$ kg-^{1}with a mean of 2.0702cmol$_c$ kg-^{1} . Based on the rating set by Hazelton and Murphy (2007), exchangeable sodium classified as very low, low, medium, high and very high with an-area coverage of 1.3%, 2.53%, 35.18%, 43.92% and 17.05 %respectively (Figure 9).

Exchangeable Calcium

The exchangeable calcium ranged from 1.25 to 18.55cmol$_c$ kg-^{1}with a mean of 9.90cmol$_c$ kg-^{1}. Based on the rating set by Hazelton and Murphy (2007), exchangeable calcium classified as very low, low, medium, and high (Figure 10) with an-area coverage of 0.24%, 43.91%, 55.63%, and 0.22%, respectively

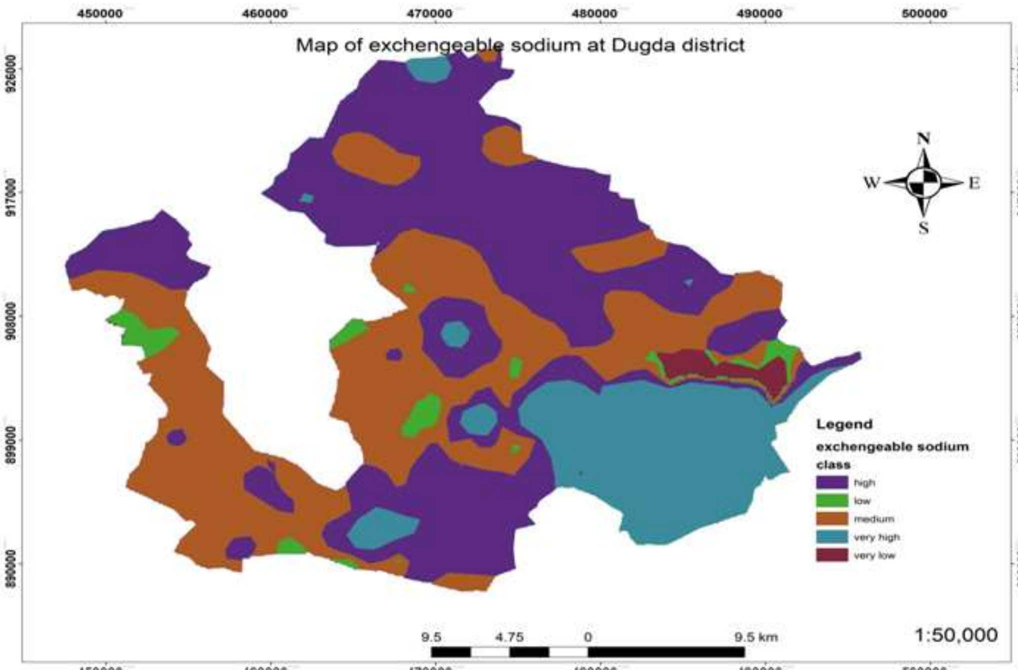

Figure 9: map exchangeable sodium at Dugda district

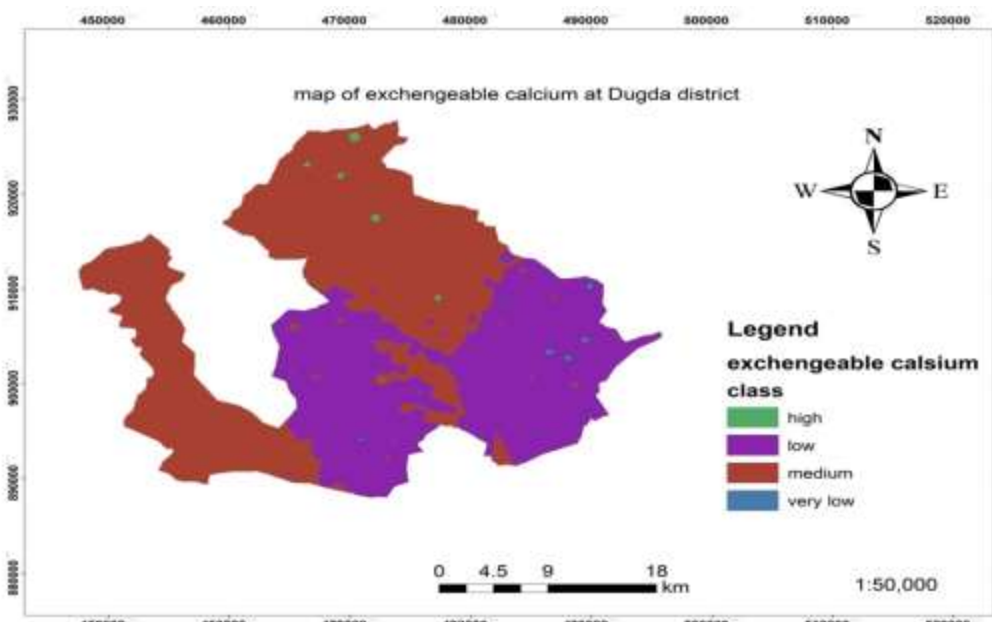

Figure 10: map exchangeable calcium at Dugda district

Conclusion and Recommendation

Soil fertility map shows plant nutrient status in the soil and useful for decision making on, fertilizer type and rate, as well as for designing appropriate soil fertility management practices. Based on the study has been done on soil fertility assessment and mapping, nine soil fertility parameters were accessed and mapped for Dugda district. Accordingly 63.10% of study area has medium available phosphorus (5-15ppm) and 78.77% of study area has medium (1-3%) organic matter. More over study area has three classes of CEC, namely, low, medium and high, were as exchangeable calcium and sodium categorized a very low, low, medium, and high, besides exchangeable sodium additional classified as very high based on Hazelton and Murphy (2007) soil rating system. Finally, exchangeable magnesium classified as very low, low, medium, high and very high on similar classification basis.

From this study we conclude that soil fertility parameters, within each district shows heterogeneity for all nutrient assessed. Finally based on these results, the following recommendation is given for decision makers, researchers and other stake holders that this soil fertility map can be used as information source regarding soil fertility management in the district. Moreover, further correlation and calibration of soil test data with plant response is recommended for site–soil–crop specific fertilizer recommendation with appropriate rate.

Acknowledgment

The authors would like to thanks Oromia agricultural research institute(IQQO) for financial, logistic , and material support during activity implementation, I provide special thanks to all researchers, field assistance ,laboratory technicians and support staff of Batu soil research center for their contribution.

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Soil Fertility Assessment and Mapping at Dama District, Guji Zone, Oromia Ethiopia

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Abstract

Soil fertility assessment and mapping is the way of assessing soil nutrients on the basis of soil sample test results and preparing maps at required scale. The study tried to map the some plant nutrients phosphorous, organic carbon and other soil fertility indicators (pH, EC, CEC) for Dama district, Ethiopia. About 135 soil samples were collected and used to map the whole study area. For every soil parameter analysis standard laboratory analysis were followed. In order to predict values for not sampled locations the Ordinary Kriging interpolation was used by ArcGIS10.3 software. The district has three categories of soil pH but the majority of the area falls in strongly acidic. The available phosphorus level is categorized low, medium and high which is 4.44%, 93.33% and 2.22%, respectively. The dominating class is medium. Soil Electrical Conductivity was ranged from 0.049 to 0.675 mmhos/cm at 25^{o}C i.e. salt free. Soil Organic matter ranges from 0.95% to 10.09% that is from low to high in rating classes.

***Keywords**: ArcGIS, Soil fertility assessment, Soil fertility Map*

Introduction

Soil fertility is considered as a key factor for agricultural and ecosystem function because soil is essential to support and sustain vegetation and helps to maintain other natural resources such as water, air, wildlife habitat and also minimize wastage of the nutrients, thus minimizing impact on environment leading to bias through optimal production (Patel and Lakdawala, 2014). Ensuring food security for the ever-increasing world population has direct relation with fertility and productivity of soils. Soil with sufficient plant nutrient is the most valuable natural resources of land which plays critical role for sustainability of agricultural products. This indicates that the overall productivity and sustainability of a given agricultural sector is highly dependent up on the fertility and productivity of soil resources (Sanginga and Woomer, 2009). The implications are that the overall productivity and sustainability of a given agricultural sector are functions of fertile soils and productive lands. Soil fertility depletion is the fundamental biophysical cause for declining per capita food production in Sub-Saharan African countries in general (Sanchez, 2002; Vanlauwe *et al.*, 2010). Soil fertility decline has been one of the most challenging and limiting factors for food security in the country (MoARD, 2010). As a result, many people have suffered from food insecurity and associated health problems due to malnutrition (Gete *et al.*, 2010).

The primary cause of soil fertility decline include loss of organic matter(OM), macro and micronutrient depletion, soil acidity, topsoil erosion and deterioration of physical soil properties (IFPRI, 2010). In addition, salinity is also a major problem in the country. Low soil fertility is also common for SSA countries (Betiono *et al*., 2006; Sommer *et al*., 2013) in which soil fertility is constrained by soil erosion, inherent fertility problem, continuous and long term cultivation and inadequate fertilizer applications. Hence, soil fertility depletion is considered as the fundamental biophysical cause for declining per capita food production in SSA countries in general and Ethiopia in particular (Sanchez *et al.*, 1997). The problems of land degradation and low agricultural productivity in the country, resulting in food insecurity and poverty, are particularly severe in the rural highlands (Nedessa *et al*., 2005). Studies indicated that in some parts of Ethiopia farmers suffer from lack of what to eat particularly in months starting from June up to September. Farmers in most parts of the country actually work hard, in seasons of the year when the rainfall is favorable for their cropping; regardless of their effort they get very little, which does not help them to escape their subsistence way of living. The fault with this agricultural problem is very intricate in nature, the complexity arises from various condition of the country such as the agroclimate, topography of the lands, the soil types and socio-economic status of the farming community and the combination of these; the overall effect of which is finally reflected by soil fertility decline and reduction in yield of crops (Alemayehu *et al*., 2006).

Knowledge about an up–to–date status of different soil parameters at different landscapes and mapping their spatial distribution play a vital role in site–specific fertilizer recommendation to enhance production and productivity of the agricultural sector on sustainable basis. However, information on the status and spatial distribution of soil macronutrients are limited for Guji zone. Therefore, as part of the regional initiative, this study was conducted with specific objectives to assess and map the status and spatial distribution of soil major nutrients for Dama district of Guji zone. The results of this study are expected to add value to the up–to–date scientific documentation of the status of soil fertility for regional soil atlas which is being considered the recommended fertilizer source for maximizing crop yields and further to maintain the sustainable agriculture. Although soil fertility assessment and mapping at Dama district was initiated as response of where and how to use the soil test based crop response studies results, it has more advantage than this to give information about soil fertility status of the district for different users. The objectives of the study were as follows:

- To identify and classify soil nutrient status of the study area
- To map soil fertility parameters
- To avail information on fertilizer application

Materials and Methods

Site Description

Location

This study was conducted at Dama woreda of Guji zone, in Oromia Regional State (Figure 1). Geographically, the study area is situated at 6º79’27” to 7º51’82” North latitude and 43º54’43” to 46º11’12” East longitude and is situated about 401 km south of Addis Ababa. Altitude of the whole district area is situated between 1800 and 2900 meters above sea level (m.a.s.l).

Land Use and Vegetation

Mixed crop–livestock system is the main land use system in the studied area. The major food crops grown are wheat (*Triticum aestivum* L.), maize (*Zea mays L*,), barley (Hordeum vulagare L.), faba beans (Vicia faba), field peas (Pisum stivum), enset (*Ensete ventricosum*), and other vegetables are the dominant non–food cash crops. Agriculture is entirely rain fed. There are different types of natural vegetation in the grazing and arable land including wide grazing land with waterlogged area.

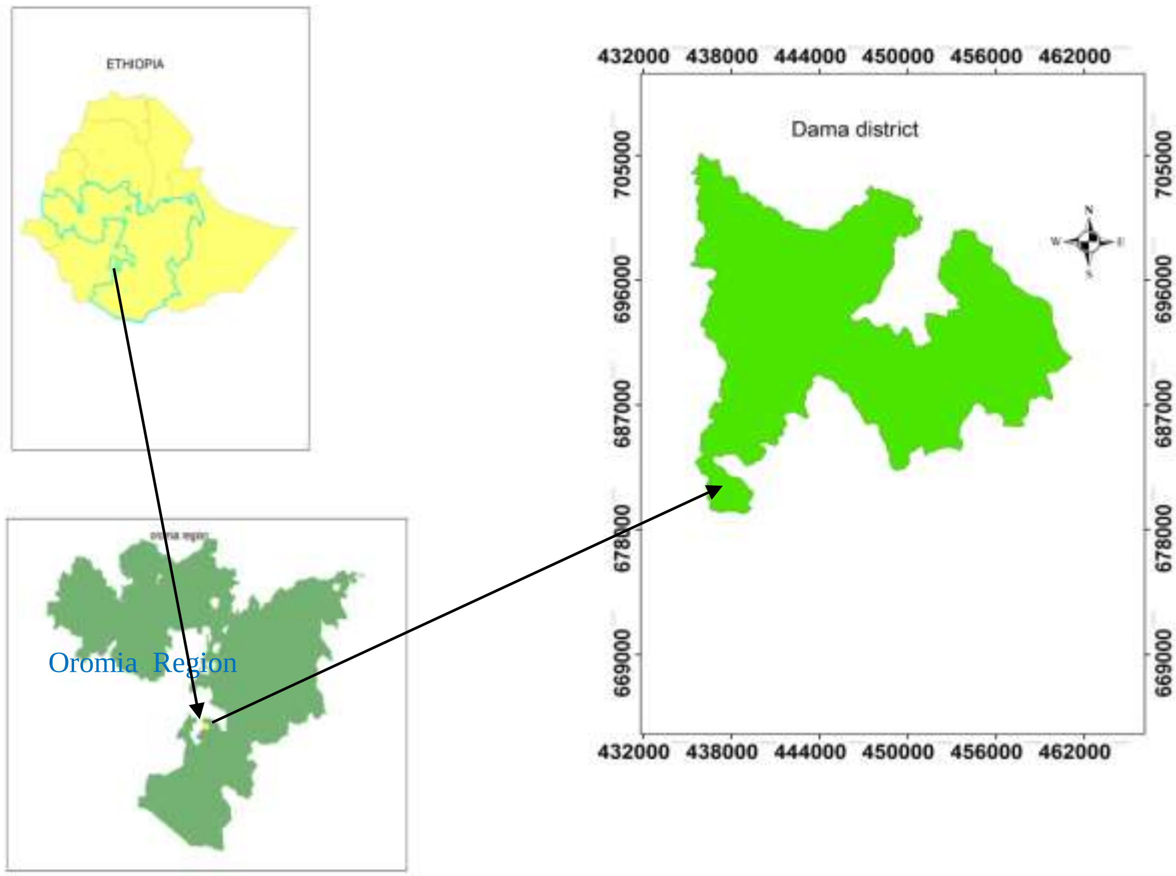

Figure 1. Location map of the study area

Soil Sampling

A composite soil sample was taken from 15-20 subsamples were augured from each possible mapping unit or uniform sampling area. The depth of Auger soil sampling was 0-20cm for every mapping unit. The sub samples were collected properly to represent the mapping units and mixed in a bucket to be homogenized and then 1kg of the composite sample was taken by quartering to laboratory.

Soil Sample Preparation

Sample preparation was conducted at Batu Soil Research Centers (BSRC), Batu, Ethiopia. The samples were air-dried and crushed using a mortar and pestle and passed through a 2 mm mesh sieve.

Soil Laboratory Analysis

Soil properties that were analyzed were texture, organic matter content, pH, ECe, cation exchange capacity (CEC), available P, organic carbon and total nitrogen were calculated using standard equations. Particle size distribution was analyzed in laboratory by the Bouyoucos hydrometer method using sodium hexameta phosphate as dispersing agent as described by Sahlemedhin and Taye (2000). Soil pH was measured in a 1:2.5 soil:water suspension potentiometrically by using pH meter and electrical conductivity of a saturated soil paste extracted (ECe) at 25^0c was determined using electrical conductivity meter. Organic carbon (OC) was determined using walkley black method. The percent soil organic matter was calculated by multiplying the percent organic carbon by a factor 1.724, considering fact that organic matter is composed of 58% carbon. Total nitrogen contents in soil was determined by using the kjeldhal procedure by oxidizing the organic matter with sulphuric acid and converting the nitrogen into NH+4 as ammonium sulphate Sahlemedhin and Taye (2000).Available p was determined using the standard Olsen extraction method (Okalebo *et al.,* 2002). Total exchangeable bases were determined after leaching soils with ammonium acetate (Thomas, 1990). Cation exchange capacity (CEC) was determined at soil pH level of 7 after displacement by using 1N ammonium acetate method in which it was thereafter, estimated titrimetrically by distillation of ammonium that were displaced by sodium as described in (Okalebo *et al.,* 2002).

Methods Followed

Selecting Uniform Sampling Area

Soil conditions are influenced by many environmental factors those could be aggravated accordingly through intervention of human beings and natural disasters, therefore while studying soil qualities including fertility status; it is important to investigate the relationship of soil forming factors and others factors. In this study as much as possible it was attempted to comprehensively investigate different factors such as topographic, land use, climate and soils of the area at required scale. The influencing factors were collected from different sources and prepared for further spatial analysis in order to produce spatial layers/ features of the study area. These factors were compared to each other and areas those have almost similar characteristics were grouped in to the same category by using GIS overlay analysis. These categories were used as mapping units and soil samples were collected from these units. Then the district was divided into 135 units.

Soil Rating

Based on Booker tropical soil manual 1991 the result of analysis of individual parameters of soils were classified into different categories, i.e. low, medium, high and very high in respect of available contents of each nutrients.

Map Preparation

After data base of samples prepared bot Statistical evaluation and geospatial evaluation were conducted. Then at the end of the activities soil Fertility map of the district was produced for total nitrogen, available phosphorous, CEC meq/100 g soil, organic matter (%) and soil pH.

Results and Discussion

Soil Reaction (pH)

The soil pH of the study area ranged from 3.5 to 6.8 with average value of 5.15. The soil pH value of the area was low and ranged from extremely acidic (pH <4.5) to neutral as per the pH rating category suggested by booker tropical soil manual (1991) (Figure 2). Thus, it is pertinent to raise the soil pH through liming to increase crop productivity in the study area.

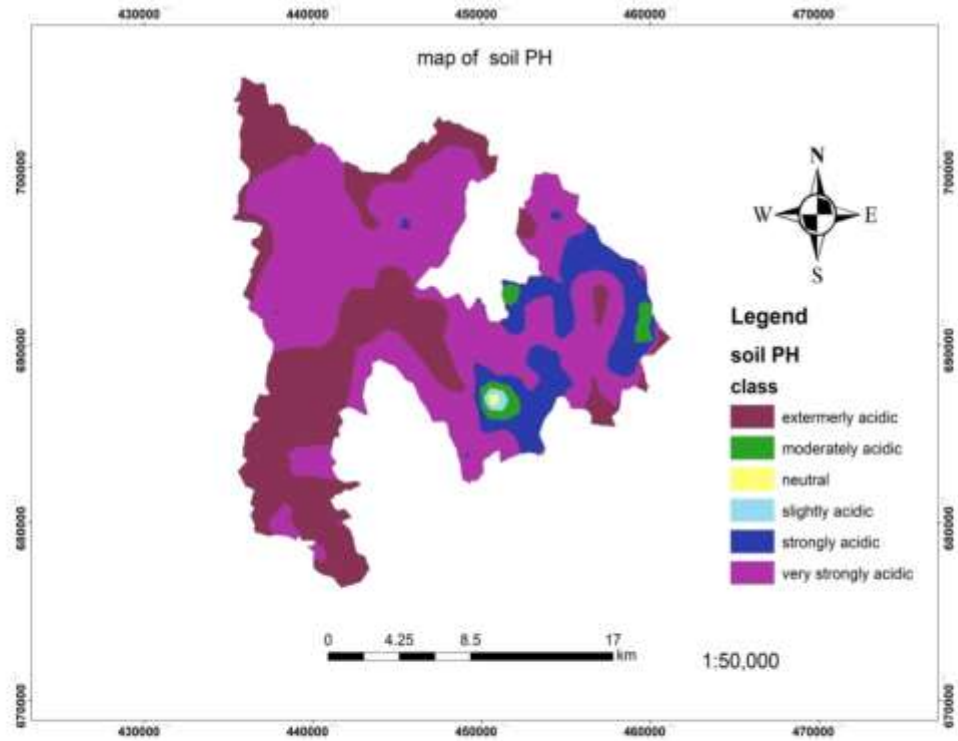

Figure 2. Map of soil pH at Dama district

The first reason for the lowest values of soil pH at the study sites may be high rainfall that results in loss of base forming cations through leaching and drain to streams in runoff generated from accelerated erosion. This enhances the activity of Al^{3+} and H^{+} in the soil solution, which reduces soil pH and thereby increases soil acidity. Although soil acidity is naturally occurring in some areas, human activity can change the pH of a soil too; agricultural practices have accelerated the process of soil acidification (Kizilkaya and Dengiz, 2010). Hence, the second reason might be continuous use of ammonium based fertilizers such as diammonium phosphate, $(NH^4)_2$, HPO_4, in such cereal based cultivated fields, which upon its oxidation by soil microbes produce strong inorganic acids. These strong acids in turn provide H^{+} ions to the soil solution that in turn lower soil pH (Abebe and Endalkachew, 2012). Moreover, long-term usage of urea, replacement of ammonium with basic cations and production of hydrogen ion during nitration process, decreases the amount of pH (Juo, *et al.*, 1996). Continuous cultivation practices, excessive precipitation and steepness of the topography could also be some of the factors responsible for the reduction of pH in soils at the middle and upper elevation areas (Ahmed, 2002). The statistical summary of the parameters are indicated in (Table 1).

Table 1. Statistical summary of the parameters

Soil parameters	pH	EC	OM	Av.P	CEC
Minimum	3.5	0.049	0.85	0.95	2.352
Maximum	6.8	0.675	10.09	30.0	50.440
Mean	5.15	0.362	6.47	15.475	26.396

Relatively the lowest electrical conductivity (0.049 mmhos/cm at 25^{o}c) was recorded for soils of soil mapping unit 24, whereas the highest value (0.675 mmhos/cm at 25^{o}c) was recorded on soil mapping unit 157. The electrical conductivity of soils of all mapping units was, however, categorized under low according to Landon (1991). The low EC value recorded for soils of the study area could be attributed to the removal of basic cations through erosion with soil and runoff from the relatively sloping mapping units and leaching down of basic cations.Generally, low electrical conductivity recorded in all the mapping units could be related to the intensive weathering associated with the high rainfall of the area, which removes basic soluble cations by leaching and/or erosion from these soils. This finding is in agreement with the work of Abebe and Endalkachew (2012) who reported that electrical conductivity of soils declined with high amount of rainfall.

Soil Texture

The soil data indicates that, According to USDA soil texture classification system, three soil textural classes were analyzed in the district. Soil textural classes of all land mapping units of the study area were loam, sandy loam and loamy sand with Sand size fraction followed by silty fraction dominates the study area. The textural classes recorded in almost all the land mapping units imply that, under natural Conditions, the soils have good drainage and this sand proportion may suggest relatively poor water retention capacity in the area.The difference in sand, silt and clay content among the land mapping units could be associated to variations in soil management practices, slope type of the area, topography and land use system of the district. In agreement with this work, Usmael *et al.* (2018) and Thangasamy *et al*. (2005) reported that variation in soil texture may be caused by variation in situ weathering, topography, parent materials and translocation of clay.

Soil Organic Matter

Similar to the other soil parameters discussed so far, the organic matter content of soils through the district showed spatial variation ranging from 1.51% to 10.09% (Table 1). Following organic matter rating suggested by Booker, 1991, the organic matter content of soils in the district ranged from low to high. The source of variation in OM contents among mapping units might be variation in altitude, intensity of cultivation, cropping system and soil management practices. The low and medium levels of OM in the soil of mapping units might be attributed to continuous cultivation with complete removal of crop residue and limited application of organic fertilizers. This was in line with the findings of several authors (Duff *et al*., 1995; Grace *et al*., 1995). The intensive cultivation is expected to aggravate rapid oxidation of the small amount of organic matter returned to soils of the cultivated land units. Furthermore, total removal of crop residues for other purposes, such as animal feed, fuel, cash, and construction, is a common practice in the study area. In consent with the findings in this study, Wakene and Heluf (2003) and Alemayehu and Sheleme (2013) demonstrated that intensive cultivation results in rapid oxidation of soil organic matter. Furthermore, the total removal of crop residues for animal feed and as source of energy was reported as being among the main reasons for low organic matter content in soils of Ethiopia by Sheleme (2011). Yihenew (2002) also confirmed that most cultivated soils of Ethiopia are generally poor in organic matter content.

On the other hand, relatively higher (high) content of OM was recorded in most mapping units (about 98%). This might be due to the fact that wide land mapping units were covered by higher vegetation, lower rate OM decomposition (high rainfall result into high plant residue in the area), fallowing activity in the study area (to solve acidity and to increase fertility of farm land) and their relatively level to gentle slope gradient where the soil moisture storage is better, resulting in better biomass production.

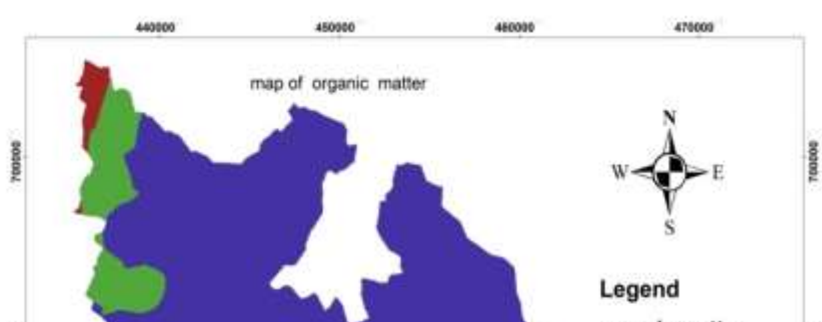

Figure 3. Map of soil organic matter at Dama district

Total Nitrogen

Similar to the other soil parameters discussed so far, the total nitrogen content of soils through the district showed spatial variation. Total N content of the soils in the study area followed almost similar trend as that of OM (figure 3 and 4).Across the soil mapping units, TN ranged from 0.205% to 0.883% (Table 1). On the basis of the rating suggested by Booker (1991), the Total N content of soils in the district ranged from low to high. The higher total N content of soils of study area could be the results of higher OM content of the area, for about 95% of the total nitrogen comes from organic matter (Landon, 1991).

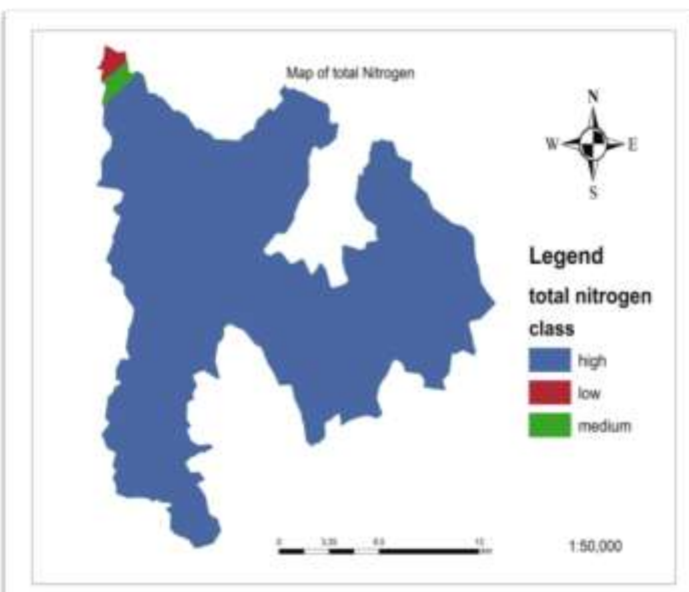

Figure 4. Map of soil Total Nitrogen at Dama district

Available Phosphorus

Among soil mapping units of the study area available phosphorus content of soils varied from 0.95 ppm to 30 ppm. The classification was made according to (Booker, 1991) that was on the basis of its suitability for agricultural production and it has three classes as indicated in (figure 5). The available phosphorus level in Dama district was categorized low, medium and High which accounts about 4.44, 93.33% and 2.22%, respectively. As per ratings set by Booker, 1991 the dominating class is medium which is 5-15 ppm of available phosphorus; this might be associated with higher organic matter content of area and accounts about 93.33% of the area where as the least dominant was high which was not more than 2.22% of the area. As information obtained from development agents and farmers the area receives higher rainfall for about two seasons with low temperature which result into low decomposition rate of organic matter and lowering of soil reaction and this low soil reaction directly affects almost all crop yields in the study area. To solve these problems the farmers of area uses fallowing system, high DAP application and others organic fertilizers like farm yard manure which might be result into higher available phosphorus in the study area. The map of the Available phosphorus for the Dama district is illustrated in the (Figure 5 below). The variability in available P contents of soils might be due to different soil management practices, specifically, inherent soil fertility status, type and rate of organic and inorganic fertilizers used in cultivated lands. Besides these factors, variation in parent material, degree of P-fixation, soil pH and slope gradient may also contribute for the difference in available P contents among agricultural soils which in line with the findings of (Usmael *et al.*,2018).

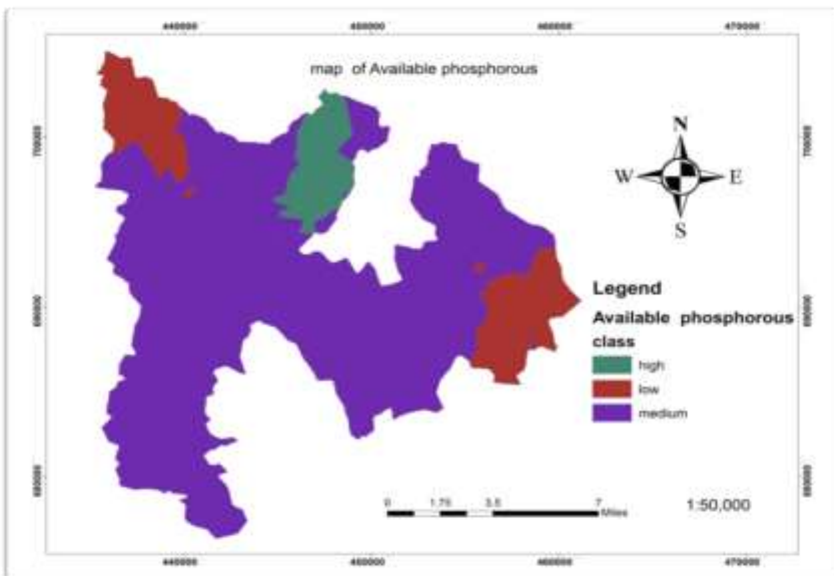

Figure 5. Map of available Phosphorous at Dama district

Cation Exchange Capacity

The CEC of the soils in the study area ranged from cmol(+) kg^{-1} soil 2.352 cmol(+) kg^{-1} soil to 50.440 cmol(+) kg^{-1} soil (Table 1).As per CEC rating indicated in Hazelton and Murphy (2007) (Appendix Table 1), the CEC of soils under the different mapping units varied from low to high. The variation in CEC values of the studied soils might be the result of observed differences in OM and soil management practices (intensity of cultivation). The intensive cultivation in the study area, for instance, might have reduced CEC indirectly through its effect on rapid oxidation of the small amount of organic matter in the soil. This result was in line with Alemayehu (2007). Also Fentaw and Yimer (2011) reported that depletion of OM as a result of intensive cultivation contributed to lower CEC of the soils.

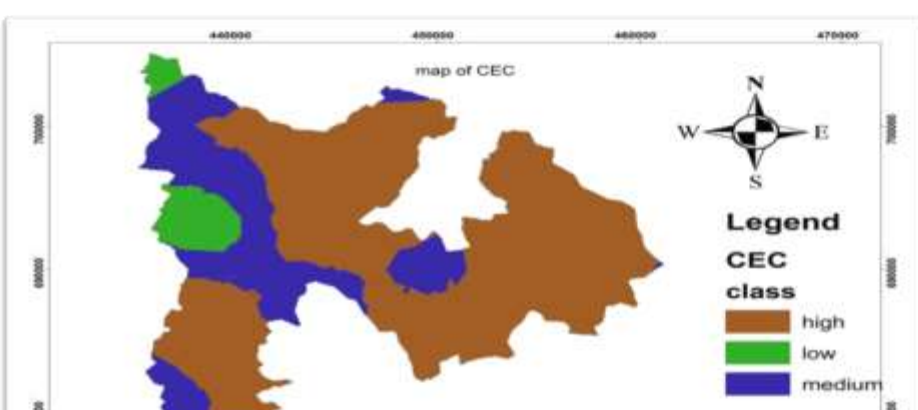

Figure 6. Map of soil CEC at Dama district

Conclusion and Recommendation

A study was undertaken to assess soil fertility status of soils of Dama district for major soil properties. Primarily field observation was undertaken in the study area. Soil color, altitude, slope gradient, topography, land use type and soil management history were used to sub-divide the district into different mapping units. Soils of the study area are loam, sandy loam and loamy sand in textural classes. Generally, sand size fraction dominated the study area.

The pH of the soil ranged from 3.5 to 6.8, indicting variation with status of extremely acidic to neutral. Therefore, appropriate rate of lime needs to be applied or cultivating acid tolerant crops is recommended for all very strongly acidic, strongly acidic and moderately acidic soils of the study area to obtain optimum crop yields. The electrical conductivity values recorded in soils under the different mapping units indicate that the soils are free from salinity problem currently and in the foreseeable future. Soil OM ranges from 1.51% to 10.09% namely from low to high. The plant available P status ranged from 0.95 ppm to 30 ppm. But most of the agricultural soils of the study area were below the optimum level mainly due to the acidity of the soil reaction. Thus, site specific organic or inorganic P fertilizer sources are recommended with lime to boost the agricultural productivity of the study areas.

Finally, further correlation and calibration of soil test data with plant response is recommended for site–soil–crop specific fertilizer recommendation with appropriate rate since soil analysis alone cannot go beyond the identification of toxicity, sufficiency or deficiency level of soil nutrients due to complex and dynamic nature of the soil.

Acknowledgment

Oromia Agriculture Research Institute deserves special thanks for the budget support provided during our study. We would also like to thank Batu Soil Research Center for providing us necessary logistics to conduct the research successfully.

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Soil Fertility Management Research

Soil Test Crop Response Based Phosphorus Calibration Study on Bread Wheat (TriticumAestivum L.) at Negelle Arsi District, West Arsi Zone, Oromia, Ethiopia

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Abstract

Soil test based crop response fertilizer recommendation for production and productivity of bread wheat is critical at Negelle Arsi district. On farm experiment was conducted at Negelle Arsi district from2015-2017 cropping seasons. The objectives of this experiment were determination of optimum nitrogen, Phosphorus critical (Pc) and requirement factor (Pf) for bread wheat at Negelle Arsi district on Mollic Andosols and Eutric Vertisols soils. On the first phase the experiment had sixteen (16) factorialcombined treatments of Nitrogen (0, 46, 69 & 92) and Phosphorus (0, 23, 46 & 92) for optimum nitrogen determination. The treatments were arranged in randomized complete block design (RCBD) with two replications. In the second phase the experiment had uniform application of Nitrogen rate and Six(6)level of phosphorus(0,10,20,30,40,50) treatments were arranged in RCBD with two Replication for phosphorus critical and requirement factor. The grain yield data was analyzed by SAS 2004 statistical software package and mean grain yield were separated by Fisher LSD at (α<0.05). Analysis of variance revealed that there were highly significant difference at p<0.05. Maximum grain yield was recorded on the application of 46N kg ha^{-1}and 69Nkg ha^{-1} on Mollic Andosols and Eutric Vertisols, respectively. Whereas minimum grain yields was recorded on control plots of both Mollic Andosols and Eutric Vertisols. The partial budget analysis was computed and economical optimum nitrogen fertilizer was identified for wheat crop of the district. Therefore economically optimum nitrogen (N) fertilizer will be 46N kgha^{-1} and 69Nkgha^{-1} at 856.7% and 2256.7% MRR for Mollic Andosols and Eutric Vertisols respectively. On the other hand, the determined phosphorus critical (Pc) and phosphorus requirement factor (Pf) was 18ppm and 3.63 for Mollic Andosols, while18ppmand 4.72 for Eutric Vertisols, respectively for bread wheat crop production at Negelle ArsiDistrict. Therefore, Pc and pf obtained for Mollic Andosols and Eutric Vertisols for bread wheat will be verified and used for fertilizer recommendation guide line for Negelle Arsi district.

Keywords: *Optimum Nitrogen; Phosphorus critical, Phosphorus requirement; MRR; Mollic Andosols; Eutric Vertisols.*

Introduction

The population of Ethiopia is currently growing at a faster rate that demands an increased proportion of agricultural products. On the other hand, growth in food production is not in equal footings because of high nutrient loss due to different factors.According to Stoorvogel *et al*. 1993 annual nutrient depletion due to erosion was estimated 47Nkg/ha from agricultural land and similarly Scoones and Toulmin, 1999 nutrient like Phosphorus 6.6 kg/ha and Potassium 33.2 kg /ha were lost due to mismanagement of agricultural lands. Now a day the small holder farmers have been applying sub optimal levels of mineral fertilizers (Mwangi, 1995).

However, profitable crop production requires adequate levels of nitrogen, phosphorus (P) and other nutrients. So, a sound soil test calibration is essential for successful fertilizer program and crop production. That means, fertilizer recommendation based on soil test crop response for economic crop production should be both soil and situation (agro ecology) specific. Based on this concept, soil test crop response p-calibration study was made on bread wheat at Negelle Arsi district on *Mollic Andosols* and *Eutric Vertisols* having objectives to determine optimum nitrogen, phosphorus critical and requirement factor.

Materials and Methods

Description of the Study Area

The study was conducted in bread wheat growing area of Negelle Arsi district, West Arsi zone of Oromia regional state. Geographically, the area issituated$7^0$25´ to 7^0 40´N and 38° 47.7' to 38° 44.3' E south to Addis Ababa, the Capital of Ethiopia(Figure 1). The district is part of the Ethiopian central rift valley, covering an area of 1400 km^2 (Efrem Garedew *et al*., 2009). The topography of the area is flat to undulating. The average elevation 1913 m.a.s.l and the annual rain fall varied from 500-1000mm.The average annual temperature varies from 14 – 25 ^{0}C. More over the area is classified under bimodal rain fall distribution, i.e., in the period of July to October (wet season) and March to June (small rain season). According to FAO soil classification also, *Mollic Andosols* and *Eutric Vertisols* are the major soil types of the area

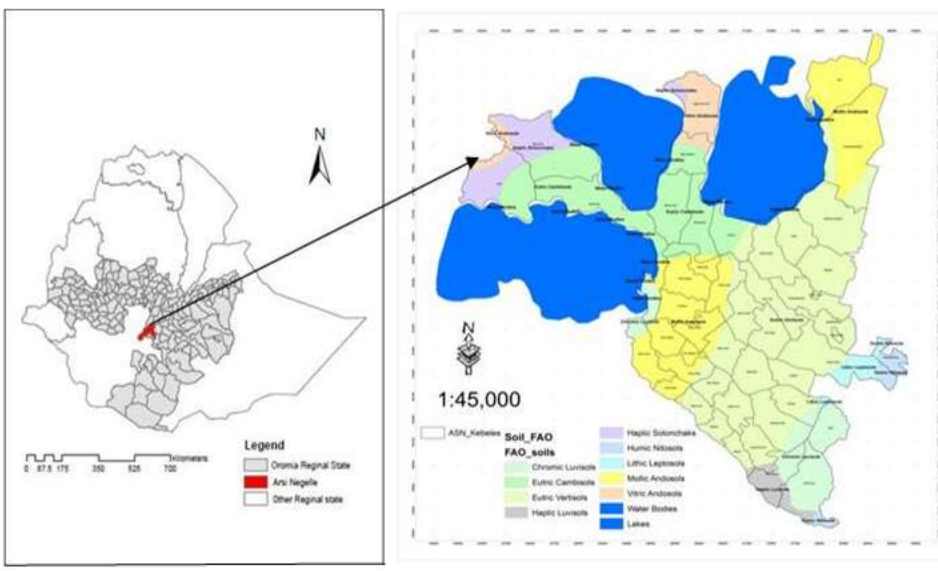

Fig 1: Description of study sites

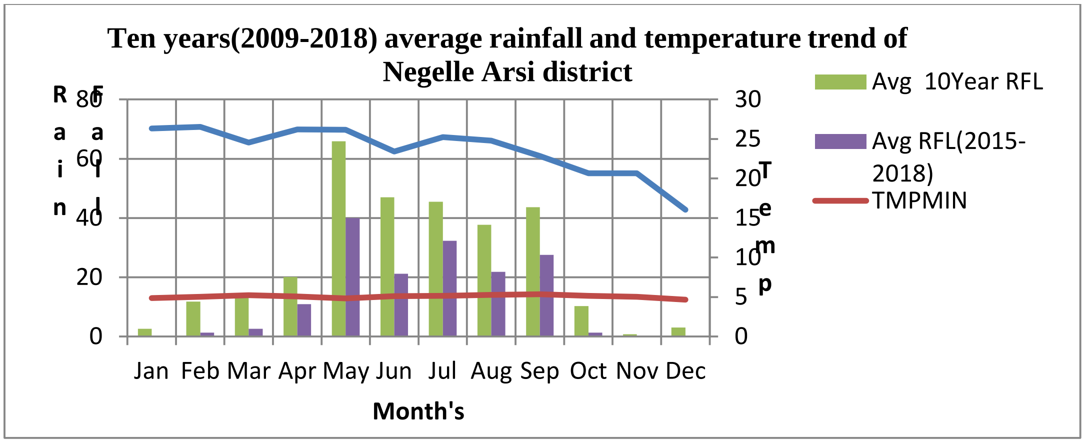

Figure 2: Rain Fall and Temperature trend of Arsi Negelle

Soil Sampling and Site Selection

For selecting representative experimental sites, a total of six (three sites for *Mollic Andisols* and three sites for *Eutric Vertisols*) composite soil samples were collected from both *Mollic Andosols* and *Eutric Vertisols* of farmer's field. Based on available soil phosphors, sites were categorised to medium and high soil p groups and selected depending on the accessibility of the management for the optimum nitrogen determination for the first year.

In the second and third consecutive years (2016-2017) randomly forty-one sites were selected for phosphorus critical and phosphorus requirement determination for *Mollic Andosols* and *Eutric Vertisols*. Composite soil samples were collected from each site by using soil auger from a depth of 0-20cm. All Soil samples were air dried, ground and passed through 2mm Sieve at Batu Soil Research Center.

Treatments, Experimental Designs and Procedures

The treatments considered for Optimum nitrogen determination were four levels of 'nitrogen (0, 46, 69 & 92) and phosphorus (0, 23, 46 & 92) levels of fertilizer included in the treatments.The treatments were arranged in factorial combination of complete block design with two replication. Treatments considered for phosphorus critical and requirement factor determination were six level (6) of P (0, 10, 20, 30, 40, 50) and 46 N Kg/ha, 69N Kg/ha for *Mollic Andosols* and *Eutric Vertisols*, respectively. Treatments were arranged on single factor Complete randomize block design with two replication.

Soil Analysis

Soil available phosphorus was analyzed using 0.5M ($NaHCO^3$) extraction solution (pH =8.5) following the method of Olsen *et al*., (1954).

Determination of Critical P Concentrations

Critical phosphorus concentration is below which there were a response while above phosphorus was not respond. Intensive composite soil samples were collected after 21 days of planting. At this time the applied phosphorus was ready to be utilized by crop. Critical P value (mg/kg) has been determined following the Cate-Nelson graphical method where soil P values were put on the X-axis and the relative grainyield values on the Y-axis.

$$\text{Relative grain Yield \%} = \frac{\text{Yield}}{\text{Maximum Yield}} * 100$$

The Cate-Nelson graphical method was dividing the Y axis and X axis scatter diagram into four quadrants and maximizing the number of points in the positive quadrants while minimizing the number of points in the negative quadrants (Nelson and Anderson, 1977).

Determination of Phosphorus Requirement Factor

Phosphorus requirement factor (Pf) is the amount of Phosphorus in kg needed to raise the soil P by 1ppm. Average of Olsen P-ppm after 21 days of each applied P-treatment and Phosphorus increase over the control were calculated. Finally Pf (phosphorus requirement factor) was determined by the following formula.

$$\mathbf{Pf} = \frac{\mathbf{Kg\ P\ applied}}{\mathbf{\Delta\ Soil\ P}}$$

Statistical Analysis

Yield and soil available data from all sites were managed on Excel soft ware. The collected data were subjected to analysis variance (ANOVA) using the General Linear Model (GLM) procedures of SAS software (SAS, 2002). Mean comparison of treatments were performed using Fisher's least significant difference test at $p<0.05$ probability level.

Economic Analysis

To identify the economic significance of the treatments, partial budget analysis was employed and calculates the marginal rate of return (MRR) (CIMMYT, 1988).Since the treatments are significance, economic analysis was done for nitrogen and phosphorus fertilizers. The grain yield was adjusted by 10% to reduce the exaggeration of small plot management.

The farm gate price was estimated to be 7.5ETB Kg^{-1} for bread wheat grain during harvesting in Negelle Arsi on November, 2018. The cost of fertilizer at local market on June, 2018 (Urea and NPS/DAP 12.47ETB Kg^{-1} and 15.12ETB Kg^{-1}, respectively).Transport, broad casting, harvesting and bagging cost was estimated 5Birr Kg^{-1} for study area. To use the marginal rate of return (MRR) as a basis for fertilizer recommendation, the minimum acceptable rate of return (MARR) was set to 100% (CIMMYT, 1988). Treatments below MARR that was dominated not included in the partial budget analysis (Table 4 and 5).

Results and Discussion

Soil Available Phosphorus

Initial soil available phosphorus values of *Mollic Andosols* and *Eutric Vertisols* are presented in Table 1. According to Booker, (1991), available soil phosphorus was categorized under medium to high rate.

Table 1: Initial soil phosphorus values of the experimental sites, Negelle Arsi District

Sites	Soil Type	Av.p(ppm)	Category
1	Mollic Andosols	14.76	Medium
2	Mollic Andosols	9.88	Medium
3	Mollic Andosols	16.70	High
4	Eutric Vertisols	10.82	Medium
5	Eutric Vertisols	13.00	Medium
6	Eutric Vertisols	18.00	High

Sites1= Mr. Tamiru Basore; 2= Mis. GadisseArarso; 3= Mr. Dadi Buta; 4= Mis. Ashu Bulo; 5= Mis. AyumaBariso; 6= FTC Meko Oda

Grain Yield as Influenced by the Treatments on *Mollic Andosols* and *Eutric Vertisols*

The analysis of variance showed that there were significance difference ($p<0.05$) among treatments application on both soil types (*Mollic Andosols* and *Eutric Vertisols*). The highest grain yield was obtained on the application 69N kg/ha; 92P p_2O_5 kg/ha, 69N kg/ha; 0P P_2O_5kg/ha on *Mollic Andosols* and *Eutric Vertisols*, respectively. Minimum grain yield was obtained on the control plots on both soil types (Table 2 and 3). Application of nitrogen fertilizer increased wheat grain yield, up to 27% on *Mollic Andosols* over the control whereas 35% yield increment on *Eutric Vertisols* (Table3).

In addition, the statistical analysis showed that an increasing order of mean grain yield, with an increase of NP fertilization from no application to the highest required level for *Mollic Andosols* and *Eutric Vertisols* (Table 2 & 3). The result was in agreement with similar studies done by Kefyalew and Tilahun (2018) at Lume district for bread wheat on *Eutric Vertisols*.

Table 2: Mean grain yield of bread wheat crop as influenced by nitrogen and phosphorus fertilizer on *Mollic Andosols* at Negelle Arsi district

N rate (kgha^{-1})	P rate (kgha^{-1})			
	0	23	46	92
0	2685.20^{e}	2833.30^{de}	2944.40^{de}	3129.60^{bcd}
46	3154.4^{bcd}	3500.00^{ba}	3500.00^{ba}	3611.10^{a}
69	2981.50^{de}	3166.70^{bcd}	3185.20^{bdc}	3722.20^{a}
92	2963.00^{dec}	3185.20^{bcd}	3388.90^{bac}	3463.00^{ba}
LSD(<0.05)	167.3			
CV(%)	11			

** Means with the same letter are not significantly different

Table 3: Mean grain yield of bread wheat crop as influenced by nitrogen and phosphorus fertilizer on *Eutric Vertisols* in Negelle Arsi district.

N rate (kgha^{-1})	P rate (kgha^{-1})			
	0	23	46	92
0	2224.40^{def}	2671.10^{b}	2567.80^{bc}	2256.70^{ef}
46	2485.00^{bcde}	2656.70^{cb}	2408.90^{cdef}	2686.10^{b}
69	3466.7^{a}	2644.40^{bc}	2591.70^{bc}	2610.00^{bc}
92	2658.30^{bc}	2317.80^{f}	2527.20^{bcd}	2498.30^{bcd}
LSD(<0.05)	216.10			
CV(%)	5.88			

** Means with the same letter are not significantly different

Economic Analysis

Partial budget analysis revealed that 46 Nkgha^{-1} and 69 N kgha^{-1} economically feasible optimum nitrogen for *Mollic Andosols* and *Eutric Vertisols* at 856.7% (MRR) and 2256.7% (MRR), respectively (Table 4 and 5).

Table 4: Partial budget analysis of optimum nitrogen determination for bread wheat crop on *Mollic Andosols* in Negelle Arsi district

N(kgha$^{-1)}$	P(kg/ha)	AGY(kg/ha)	GFB(EB/ha)	TVC(EB/ha)	NB(EB/ha)	MRR(%)
0	0	2416.7	18125.0	1208.33	16916.67	0.0
46	0	2839.0	21292.5	2716.50	18576.00	228.2
46	23	3150.0	23625.0	3653.00	19972.00	856.7
69	23	2850.0	21375.0	4151.50	17223.50	513.4
46	46	3150.0	23625.0	4434.00	19191.00	696.5
46	92	3256.7	24425.0	6049.33	18375.67	309.2

AGYL= Adjusted Grain Yield; TVC= Total variable cost ;NB= Net benefit; EB= Ethiopian Birr; MRR = Marginal rate of return.

Table 5: Partial budget analysis of optimum nitrogen determination for bread wheat crop on *Eutric Vertisols* in Negelle Arsi district

N(kg/ha)	P(kg/ha)	AGYkg/ha)	GFB(EB/ha)	TVC(EB/ha)	NB(EB/ha)	MRR(%)
0	0	2001.96	15014.7	1000.98	14013.72	0.0
0	23	2403.99	18029.92	1983.00	16046.93	207.0
69	0	3120.03	23400.22	3505.52	19894.71	2256.7
69	46	2332.53	17493.97	4673.77	12820.21	622.9
46	92	2417.49	18131.17	5629.75	12501.43	218.7

AGYL= Adjusted Grain Yield; TVC= Total variable cost; NB= Net benefit; EB= Ethiopian Birr; MRR = Marginal rate of return.

Determination of Phosphorus Critical Concentration and P-requirement Factor

The Cate_Nelson graphical method was employed to determine phosphorus critical point for *Mollic Andosols* and *Eutric Vertisols*. Accordingly, the phosphorus critical concentration above which the response of the crop becomes minimal was 18ppm for *Mollic Andosols* and *Eutric Vertisols* (Fig 3 and Fig4). Phosphorus requirement factor is the amount of p in kg needed to raise the soil p by 1ppm for *Mollic Andosols* and *Eutric Vertisols* for bread wheat crop at Negelle Arsi district was 3.63 and 4.72, respectively(Table 6 and 7).

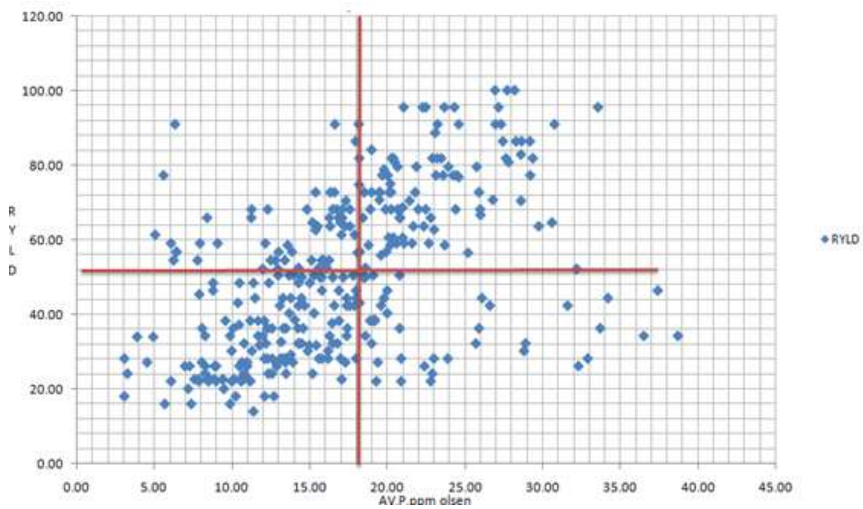

Fig 3: Phosphorus critical concentration for bread wheat on *Mollic Andosols* in Negelle Arsi district

Table 6: Determination of P requirement factor (Pf) for bread wheat crop on *Mollic Andosols*, Negelle Arsi

Fertilizer treatment kg P ha^{-1}	Olsen - P (ppm)		P increase Over control	*P requirements factor kg P^{-1} (ppm)/ Δ P
	Range	Average		
0	3.10-32.30	10.97	0	0.00
10	7.86-25.98	16.97	6.00	1.67
20	8.6-32.90	17.29	6.32	3.16
30	9.42-36.50	19.06	8.09	3.71
40	8.4-34.20	19.83	8.86	4.51
50	10.5-38.7	20.81	9.84	5.08
Mean				3.63

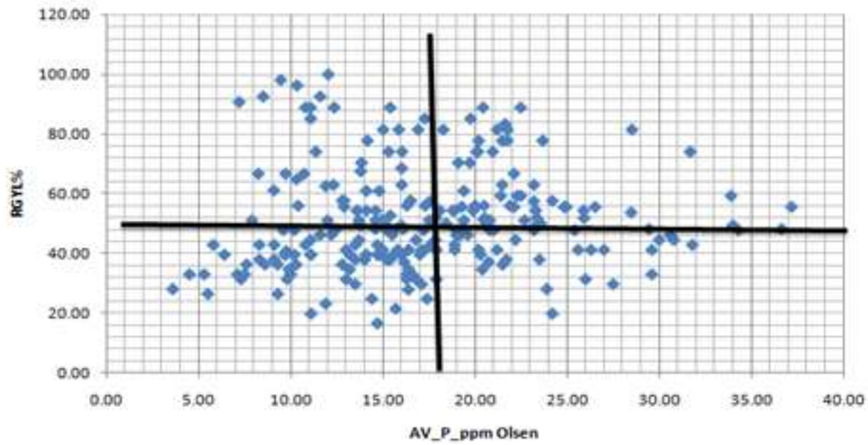

Fig 4: Phosphorous critical concentration for bread wheat crop on *Eutric Vertisols* in Negelle Arsi district.

Table 7: Determination of P requirement factor (Pf) for bread wheat crop on *Eutric Vertisols*, Negelle Arsi

Fertilizer treatment kg P ha^{-1}	Olsen - P (ppm)		P increase Over control	*P requirements factor kg P^{-1} (ppm) Δ P
	Range	Average		
0	3.60 - 15.4	11.82	0.00	0
10	7.50-27.0	15.71	3.89	2.57
20	4.50-34.30	16.94	5.12	3.91
30	6.40-34.0	17.79	5.97	5.03
40	5.30-36.64	18.82	7.00	5.71
50	5.8-37.18	19.68	7.86	6.36
Mean				4.72

Conclusions and Recommendation

Soil test based crop response phosphorus calibration study was executed on two major soil types (*Mollic Andosols* and *Eutric Vertisols*) at Negelle Arsi for the determination of optimum nitrogen, P_critica(Pc) and phosphorus requirement factor(pf). Economically Optimum Nitrogen rate determined for *Mollic Andosols* and *Eutric Vertisols* were 46N kg ha^{-1} and 69 N kgha^{-1}, respectively. While determined P-critical (Pc) concentrations and Phosphorus requirement factors(Pf) on *Mollic Andosols* and *Eutric Vertisols* for bread wheat at Negelle Arsi district were 18ppm and 3.63, and 18ppm and 4.72, respectively. Verification and demonstration of phosphorus critical(Pc) and phosphorus requirement factor(Pf) will be essential for increase confidence on the technology before scaling up to wider areas.

Acknowledgments

The authors would like to acknowledge Oromia Agricultural Research Institute (IQQO) for Financial support. Especial gratitude to all soil fertility team, laboratory technician and technical assistant of Batu Soil Research Center for their cooperation, Thank you all of Negelle Arsi Agricultural office Experts, Development agents and Farmers for your un endless support and allowing lands without incurred any cost.

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Verification of Soil Test Crop Response Based Phosphorus Recommendation for Bread Wheat (TriticumAestivum L.) in Negelle Arsi District, West Arsi Zone, Oromia, Ethiopia

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Abstract

Economic Feasibility of the phosphorus critical and phosphorus requirement factor should be verified before the wider scaling up to the end users. Based on this on-farm experiments were executed on-20(twenty) and16(sixteen) farmers' field on Mollic Andosols and Eutric Vertisols, respectively with the objective of verifying and ensuring soil test crop response based fertilizer recommendation for bread wheat production. The experiment had three treatments (Control, Blanket recommendation (farmer practice) and Phosphorus critical and Requirement factor), and laid out with simple adjacent plots and replicated over farmers. The study undertaken on Mollic Andosols revealed that, soil test based fertilizer application gave the highest grain yield of 3475 kg ha^{-1} and also enhances grain yield over blanket by 23 % while the lowest grain yield 1902 kg ha^{-1} was harvested from control plot. Similarly, on Eutric Vertisols the highest grain yield 3784 kg ha^{-1} was recorded by Soil test crop response based fertilizer recommendation and increased grain yield by 19% over blanket while the lowest grain yield 2111 kg ha^{-1} was recorded by control plot. Moreover, the Economic analysis also indicated that phosphoruscritical and requirement factor were acceptable at 284.9 and 118 %MRR on Mollic Andosols and Eutric Vertisols, respectively. Therefore, these Pc and Pf were verified and recommended for farmers of Negelle Arsi to produce and get optimum yield from bread wheat while further scaling up will be a pre request to introduce and popularize the technology to farmers of the area.

Key words: -Bread wheat, *Eutric Vertisols; Mollic Andosols; Verification Pc and Pf*

Introduction

In Ethiopia, wheat accounts the fourth level from the total cultivated area and also in production (Bekele *et al*.,2000).Fertilizer recommendations, in Ethiopia in general and Negelle Arsi district, in particular, are of blanket type that do not based on soil test results and crop requirements. Such a practice leads to inefficient use of fertilizers by the crop since the amount to be applied can be more or less than the crop requires. So site specific fertilizer recommendations are more comprehensive and beneficial since they can help to tailor fertilizer use more efficiently.

soil test calibration is specific for each crop type and they may also differ by soil type, climate, and the crop variety (Sonon and Zhang, 2014) and relates soil test measurement in terms of crop response (Bray, 1945 and Rouse, 1965) and essential that the results of soil tests be calibrated against crop responses from applications of the plant nutrients in question as it is the ultimate measure of a fertilization program. Due to this Batu Soil Research Center was recommended soil test based phosphorus critical value and p requirement factor for bread wheat crop on *Mollic Andosols* and *Eutric Vertisols* in Negelle Arsi. So this research activity was designed to verify an achievement for the whole districts to develop phosphorus fertilizer recommendation guide line for bread wheat growing areas in the district.

Materials and Methods

Description of the Study Area

The study was conducted in Negelle Arsi district, West Arsi zone of Oromia regional state. The area geographically situated between $7^0$25´ to 7^0 40´N and 38° 47.7' to 38° 44.3' E south to Addis Ababa, the Capital of Ethiopia (Figure 1). The district is part of the Ethiopian central rift valley, covering an area of 1400 km^2 (Efrem Garedew *et al*., 2009). The topography of the area is flat to undulating. The average elevation of district is 1913 m.a.s.l. The average annual temperature varies from 14 – 25 ^{0}C. More over the area classified in bimodal rain fall distribution, i.e., in the period of July to October (wet season) and March to June (small rain season).

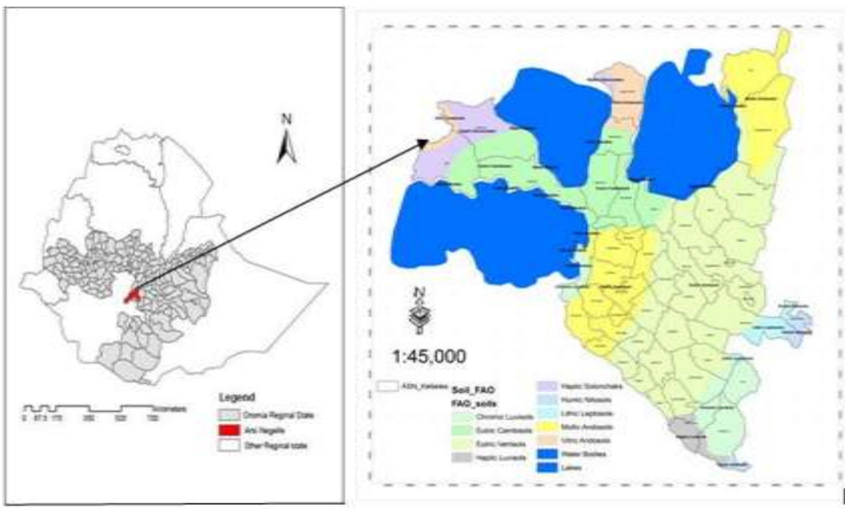

Fig 1: Description of study site

Experimental Design and Procedure

The experiment had three treatments (Control, Blanket recommendation (farmer practice) and Phosphorus critical and Requirement factor), with simple design and replicated over farmers. Based on the phosphorus initial values P fertilizer was recommended by using the following formula.

Rate of fertilizer to be applied (kg P/ha) = (Pc-Po)*Pf

Where: Pc = Critical P concentration (18ppm) for both soil types; Po = Initial P values for site (mg/kg); Pf = P-requirement factor 3.63 and 4.72 for *Mollic Andosols* and *EutricVertisols*, respectively. Improved bread wheat variety *Qubsa* was used for the trial and a total Plot size was 10m*10m (100m^2) for each treatment with the seed rate of 150$kgha^{-1}$. All crop management was done according to farmers' practices.

Soil Sampling and Analysis

Composite soil samples were collected from 36 sites (selected farmers' land) at depth of 0-20cm before planting to determine initial soil available phosphorus (Po).The collected samples were labeled, packed and transported to Batu Soil Research Center. Available soil phosphorus was analyzed by following the Olsen method (Olsen *et al*., 1954)

Data Collection and Analysis

Yield data: Grain yield was collected from net plot 4m*4m (16m^2) to identify significance between treatments.All data were collected across the location and properly managed using the EXCEL computer software. Finally, the collected data was subjected to the analysis of variance using the SAS computer package version 9.0 (SAS Institute, 2002) statistical software. Means separation was done using least significant difference (LSD) after the treatments were found significant at P<0.05

Economic Analysis

Partial budget analysis was employed and calculate the marginal rate of return(MRR) for both soil test based and farmer practice and compare it with no application, (CIMMYT,1988). Marginal rate of return was calculated by the following formula.

$$MRR = \frac{\text{Net Income From Fertilized Field- Net Income From Unfertilized Field}}{\text{Total Variable Cost From Fertilizer Application}}$$

The Farm gate price was estimated to be 7.5ETB Kg^{-1}of wheat grain during harvesting of bread wheat grain at Negelle Arsi on December, 2018. The cost of Fertilizer at local market on June, 2018 (Urea and NPS/DAP 12.47ETB Kg^{-1} and 15.12ETB Kg^{-1} respectively). Transport cost, broad casting, harvesting and bagging cost where similar for all treatments of District. To use the marginal rate of return (MRR) as a basis for fertilizer recommendation, the minimum acceptable rate of return (MARR) was set to 100% (CIMMYT, 1988).

Results and Discussion

Grain Yield

The analysis of variance revealed that significance difference between mean grain yield at p<0.05, (Table 1 and Table 2). The highest average grain yield was recorded on soil test based fertilizer recommendation while average lowest grain yield was recorded on the control plot on both *Mollic Andosols* and *Eutric Vertisols* (Table 1 and 2). The result was in line with similar study by Kefyalew *et.al*, 2016; Abera D. and Abreham.F 2019 at Lume District East Shewa Zone and Wuchale District of North Shewa Zone, respectively. This result indicated that soil test based crop response based fertilizer recommendation is suitable and economical method to get optimum yield of bread wheat in the study area through optimum fertilizer application that efficiently the plant requires.

Table 1: Mean Grain Yield of Bread wheat on the verification of phosphorus critical and requirement factor of *Mollic Andosols*.

Treatments	GYLD Kg/ha
Control	1902[c]
Pc and Pf	3475[a]
BK	2816[b]
CV(%)	28.25
LSD(α<0.05)	488.74

**Pc and Pf = phosphorus critical and Requirement factor; BK= Blanket recommendation

*Means with the same letter are not significantly different

Table 2: Mean Grain Yield of Bread wheat on the verification of phosphorus critical and requirement on *Eutric Vertisols*

Treatments	GYLD Kg/ha
Control	2111[c]
Pc and Pf	3784[a]
BK	3179[b]
CV(%)	14.14
LSD(α<0.05)	304.58

**Pc and Pf = phosphorus critical and Requirement factor; BK= Blanket recommendation
*Means with the same letter are not significantly different

Economic analysis

The partial Budget analysis also revealed that soil test based crop response fertilizer recommendation on *Mollic Andosols* and *Eutric Vertisols* for bread wheat at Negelle Arsi was acceptable at 284% MRR 118% MRR, respectively(Table 3 and 4).

Table 3: Partial budget analysis for *Mollic Andosols*

Treatment	Urea N(kg/ha)	NPS P(kg/ha)	AGYkg/ha)	GFB(EB/ha)	TVC(EB/ha)	NB(EB/ha)	MRR(%)
Control	0	0	1711.8	12838.5	855.90	11982.60	0.0
BK	100	100	2534.4	19008.0	4126.20	14881.80	88.7
STBFR	100	155	3127.5	23456.3	5281.85	18174.40	284.9

AGYL= Adjusted Grain Yield; GFB= Gross field benefit TVC= Total variable cost ;NB= Net benefit; MRR= Marginal rate of return; EB= Ethiopian Birr; BK= Blanket recommendation; STBFR= Soil test based Fertilizer recommendation

Table 4: Partial budget analysis for *Eutric Vertisols*

Treatment	Urea N(kg/ha)	NPS P(kg/ha)	AGYkg/ha)	GFB(EB/ha)	TVC(EB/ha)	NB(EB/ha)	MRR(%)
Control	0	0	1899.9	14249.3	949.95	13299.30	0.0
BK	100	100	2861.1	21458.3	4289.55	17168.70	115.9
STBFR	150	161	3405.6	25542.0	6163.12	19378.88	118.0

AGYL= Adjusted Grain Yield; GFB= Gross field benefit TVC= Total variable cost ;NB= Net benefit; MRR= Marginal rate of return; EB= Ethiopian Birr; BK= Blanket recommendation; STBFR= Soil test based Fertilizer recommendation

Conclusions and Recommendations

Verification of Soil test crop response based phosphorus calibration study was confirmed to Phosphorus critical and Phosphorus requirement factor with comparative response of farmer practice and control on two major soil types (*Mollic Andosols* and *Eutric Vertisols*) in Negelle Arsi district. Application of 46Nkgha^{-1}, Pc(18ppm) and Pf(3.63) on *Mollic Andosols* and 69kgha^{-1}, Pc(18ppm) and Pf(4.72) on *Eutric Vertisols* was obtained maximum net benefit at 284 and 118MRR(%), respectively. Because phosphorus critical and phosphorus requirement factor for *Mollic Andosols* and *Eutric Vertisols* was good response on both soil types when compared to framer practice and control in the district.

That means, soil test based crop response fertilizer recommendation (determined optimum nitrogen fertilizer, Pc and Pf) is feasible over the blanket recommendation and control in the study area. Therefore this could be used as a base line information for fertilizer recommendation in the area while further scaling up will be pre request to introduce and popularize the information generated for farming community of the area.

Acknowledgments

The authors would like to acknowledge Oromia Agricultural Research Institute (IQQO) for financial support. Likewise, Especial gratitude to all soil fertility team members, laboratory technicians and technical assistants of Batu Soil Research Center for their cooperation. At the last, we forwarded our acknowledgement to experts, development agents and farmers of Negelle Arsi District.

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On farm Verification of Soil Test Based Crop Response Recommended Pc and Pf for Maize in Bako Tibe and Gobu Sayo Districts of West Shewa and East Wellega Zones

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Abstract

Soil test based crop response P calibration provides P nutrition that can serve as a guide to improved crop production system. On farm verification of recommended P_c and P_f study was executed on 20 farmers' field at Bako Tibe and Gobo Sayo Districts of West Shewa and East Wellega Zones during 2018 main cropping season. It was verified against 0 NP and 110, 46 kg N/P_2O_5 on plot area of 100 m^2. Maize tasseling silking and maturity took significantly shorter days for recommended P_c and P_f compared to 0 NP and 110, 46 kg ha^{-1} N P_2O_5. Farmers' observation justified the advantage of early crop phenology escaping early cessation of rainfall. Mean yields were significantly different among treatments whereby recommended P_c and P_f produced 10% and 51% biomass yield and 14% and 58% grain yield advantages over 110, 46 kg N/ P_2O_5 and control treatment; respectively. Performance evaluations of farmers were also in favor of recommended P_c and P_f due to large and healthy cob size and strong stalks. In addition to enhancement of maize maturity, net benefit of 3840 Birr ha^{-1} and MRR of 129% were also obtained by recommended P_c and P_f. The result confirmed a net benefit of 1.29 Birr per 1 Birr investment for changing from producing maize using 20 P to 27 P. Hence recommended P_c and P_f for maize was preferred by farmers for early crop phenology, produced high yields and performed high economic return, it is suggested to use recommended P_c and P_f for further NPS rate study in Bako Tibe and Gobo Sayo districts.

Key words: P concentration, P requirement factor, Phosphorus, Maize

Introduction

Impact of soil nutrient availability to plants is critically influenced by soil chemical, physical and mechanical properties. Amount of organic matter content, weather conditions like moisture and temperature and crop characters have also significance influence. Furthermore, applied nutrients under poor soil management conditions can not necessarily mean they are available. Soil properties and environmental factors that restrict root growth and plant activity have the potential to restrict nutrient availability and uptake. In acid soils, nutrient availability and biological activities are restricted whereby P availability is highly affected by P fixation to Fe and Al. Volatilization loss of N also can be considerable even at pH as low as 5.5.

Plants require adequate supply of P from the very early stage of growth for optimum crop production (Grant *et al.*, 2001). Total P in the soil could be higher in the surface 25 cm of the soil although only the small portion of this P is immediately available for plant uptake. Crop removal may range from 3 to 30 kg ha^{-1} hence; crop production will gradually deplete available soil P in absence of P application (Morel, 2002). Optimum P is required for optimum plant growth and reproduction. P is involved in several key plant functions like energy transfer, photosynthesis, growth, reproduction, maturity, transformation of sugar and starch, nutrient movement within the plant and transfer of genetic characters (Better crops, 1999). Indeed, fertilizer P recommendations depend on a) the existing level of available soil P, b) the optimum level of soil P for the crop to be grown and c) the level of fertilizer which must be added to raise available soil P to the optimum level (Kamprath and Watson, 1980). P is also unavailable in soils of high erosion aggravated by high rain fall. 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.

The blanket recommendation of 46 kg ha^{-1} 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.

Objective:

- To verify the soil test crop response recommended P_c and P_f for maize at Bako Tibe and Gobu Sayo Districts.

Materials and Methods

On farm verifications of soil test based crop response recommended P_c and P_f for maize was tested on 20 farmers' field around Bako during 2018 main cropping season. 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 2018 cropping season was 1317 mm which was reduced in month of September, during maize grain filling (Fig. 2). The area is characterized by reddish-brown clay-loam Nitisol which is acidic, with pH of 5.23.

The study was conducted in Bako Tibe and Gobu Sayo districts of West Shewa and East Wellega zones; respectively. It consisted of 3 levels of NP fertilizers (0 NP, 110 46 kg N P_2O_5) and recommended Pc = 14.5 and P_f = 5.5. Ten soil samples were collected from each sites before planting and made composite soil samples. Soil samples collection and planting were done considering the condition mentioned impacting nutrient unavailability. Each composite sample was tested for initial P levels. Using the formula $P_a = (P_c - P_i) \times P_f$; where P_a the rate of P fertilizer applied; P_c P concentration; P_i initial soil P vale; P_f P requirement factor, the rate of P fertilizer applied for each farmer's field were identified. The bases for determination of P requirement for each field (Table 1) was the result obtained from experiment of soil test crop response P calibration with the outcome of Pc = 14.5 and Pf = 5.5 (Shiferaw *et al.,* 2018).

Maize variety, BH 661 was planted on plot area of 100 m^2 at the spacing of 75 cm between rows and 30 cm between plants. Crop phenology (tasseling, silking and maturity) were recorded when 95% of the plant population of respective plots attained the required physiological phenology while biomass and grain yields were weighed and corrected to standard moisture (12.5% for grain). Crop growth and performance evaluation were undertaken during maize grain filling stage. A total of 40 farmers (twenty host farmers and the other 20 non-host farmers) were participated on performance evaluation of all 20 experimental sites.

Table 1. Initial P and calculated required on 20 farmers' field during 2018 main cropping season

No	Farmer's name	Zone	District	P initial	P applied
1	Mamo Chala	West Shewa	Bako Tibe	9	30.75
2	Indalu Jaleta	West Shewa	Bako Tibe	10	25.75
3	Shugut Aboma	West Shewa	Bako Tibe	13	8.25
4	Mideksa Kurmane	West Shewa	Bako Tibe	8	35.75
5	Bongase Warkesa	West Shewa	Bako Tibe	8	35.75
6	Diribi Guta	West Shewa	Bako Tibe	10	25.75
7	Oda Haro School	West Shewa	Bako Tibe	7	41.25
8	Takele Wakgari	West Shewa	Bako Tibe	8	35.75
9	Mesfine Bekele	West Shewa	Bako Tibe	8	35.75
10	Dereje Shiferaw	West Shewa	BakoTibe	9	30.75
11	Ashim Fayisa	West Shewa	Bako Tibe	7	41.25
12	Fikadu Tariku	West Shewa	Bako Tibe	10	25.75
13	Abdela Bashir	East Wellega	Gobo Sayo	11	19.25
14	Fikadu Kebede	East Wellega	Gobo Sayo	8	35.75
15	Diriba Bosha	East Wellega	Gobo Sayo	11	19.25
16	Temesgen Kebede	East Wellega	Gobo Sayo	14	2.75
17	Gidisa Chilfa	East Wellega	Gobo Sayo	8	35.75
18	Werku Chali	East Wellega	Gobo Sayo	11	19.25
19	Diriba Teshome	East Wellega	Gobo Sayo	10	25.75
20	Geremu Olani	East Wellega	Gobo Sayo	11	19.25

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, considering farmers' fields as replications. Means were separated using LSD test. For all analyzed parameters, $P<0.05$ was interpreted as statistically significant.

Results and Discussion

Phenology

Mean maize phenology like days to Tasseling, silking and maturity were significantly affected by P level. Indeed, recommended P_c and P_f took significantly shorter 80 and 84 days to taseling and silking compared to 84 an6 87 for 110, 46 kg ha^{-1} N P_2O_5 and 87 and 89 for control treatments; respectively. Similarly, recommended P_c and P_f matured in 161 days compared to 166 and 169 days for 110, 46 kg ha^{-1}N P_2O_5 and control treatments, respectively (Fig. 1). Similar results, early silking, tasseling and maturity were reported at higher P application compared to the lower rates (Amanullah and Khalid, 2015). According to farmers' performance evaluation, all 40 respondents confirmed recommended P_c and P_f plots were preferable in the crop phenology. As it was justified by evaluators, recommended P_c and P_f treatments are advantageous escaping risks of short rainy season and particularly early cessation of rainfall (Fig. 2).

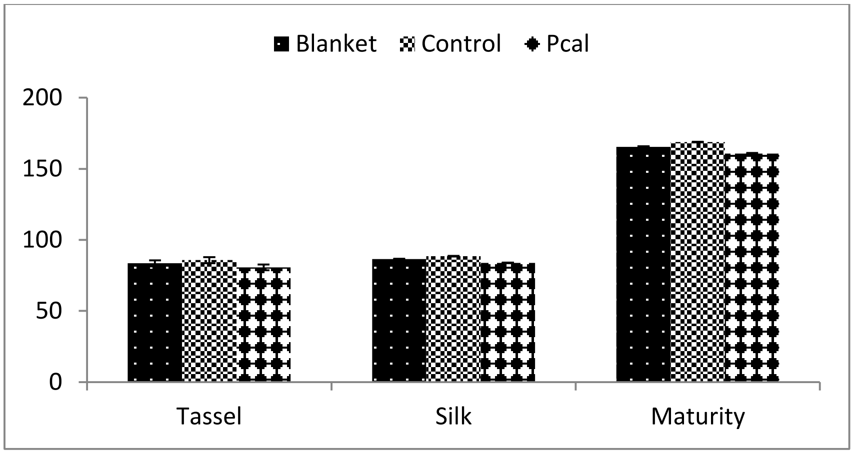

Fig. 1 Crop phenology as affected by recommended P_c and P_f at Bako Tibe and Gobo Sayo during 2018 main cropping season

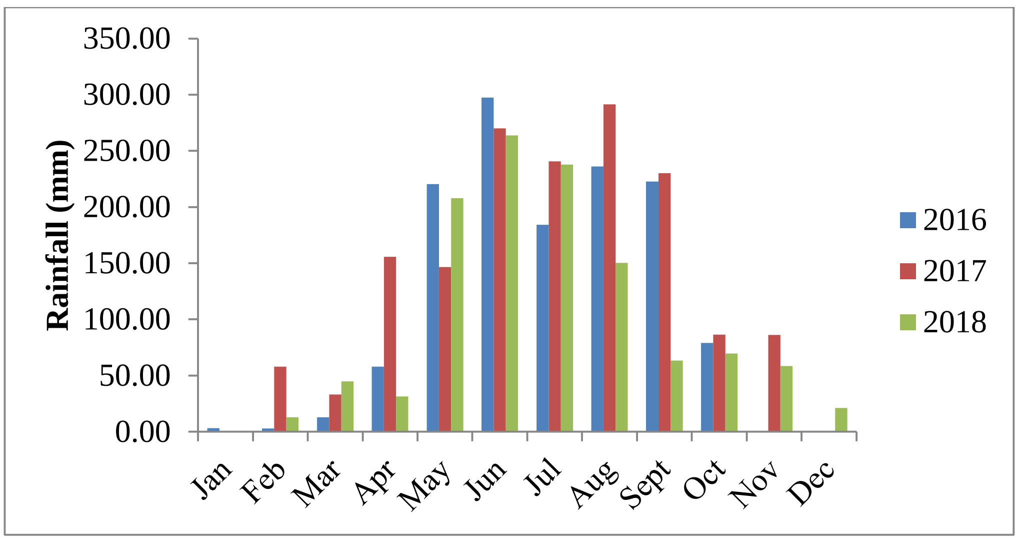

Fig. 2 Rainfall distribution in Bako area during 2016, 2017 and 2018.

Yields

Mean maize biomass yield, grain yield and harvest index obtained from 20 farmers' field were significantly different among treatments. Accordingly, recommended P_c and P_f and 110, 46 kg ha^{-1} N P_2O_5 treatments which didn't show significant differences among each other significantly produced the highest biomass yield and harvest index compared to the controlled treatment. On the other hand, mean grain yield was significantly different among treatments. Indeed, recommended P_c and P_f treatment produced 10% and 51% biomass yield and 14% and 58% grain yield advantages over 110, 46 kg ha^{-1} N P_2O_5 and control treatment, respectively. The results agree with (Geremew *et al.*, 2015) who reported higher P rate produced significantly higher biomass and grain yields. Harvest index was also significantly lower (0.36) for control treatment compared to 0.41 for recommended P_c and P_f and 110, 46 kg ha^{-1}N P_2O_5 (Table 1).

Economic Evaluation

The grain yield was down adjusted by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment whereby the average maize price and fertilizer cost were 4.81 and 14.10 Birr kg^{-1}; respectively. The highest net benefit (27994 Birr ha^{-1}) was obtained by the soil test based crop response P calibrated treatment. In addition to enhancement of maize maturity, net benefit of 3840 Birr ha^{-1} and MRR of 129% were also obtained by soil test based crop response recommended P_c and P_f treatment. The result confirmed a net benefit of 1.29 Birr per 1 Birr investment for changing from producing maize using 20 P to 27 P (Table 2).

Performance Evaluation

Soil test based phosphorus calibrated treatments were preferred by 85% of the respondents for growth performance, cob vigor, stalk vigor, and early maturity to escape early cessation of rainfall. Obviously higher rate of P (Phosphorus calibrated treatment in this case) might have enhanced better root development and better nutrient uptake that improved cob and stalk vigor. Soil test based P calibrated and blanket recommendation were found similar by 10% of the respondents while 5% of the respondents preferred blanket recommendation treatment for the mentioned criteria.

Table 1. Maize biomass yield, grain yield and HI as affected by soil test based crop response P requirement for maize at Bako Tibe and Gobu Sayo districts during 2018 main cropping season

Treatments	Biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest Index (HI)
Control	7443	2731	0.36
Recommended P_c and P_f	15102	6467	0.41
110, 46 (kg ha^{-1}) N P_2O_5	13687	5580	0.41
SE	569.83	228.27	0.0034
LSD (5%)	1631	653.53	0.01
CV (%)	21.10	20.72	3.91

Table 2. Economic evaluation of on farm verification of soil test based crop response P requirement for maize during 2018 main cropping season

Treatments	TCV Birr ha^{-1}	Benefit Birr ha^{-1}	Dominance Analysis	MRR (%)
Control (0, N P_2O_5)	0	11823		
Blanket (110, 46 (kg ha^{-1}) N P_2O_5	1410	24156	ND	114
P calibrated	1904	27994		129

Conclusion and Recommendation

On farm verification of soil test based crop response recommended P_c and P_f for maize was preferred by farmers for early crop phenology, produced high biomass yield, high grain yield and high HI. Its high economic return and preference by 85% of the evaluators as best technology at Bako Tibe and Gobu Sayo Districts of West Shewa and East Wellega zones, requires further NPS rate study.

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Soil Test Crop Response Based Phosphorous Calibration Study for Maize in Darimu District of Ilubabor Zone, Southwest Oromia, Ethiopia

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Abstract

On-farm phosphorus calibration study was conducted in Darimu District of Ilubabor Zone, Southwest Oromia to determine Phosphorus critical level and correction factor for Phosphorus recommendation for maize, during the main cropping seasons of 2016 to 2018. Factorial combination of four levels of N (0, 46, 92 and 138 kg N ha^{-1}) and four levels of P (0, 20, 40 and 60 kg P ha^{-1}) in the first year to determine N rate. Moreover, Single factor of seven levels of P (0 ,10 ,20, 30 ,40, 50 and 60 kg P ha^{-1}) and (138 kg N ha^{-1}) in the second and third years to determine Phosphorus critical level and requirement factor were laid out in RCBD with three replications. Maize variety (BH-661) was used as test crop. Maize grain yield was analyzed with SAS. Composite surface soil samples (0-20) cm depth were collected before and after planting and analyzed. The surface soil before planting was characterized by strongly acidic in reaction ranged from (4.01 to 5.02), very low available P from (0.59 to 3.98) ppm, low organic matter content from (1.71 to 4.73) %, and moderate CEC (11.94 to 18.55).The analysis of variance indicated that maize grain yield of N rates were significantly different ($P<0.05$) as compared to each other, while thousand kernel weight was significantly different among p rates. The maximum mean maize grain yield (7425 kg ha^{-1}) was recorded for (138 kg N ha^{-1}), whereas the lowest (1782 kg ha^{-1}) was recorded for control plot (without fertilizer) and it would yield 2.68 Birr for every Birr invested. The highest thousand kernel weight (427g) was recorded for (60 kg P ha^{-1}), whereas the lowest (251g) was recorded for control plot. Hence (138 kg N ha^{-1}), Phosphorus critical level (10 ppm), and correction factor (7.49) for maize production was recommended in Darimu District. Since N fertilizer was not reached to turn over, maize was not satisfied to applied N. There for, further study will be needed to get where the crop will be satisfied.

Key words: Maize, BH-661 variety, Nitrogen, Phosphorus, P-critical and P- correction

Introduction

Phosphorus (P) is the second key nutrient required in large quantities for growth and productivity of crops. It has a role in cell division, stimulation of early root growth, hastening plant maturity and energy transformation within cell, fruiting and seed production (Miller and Donahue, 1997). Phosphorus plays an important part in many physiological processes that occur within a developing and maturity. It involves in enzymatic reactions in the plant. It is essential for cell division because it is a constituent element of nucleoproteins, which are involved in the cell reproduction processes. It is also a component of a chemical essential to the reactions of carbohydrate synthesis and degradation. Plants deficient in P are characterized by delayed in maturity and poor seed development. The leaf color becomes a dull grayish green with a red pigment often being produced in the leaf base and in the dying leaves (Seetharaman *et al*., 1994). The growth rate of crop during flowering was significantly reduced by P deficiency, resulting in a poorer seed set and lower yields (Uhart and Andrade, 1995). Phosphorus increases number of seed per ear and grain yield (Grazia *et al.*, 2003).

The plant available phosphorus forms are limited primarily to solution HPO_4^{-2} and $H_2PO_4^-$, with the dominant form determined by soil pH. In acid soils, Al and iron (Fe) are more soluble and make phosphorus less available. The concentration of soluble P in soil solution is very low (Hodges, 2009). Nitisols contain high Fe and Al oxides and hydrous oxides, whereas available P content is very low (Mesfin, 1998) because of P fixation in Nitisols. This indicated that in highland soils of Ethiopia phosphorus is potentially limiting element in crop production (Desta, 1982; Tekalign and Haque, 1987). Phosphorus deficiency for crop growth exists in most soils because of losses due to erosion and high phosphorus fixation (Miller and Donahue, 1997: Brady and Weil, 2002). This problem is more severe in highly weathered acid soils. The use of chemical fertilizer to overcome this nutrient deficiency is a practice that is receiving a wide acceptance in the country.

Nutrient mining or depletion is also a widespread problem in low- and medium input agriculture. Nutrient mining can cause the exhaustion of any nutrient required in moderate to large amounts. It can be particularly severe in the case of N, P, K and S depending on soil nutrient reserves and the amounts replenished. A negative balance can be acceptable for a short period, but, where prolonged, it will lead to soil deterioration. It is expensive to improve depleted soils (FAO, 2006). Therefore, Soil test-based fertility management is an effective tool for increasing productivity of agricultural soils that have a high degree of spatial variability.

Soil test based fertilizer recommendation plays a vital role in ensuring balanced nutrition to crops and fertilizer schedules should therefore be based on the magnitude of crop response to applied nutrients at different soil fertility levels (Santhi *et al.*, 2003*)*. Soil testing as a diagnostic tool is useful only when the interpretation of test results is based on correlation with crop response to arrive at practically usable fertilizer recommendations for a given soil–crop situation (FAO, 2006). Economical optimum fertilizer application can only be achieved by developing appropriate fertilizer recommendation scheme that takes into consideration the nutrient status of individual fields. Therefore, Soil test based fertilizer recommendations result in efficient fertilizer use and maintenance of soil fertility

In Ethiopia, maize is first in productivity and second in area coverage after *teff* (CSA, 2010). Research results in high potential maize growing areas are high but yield levels obtained by small scale farmers remained stagnant despite the availability of improved varieties even in high maize growing potential areas of western Oromia. (Benti, 1993). One of the main causes for this discrepancy is the low use of external inputs that leading to negative balances for N, P and K (Rhodes *et al.*, 1996). Low soil fertility is one among the major factors limiting maize production and productivity in western Oromia, Ethiopia (Wakene *et al*., 2005). Hence assessment of soil fertility status and plant nutrients requirement of a given area has vital role in enhancing crop production and productivity on sustainable basis. Nevertheless, little information is available in Oromia in general and in Darimu District in particular on essential plant nutrients requirement for maize production. Therefore, the objectives of this study were to generate information on soil test crop response based Phosphorus calibration, and to determine Phosphorus critical level and correction factor for maize production in Darimu District for maize.

Materials and Methods

Description of the Study Area

On farm soil test crop response based Phosphorus calibration experiment was conducted in Darimu district, Ilubabor Zone in Southwest Oromia. Darimu district is located at $08^0 37'00''$ to $08^0 38'09''$ N latitude and $035^0\ 24'27''$ to $035^0 25'40''$E longitude. The mean annual rainfall and temperatures of the district is ranged from 792 to 1192 mm, 18 C^o to $31C^0$, respectively. Altitude ranged from 700 to 1800 masl and soil type is dominated by nitisols. The economy of the area is based on mixed cropping and livestock raring agricultural production system among, which dominant crops are (maize, sorghum and finger millet), horticultural crops are (coffee, mango and spices)

Soil Sampling and Analysis

Twenty sites were selected and composite surface soil samples (0-20) cm depth were collected from each experimental sites before planting to analyze soil pH (H_2O), available P (Olsen method), Ex acidity, (%OC), CEC and textural class. Similarly, after 21 days of planting, intensive composite soil samples were collected from each experimental plot to analyze available P that was used to determine P critical level and correction factor. The experimental sites were treated with lime for soil pH less than 5.5, and the amount of lime needed per hectare was calculated based on the formula LR = Ex. acidity *1.5*10 kun ha^{-1}.

Treatments,

On-farm Phosphorus calibration study was conducted in Darimu District during the main cropping seasons of 2016 to 2018 to determine Phosphorus critical level and correction factor for maize. Factorial combination of four levels of N (0, 46, 92 and 138 kg Nha^{-1}) and four levels of P (0, 20, 40 and 60 kg P ha^{-1}) in the first year. Moreover, single factor of seven levels of P (0, 10, 20. 30, 40, 50 and 60 kg P ha^{-1}) and 138 kg N ha^{-1} in the second and third years to determine Phosphorus critical level and correction factor.

Experimental Design and Procedures

The experimental fields were prepared by using oxen plow in accordance with conventional farming practices followed by the farming community in the area where, the fields were plowed four times. Experimental design was RCBD with three replications. The gross plot size was (5 m x 6.4m) with (5 m x 4.8 m.) net plot. Maize variety (BH-661) was used as test crop with 50,000 maize populations per hectare. Full dose of phosphorous as per the treatment and one-half of N was applied at sowing. The remaining one-half of N was top dressed at 30 days of planting in the form of urea. During the different maize growth stages, all necessary field management practices were carried out as per the practices followed by the farming community. Thousand kernel weight (TKW) was determined by counting and weighing from the bulk of shelled 250 kernels and multiplied by four and expressed in gram for each plot. Grain yield and TKW were analyzed using SAS computer package and LSD was used for mean separation.

Economic Analysis

Economic analysis was based on (CIMMYT, 1988). To estimate economic parameters, products were valued based on local market price collected from local markets during January 2017 where maize grain was 5.00 ETB kg^{-1}, at field price. Fertilizers price of DAP and Urea were 16.87, 10.87 ETB kg^{-1}, respectively at planting time during a month May. For labor cost wage rate of 50.00 ETB per work-day were used

Determination of Phosphorus Critical Level for Maize

Phosphorus critical level was determined following the Cate-Nelson graphical method where soil P values were put on the X-axis and the relative yield values on the Y-axis (yield x 100/maximum yield). The Cate-Nelson graphical method is based on dividing the Y-X scatter diagram into four quadrants and maximizing the number of points in the positive quadrants. The positions of the lines on the overlay with respect to the axes of the graph were transferred to the graph by making marks on the edges of the graph. The two intersecting lines were then drawn lightly on the graph. The point where the vertical line crosses the X-axis is defined as ‘critical soil test level (Cate and Nelson, 1965)

Determination of Phosphorus Correction Factor (Pf)

Phosphorus correction factor was calculated using available P values in soil samples collected and analyzed from each unfertilized and fertilized experimental plots, after that the relation between each fertilizer rate and averaged corresponding soil test P value for each fertilizer rates was calculated.

Results and Discussion

Initial soil pH, available P, Exchangeable acidity, OC, CEC and textural class status before planting

The analysis results of soil pH (H_2O) for the soil samples collected before planting were ranged from 4.01 to 5.02 (Table 1). Accordingly, the soils were strongly acidic in reaction (FAO, 2008). Most Africans soils are of ancient origin and come from acidic rocks that are of low nutrient contents, Zake (1993).Continuous cultivation lower soil pH and aggravate the losses of basic cations from highly weathered soils (Mokwunye *et al*. 1996). The result showed that soil pH affects maize production which is less than the maize requirement proposed (FAO, 2006). The result also showed that very low available P ranged from (0.59 to 3.98) ppm and Exchangeable acidity (0.12 to 0.92) cmolkg^{-1} soil. Low to moderate organic carbon (1.71 to 4.73) %, moderate cation exchange capacity (11.94 to 18.55 cmol(+) kg^{-1} soil) and clay in texture, (Table 1). These may be because of low percent of OM content of the soil which is in agreement with the suggestion of Clark et al. (1998) who indicated that soil OM influences P availability to crops directly by contributing to P pool. The low contents of available P were also in agreement with the results reported by (Mesfin,1998; Yihenew, 2002; Dagne, 2016) who reported that the Ethiopian agricultural soils particularly the nitisols and other acid soils have low available P content due to their inherently low P content, high P fixation capacity, crop harvest and soil erosion, and poor in their organic matter content due to low amount of organic materials applied to the soil and complete removal of the biomass from the field.

Nitrogen Fertilizer Determined for Maize in Darimu District

There were significant differences ($P \leq 0.05$) on maize grain yield among the treatments. The maximum mean grain yield (7426 kg ha^{-1}) was recorded for the combination rate of (138 kg N ha^{-1}) and (60 kg P ha^{-1}) fertilizers, whereas the lowest (1782 kg ha^{-1}) was recorded for the control plot (without fertilizer) (Table 2). Increasing nitrogen fertilizer rates from 92 kg N ha^{-1} to 138 kg N ha^{-1} at 60 kg P ha^{-1}; maize grain yield increased from 6088 to 7426 kgha^{-1}, respectively. This showed that 18% maize grain yield advantage (Table 2). Maize requires adequate supply of nutrients particularly nitrogen, phosphorus and potassium for good growth and high yield (Liu *et al*., 2006). Therefore, 138 kg N ha^{-1} was selected as N fertilizer recommended for maize production in Darimu District. However, N fertilizer was not reached to turn over and maize was not satisfied to applied N fertilizer. There for, further study will be needed on N rate to get where the crop will be satisfied. It is essential to know the best level of nitrogen application for getting a higher crop yield so that maximum benefits could be achieved (Arif *et al*., 2010). .Nitrogen status of soil has a major role in maintaining maximum maize grain yield (Akmal *et al*., 2010). N plays an important role in crop life. It is one of the most important nutrients needed by plants in large quantities. Its availability in sufficient quantity throughout the growing season is essential for optimum maize yield. It also mediates the utilization of phosphorus, potassium and other elements in plants (Brady and Weil, 2002). The optimal amounts of these elements in the soil cannot be utilized efficiently if nitrogen is deficient in plants.

Table .1.Initial soil pH, av P, Ex acidity, OC, CEC and textural class status before planting in Darimu District in 2017 and 2018 cropping seasons

Sits	pH (H_2O)	Available P (ppm) Olsen method	Ex acidity cmol/kg soil	OC %	CEC cmol(+)/kg soil	Textural Class
1	4.80	0.88	0.18	3.62	14.33	Clay
2	4.87	2.14	0.12	2.41	11.94	Clay
3	4.24	1.59	0.35	1.71	14.12	Clay
4	4.63	1.06	0.23	2.40	13.54	Clay
5	4.57	2.03	0.35	2.43	13.19	Clay
6	4.73	3.78	0.47	1.88	13.51	Clay
7	4.01	2.06	0.95	2.66	13.18	Clay
8	5.02	3.98	0.45	3.61	14.78	Clay
9	4.42	1.68	0.35	3.47	14.45	Clay
10	4.65	1.37	0.27	3.11	14.07	Clay
11	4.72	0.59	0.31	2.43	18.55	silty clay loam
12	4.71	0.87	0.18	4.38	16.39	clay loam
13	4.41	0.85	0.44	3.14	13.58	Clay
14	4.70	2.60	0.27	3.88	18.03	Clay
15	4.95	2.18	0.21	2.35	15.58	clay loam
16	4.44	1.95	0.88	2.49	16.29	clay loam
17	4.29	1.19	0.92	3.15	15.25	Clay
18	4.51	2.49	0.34	3.21	14.90	Clay
19	4.78	2.42	0.22	3.69	14.76	clay loam
20	4.64	1.45	0.18	4.73	17.29	clay loam
Average	4.60	1.86	0.38	3.04	14.89	

Table 2. Interaction effect of N and P fertilizers on maize (BH-661) grain yield at Darimu District in 2016 cropping season

	P (kg ha^{-1})				
N (kg ha^{-1})	0	20	40	60	
0	1782^{i}	3000^{h}	3403^{fgh}	3921^{efg}	
46	2083^{i}	3509^{fgh}	4421^{de}	5611^{bc}	
92	3060^{gh}	4472^{de}	5051^{cd}	6088^{b}	
138	4000^{ef}	4551^{de}	5588^{bc}	7426^{a}	
Mean	4248				
LSD	902				
CV (%)	32				

Mean followed by the same letters in each column are not significantly different at P≤ 5%.

LSD = Least Significant Difference, CV = Coefficient of Variation

Effects of N Rates on Economic Feasibility of Maize Production in Darimu District

The results of economic analysis for nutrient management are indicated in (Table 3). The highest net benefit of 21408.00 ETB ha^{-1} with an acceptable marginal rate of return (MRR) of 263 % was obtained from use of 138 kg N ha^{-1} followed by net benefit of ETB 16637.50 with MRR 98 % that was achieved from application of 92 kg N ha^{-1}, which implies a very high increase in farmers' income with a simple improvement in crop managements. The minimum net benefit was obtained from the control treatments. In conclusion, application of 138 kg N ha^{-1} fertilizer is agronomical and economically feasible for maize production in Darimu District.

Table 3. Partial budget and marginal analysis for treatment applied over six sites for maize in Darimu District

N rates (Kg ha^{-1})	Av. GY (t ha^{-1})	Adj. GY (t ha^{-1})	TVC (ETB)	Gross benefit (ETB)	Net benefit (ETB)	D.A	MRR (%)
0	1.78	1.76	1500.00	8800.00	7300	-	-
46	5.61	5.55	11971.00	27750.00	15779	-	81
92	6.09	6.03	13508.00	30150.00	16642	-	98
138	7.42	7.35	15321.00	36750.00	21429	-	263

Av.GY= Average grain yield, Adj.GY= Adjusted grain yield to 10%, TVC= Total Variable Costs, D.A = Dominance analysis, D= Dominated and MRR= Marginal Rate of Return.

Phosphorus Critical Level and Correction Factor Determined for Maize in Darimu District

The study result showed that economic response of maize to added Phosphorus fertilizer is 10 ppm whereas, phosphorus correction factor is 7.49 for maize at this particular area (Darimu District).

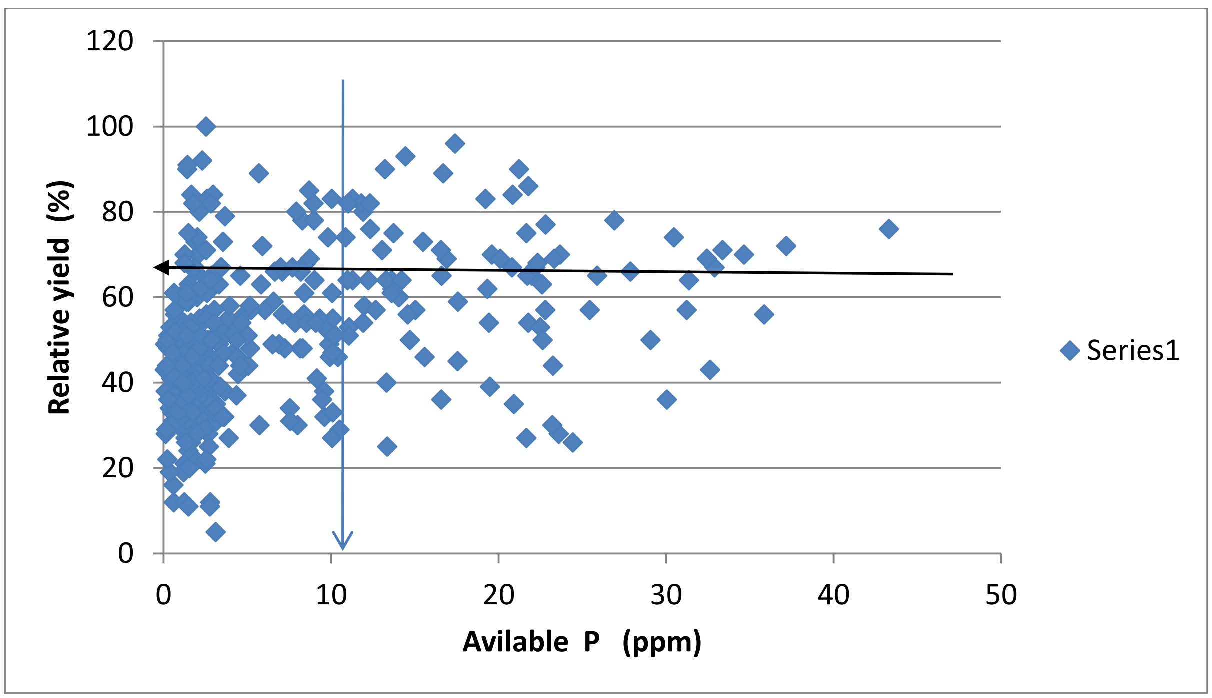

Figure 2. Phosphorus critical level (Pc) determined for maize in Darimu District

Table. 4. Phosphorus correction factor(Pf) determined for maize at Darimu District

P fertilizer applied (kg P ha^{-1})	Olsen P (ppm) mean	P increase over control	P correction factor (Pf)
0	2.01		
10	4.80	2.79	3.58
20	5.30	3.29	6.08
30	6.55	4.54	6.61
40	7.03	5.02	7.97
50	7.19	5.18	9.65
60	7.44	5.43	11.05
			7.49

Thousand Kernel Weight on Maize (BH-661) Grain Yield in Darimu District in 2017 Cropping Season

The result of analysis of variance showed that there were significant differences ($P \leq 0.05$) among P fertilizer rates on thousand kernel weight of maize (Table 5). The highest (427 g) and lowest (251 g) mean thousand kernel weight were observed for (60 kg P ha^{-1}), and control (0 kg P ha^{-1}), respectively.Phosphorus fertilizer rates from (30, 40, 50 and 60) kg P ha^{-1}; thousand kernel weight, increased from (4.6, 5 and 5.6) %, respectively. The more grain weight for the highest rate of P might be attributed to good photosynthetic efficiency, total dry matter present at harvest and on dry matter distribution among different parts of the plants The final weight of the grains is thus a result of the rate at which the kernel accumulates dry matter and the duration over which this occurs (Housely *et al*., 1982).

Table 5. Mean of thousand kernel weight of maize in Darimu District in 2017 cropping season

P (kg ha^{-1})	1000 kernels weight (g)
0	251^{g}
10	326^{f}
20	347^{e}
30	365^{d}
40	383^{c}
50	403^{b}
60	427^{a}
Mean	357.5
LSD	14
CV (%)	8

Conclusion and Recommendation

The soil of Darimu District before planting was characterized by strongly acidic, very low available Phosphorus, low organic carbon content, moderate cation exchange capacity and clay in texture. The maximum mean grain yield was recorded from the application of Nitrogen (138 kg N ha^{-1}) whereas; the lowest was recorded from the control. Increasing nitrogen fertilizer rate from (92 to 138) kg N ha^{-1} , maize grain yield increased by 18% yield advantage and it would yield 2.68 Birr for every Birr invested. Hence this paper recommends to use (138 kg N ha^{-1}), Pc (10 ppm), and Pf (7.49) for maize production in Darimu District. Therefore, 138 kg N ha^{-1} was selected as N fertilizer recommended for maize production in Darimu District. However, nitrogen rate was not reached to turn over and maize was not satisfied to applied N. There for, further study will be needed on N rate to get where the crop will be reached. Thus, farmers in the area should be advised to use soil test crop response based calibrated phosphorus to increase the productivity of maize. To sustain and/or improve the current soil fertility status of the study area, integrated soil fertility management practices (soil amendment with lime and crop rotation) can improve the current situation.

Acknowledgments

We acknowledge IQQO for granting research fund.

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Agro-Forestry Research

Assessment of the Effects of Eucalyptus Species Plantations and Crop Land on Selected Soil Properties around Bale

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Abstract

The physical and chemical properties of soil are influenced by land use system. Different studies show that monoculture plantation forestry may affect soil chemical properties in two different ways. That is through direct depletion from the soil into the tree component, and changes in the chemical status of the soil surface as the litter layer is dominated by leaf fall derived from one species. Eucalyptus is a group of tree species which is native to Australia but widely grown throughout the world. It is one of the dominant and potential tree species which is belongs to the Myrtaceae family. Due to the fast-growing nature of eucalyptus combined with its widely recognized socio-economic benefits, this introduced species has been widely planted. Even if the economic contributions there are a lot of controversies are raised from different parts of the world. Different studies have reported that Eucalyptus spp. plantations have devastating effects on the soil physico-chemical properties, depleting soil organic matter content and negatively impacts soil hydrology. In reverse to this study from the recent studies suggested that if Eucalyptus are properly planted and managed it supports and improve soil nutrients and Eucalyptus species has potential positive impacts on soil pysico-chemical properties. The effects of Eucalyptus spp. plantations on soil properties and depletion of the soil essential nutrients still remain unclear. Therefore this study is planed with the aim of to evaluate the effects of Eucalyptus spp. plantations and crop land on selected soil properties and to compare the impacts of different species of Eucalyptus plantation and crop land uses on selected soil physical and chemical property around Bale. Five soil samples per site were collected for analysis of soil physical and chemical property. In the case Moisture content, except for Goro district, for the other districts (Agarfa, Dello Menna, Goba, Robe) the amount of moisture content is higher in the soil under Eucalyptus plantation land uses than crop land. When we see the overall mean wise comparison of the whole land uses, as the depth increases the overall mean potential of soil chemical properties in PH, OC%, OM % and available P is decreases. But in the case Electronic conductivity (EC) as the depth increase the concentration is slightly increases. When we see the general overview of the land uses, there is no significant differences were observed between Eucalyptus plantation land uses and crop land use. Even in most of the parameter especially in soil organic carbon and soil organic matter the highest value were recorded in Eucalyptus plantation land uses than crop land use. This is due to the recycling of nutrient through decomposition of different tree parts. In terms of crop land due to cereal crop intensive agricultural system most the soil nutrient is depleted. Therefore this finding concluding that eucalyptus could positively impact soil physical and chemical properties through decayed litter than intensively cultivated crop land.

Key words: Concentration, Crop land, Depth, Eucalyptus, Soil properties

Introduction

Eucalyptus is a group of tree species which is native to Australia but widely grown throughout the world. It is one of the dominant and potential tree species which is belongs to the Myrtaceae family with three genera such as *Eucalyptus*, *Corymbia* and *Angophora*. It is one of the most planted woody species in the world next to *Pinus* and *Cunninghamia* (FAO, 2006, Oballa et. al., 2010). There are about 900 Eucalyptus species globally gown in the world (Boland et. al., 2006). From those species more than 700 known *Eucalyptus* species are native to Australia (GOA, 2008). Outside its natural eco-region, *Eucalyptus* is expanding from 0.7 million ha in 1955 to more than 20 million ha in 2009, distributed to over 100 countries (Iglesias, 2015, Shi et. al., 2012). Eucalyptus can grow in tropics, sub tropics and some temperate regions and covers 0.5% of the global surface forest area (Grupo, 2009).

Due to high population pressure and unwise utilization, the forest resources of Ethiopia are severely declined and the land are converted in to agricultural land and fast growing trees plantation. In Ethiopia Eucalyptus is the widely grown tree species in different parts of the country. Due to its potential and its fast growing nature of the species it supports the livelihood of most of rural as well as the urban society of the country. This species used to fill the construction and fuel wood demand of the country. In Ethiopia *Eucalyptus* plantation is covering about 506,000ha from the total land (FAO, 2009). From the totally planted area 58% were planted between 1978 and 1989 as community plantation (Yitebitu et al., 2010).

In the area of Eucalyptus plantation there are a lot of controversy are raised from different parts of the world and also many concerns have been reported about the negative ecological effects of *Eucalyptus* species. Different studies have reported that *Eucalyptus* spp. plantations have devastating effects on the soil physico-chemical properties, depleting soil organic matter content and negatively impacts soil hydrology (Kindu *et al*., 2006a, Tererai *et al*., 2014). Lane *et al*. (2004) in China found that the expansion of *Eucalyptus* spp. plantation lowers water tables and reduces water availability due to its deep and dense root network. According to Wen *et al*. (2009) and Zhu *et al.* (2009) indicated, *Eucalyptus* spp. plantation is adversely affect the soil physical and chemical properties and plant community biodiversity in China . In Argentina, it affects the nutrient cycling capacity, ecological and economic implications of *Eucalyptus* spp. in terms of sustainable forestry (Goya *et al*., 2008).

The negative effects of *Eucalyptus* on neighboring food crops due to the competition of soil moisture and nutrients, and shade effect were reported in Amhara regional state of Ethiopia (Alebachew et al., 2015). According to different studies there are a lot of impacts of Eucalyptus tree species are studied in different scholars. The major impact of *Eucalyptus* tree species are impacts on water resources, soil nutrient resources, allelopathic effect on other species and impacts on agro biodiversity and human nutrition security (Aklilu et. al., 2019) .

In reverse to this studies from the recent studies suggested that if Eucalyptus are properly planted and managed it supports and improve soil nutrients. Eucalyptus species has potential positive impacts on soil pysico-chemical properties. Recent evidence from the literature suggests that eucalyptus may not always have negative effects on topsoil retention and soil nutrient availability. If Eucalyptus species are planted properly can used as a shelterbelts for crops (Oballa et. al., 2010, Beinart, 2003). Also in dry areas is used to protect the soil from wind erosion through its lateral roots by holding the top soil from erosion (Oballa et. al., 2010).

The effects of *Eucalyptus* spp. plantations on soil properties and depletion of the soil essential nutrients still remain unclear (Bernhard-Reversat, 1999; El-Amin *et al*., 2001) and conventional scientific reports are scanty (Oballa *et al*., 2010). Also in Eucalyptus plantation there are a lot of controversy was observed from different part of the world. A lot issues are raised on the impacts of Eucalyptus plantation on the soil pysico chemical properties. According to different studies such type's issues are disproved by different scholars. Due to this the effects of *Eucalyptus* spp. plantations on soil properties and depletion of the soil essential nutrients still remain unclear. These similar issues are also raised in our country as well as in our district. Due to this information gap additional documentation on the specific effects of *Eucalyptus* spp. plantations in relation to soil physical and chemical properties as well as contribution of the litter fall to soil nutrients enrichment is required. Therefore this study is planed with the aim of to evaluate the effects of *Eucalyptus spp.* plantations and crop land on selected soil properties and to compare the impacts of different species of eucalyptus plantation and crop land uses on soil physical and chemical property around Bale.

Material and Method

Study Area Description

Bale is one of the districts of Oromia regional state of Ethiopia. It is located in South-eastern part of Ethiopia. Specifically the study was conducted in Agarfa, Dello Menna, Goba, Goro and Robe districts of Bale. The study area is located in from highland up to midland agroecology areas of Bale with the bimodal rainfall pattern. The area was located from 1285 to 2732m.a.s.l. altitudinal range. The major farming system of the study area is crop production with cereal dominant crop farming system.

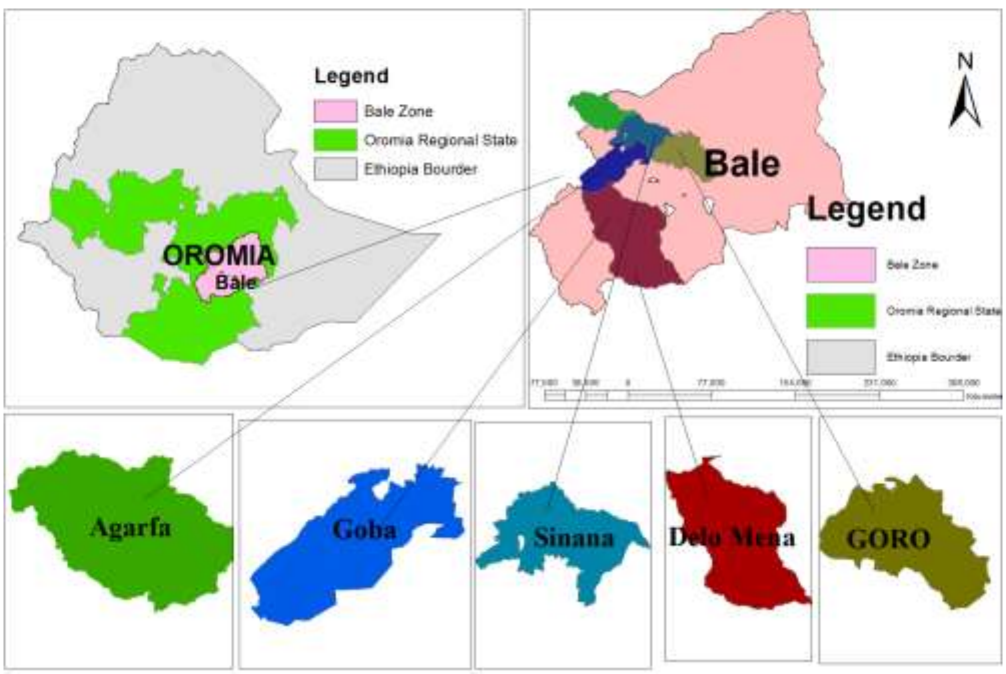


Figure 3. Map of Agarfa, Goba, Sinana, Dello Menna and Goro Distrcts of Bale zone, Southeast Ethiopia

Climatic Condition

The study was conducted in Agarfa, Dello Menna, Goba, Goro and Robe districts of Bale. When we the overall mean temperature of the study area is ranges 13.1 - 22.5°C. The rainfall pattern of the area is grouped as bimodal rainfall pattern which the annual totally of rainfall of the area is ranges between 806.9 - 1066.7 ppm.

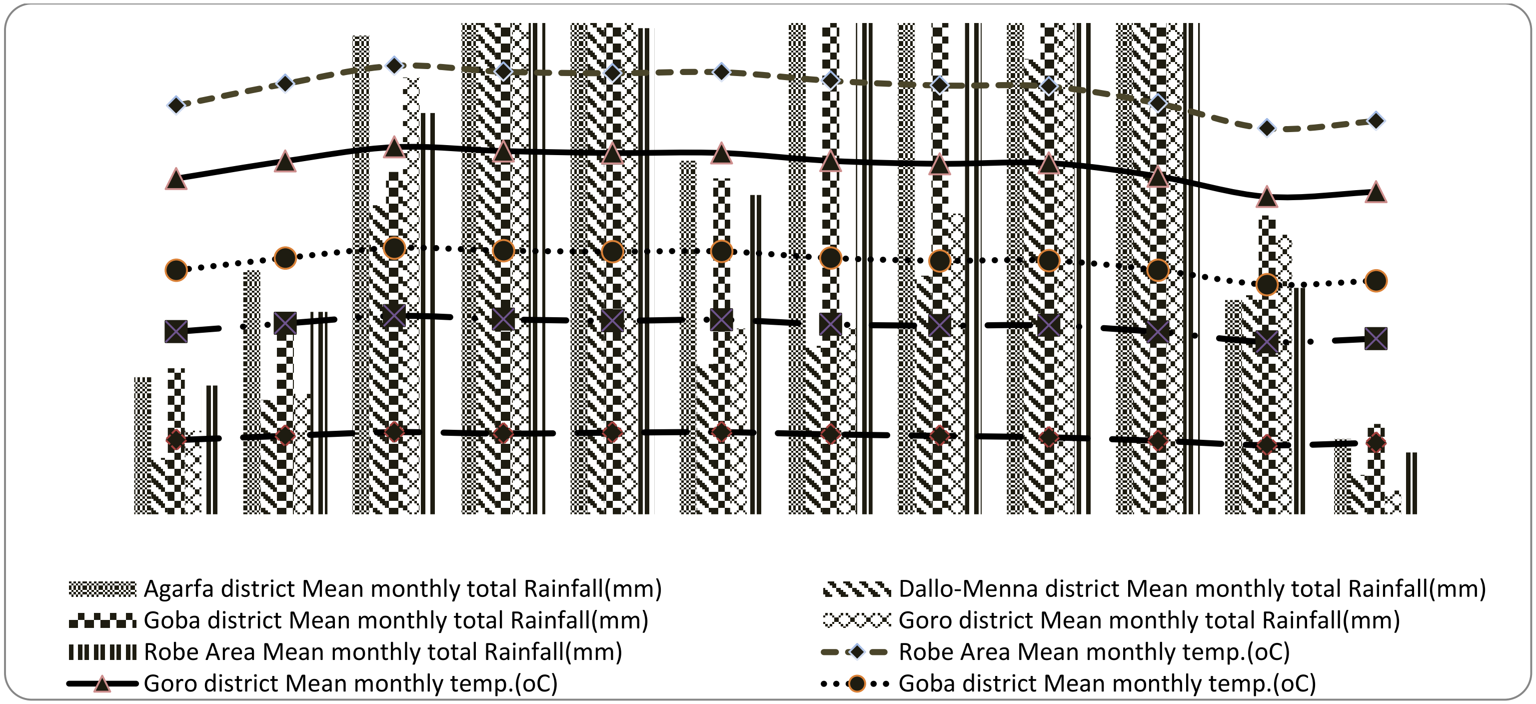


Figure 4. Mean annual temperature and rain fall distribution (2019) of Agarfa, Dello Menna, Goba, Goro and Robe districts of Bale

Sampling Techniques, Data Collection and Analysis

During this study the site was selected purposely based on land use type, type of planted species and age categories. From all location two land uses those are Eucalyptus plantation and Crop land use system was selected. From the Eucalyptus land use four types of Eucalyptus species those are *Eucalyptus globulus, Eucalyptus camaldulensis, Eucalyptus saligna* and *Eucalyptus citrodora* was selected based on age categories. The soil sample was collected based on systematic sampling approach. From each land uses the soil sample was collected from five points. During soil sampling from each land uses the sample was collected from three depth (0-15cm, 15-30cm and 30-45cm) of the soil for each systems. To get the accurate result and to minimize the error, the data collection was carried during the dry season at the month of January to February 2019. According to our context the selected month is the typical dry season of the district. This is used to get the exact moisture content of the soil.

Data Analysis

The samples were air dried in the laboratory, ground with wooden mortar and passed through 2mm nylon sieve, finally packed in the polythene bags and labeled for conducting analysis as per standard.

The soil sample was analyzed based on the following procedure.

Soil particle size distribution (texture): was analyzed using Bouyoucos hydrometer method following the procedure described by Bouyoucos (1962).

Soil pH: was measured potentiometrically using a pH meter with combined glass electrode in 1: 2.5 soil to water ratio:

Soil electrical conductivity (EC): was measured in 1:5 (soil to water ratio) (Ryan *et al.*, 2001).

Soil organic carbon content: was determine using Walkley and Black (1934) wet digestion method.

Percent soil OM: was obtained by multiplying percent soil organic carbon by a factor of 1.724.

Available P: was carried out by the Olsen method using sodium bicarbonate as extracting solution (Olsen *et al.,* 1954).

Statistical Analysis

Soil parameter for all land uses was analyzed by using one way ANOVA. Mean comparison of the four systems interims of soil depth and land uses were tested by least significant difference (LSD) test at $P < 0.05$ by using SAS statistical software version 9.1.

Result and Discussion

Soil Physical Properties in Eucalyptus Species Plantation and Crop Land Use Systems

The results of the laboratory showed that a high percentage of clay was observed in all soils across all locations. From all textural class over 50% clay concentrations were recorded in between 0-45cm soil depths. The soil texture was classified as Clay both for the Eucalyptus and crop land uses.

Table 3. Particle size distribution (%) in the different land use systems and depths, 0-15 and 15-30, 30-45 (n=5)

Land use	Soil Depth (cm)	Fine Sand %	Clay %	Silt %	Textural Class
Dello Menna *Eucalyptus saligna* plantation	0 – 45	3	78	19	Clay
Dello Menna *Eucalyptus citrodora* plantation	0 – 45	15	58	27	Clay
Dello Menna *Eucalyptus camaldulensis* plantation	0 – 45	5	74	21	Clay
Dello Menna Crop land use system	0 – 45	3	88	9	Clay
Robe *Eucalyptus camaldulensis* plantation	0 – 45	5	74	21	Clay
Robe Crop land use system	0 – 45	5	68	27	Clay
Goro *Eucalyptus camaldulensis* plantation	0 – 45	9	64	27	Clay
Goro Crop land use system	0 – 45	13	52	35	Clay
Agarfa *Eucalyptus globules* plantation -1	0 – 45	11	68	21	Clay
Agarfa *Eucalyptus globules* plantation -2	0 – 45	13	54	33	Clay
Agarfa Crop land use system	0 – 45	5	76	19	Clay
Goba *Eucalyptus globules* plantation	0 – 45	9	52	39	Clay
Goba Crop land use system	0 – 45	23	44	33	Clay

Table 4. Soil Moisture Content under Eucalyptus plantation and Crop land systems

Agarfa

Land use	Moisture Content %
Eucalyptus globules-1	29.83 (± 4.76)[a]
Eucalyptus globules-2	26.30 (± 3.52)[b]
Crop land	28.79 (± 7.50)[a]
Mean	28.30 (± 5.59)
P-value	< .0001
CV	9.71

Dello Menna

Land use	Moisture Content %
Eucalyptus saligna	21.16 (± 3.24)[b]
Eucalyptus citrodora	21.01 (± 1.65)[b]
Eucalyptus camaldulensis	23.23 (± 3.87)[a]
Crop land	18.04 (± 4.47)[c]
Mean	20.86 (± 3.86)
P-value	< .0001
CV	12.39

Goba

Land use	Moisture Content %
Eucalyptus globules	23.05 (± 2.76)[a]
Crop land	12.96 (± 16.56)[b]
Mean	18.00 (± 12.74)
P-value	0.0005
CV	7.74

Goro

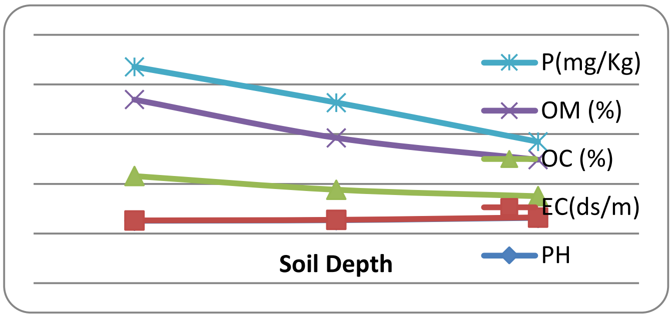
Land use	Moisture Content %
Eucalyptus camaldulensis	30.57 (± 15.88)[a]
Crop land	36.48 (± 37.02)[a]
Mean	(± 28.15)
P-value	0.2371
CV	9.63

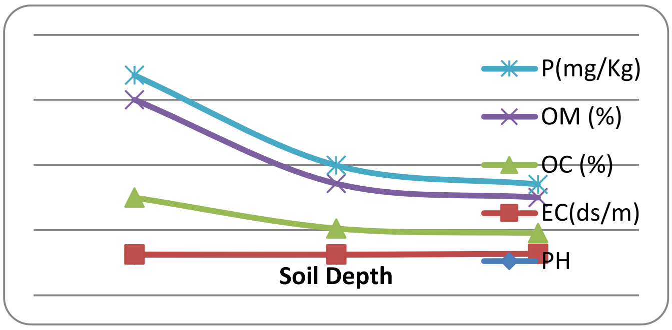
Robe

Land use	Moisture Content %
Eucalyptus camaldulensis	28.78 (± 3.74)[a]
Crop land	20.74 (± 6.56)[b]
Mean	24.76 (± 6.65)
P-value	< .0001
CV	10.09

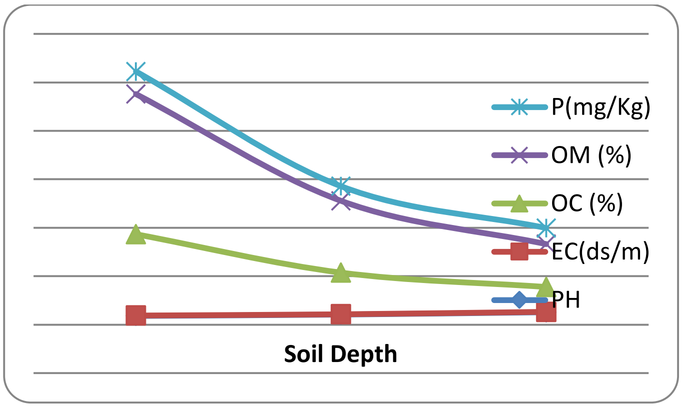
Soil Chemical Properties under Different Depths in Different Land Use

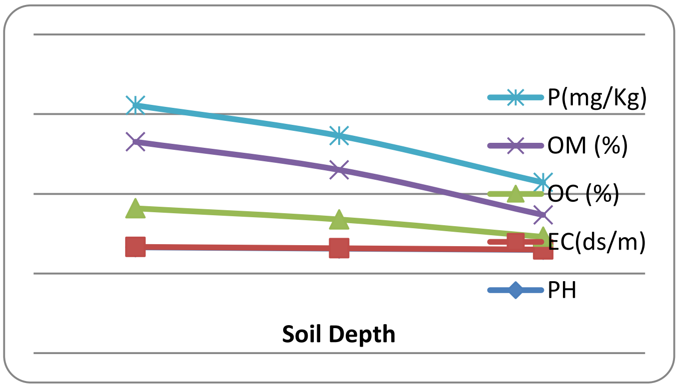
Agarfa crop land use system b) Agarfa *Eucalyptus globules* plantation -1



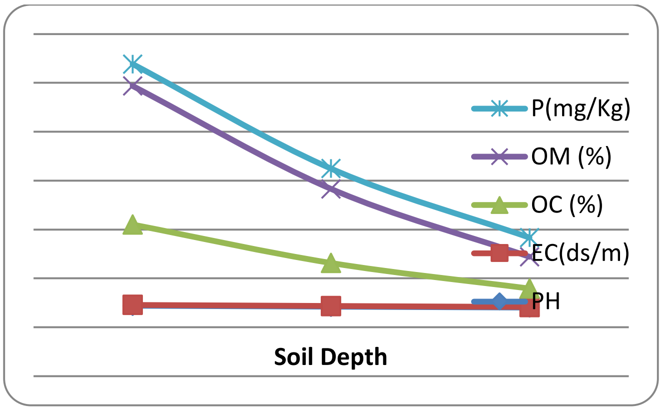


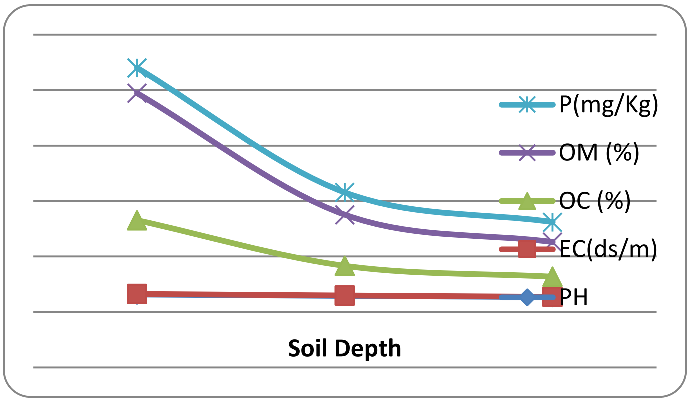
C) Agarfa *Eucalyptus globules* plantation -2 d) Dello Menna crop land use system





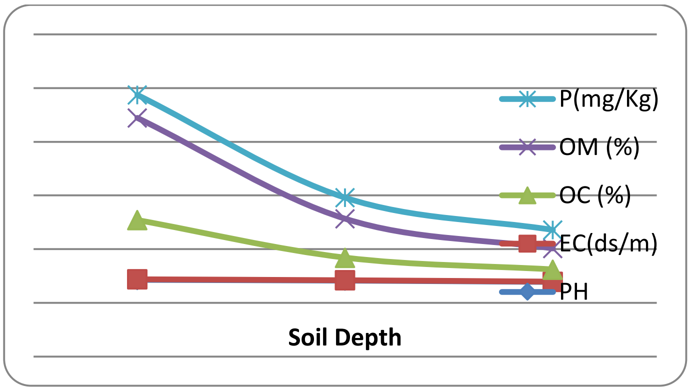
e) Dello Menna *Eucalyptus camaldulensis* plantation f) Dello Menna *Eucalyptus citrodora* plantation

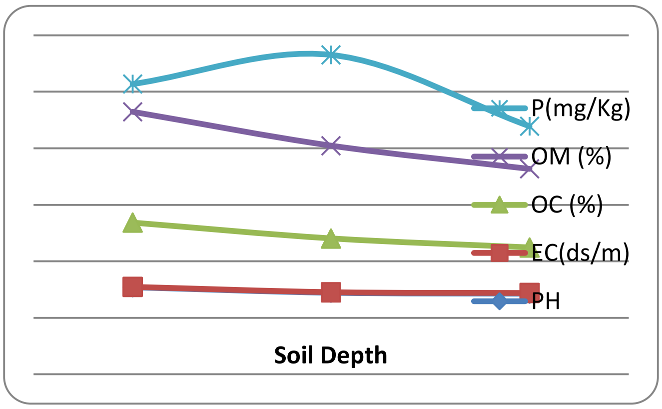




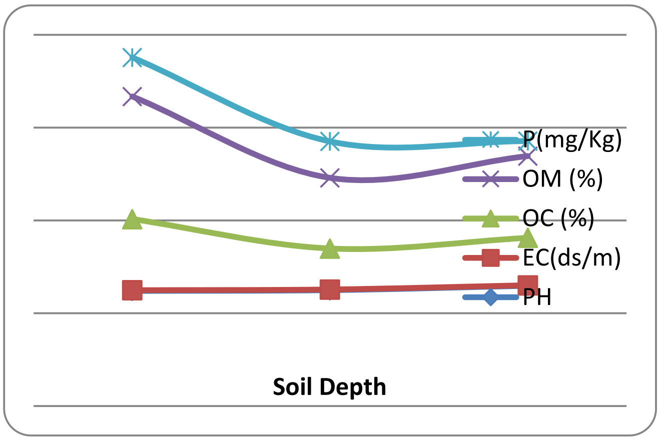
g) Dello Menna *Eucalyptus saligna* plantation

h) Goro crop land use system

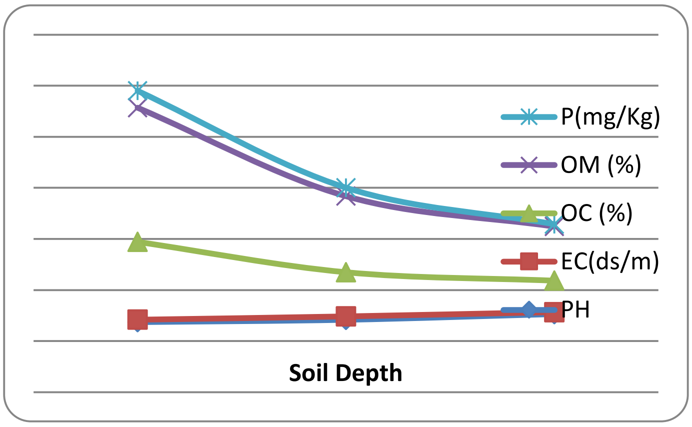




i) Goro *Eucalyptus camaldulensis* plantation

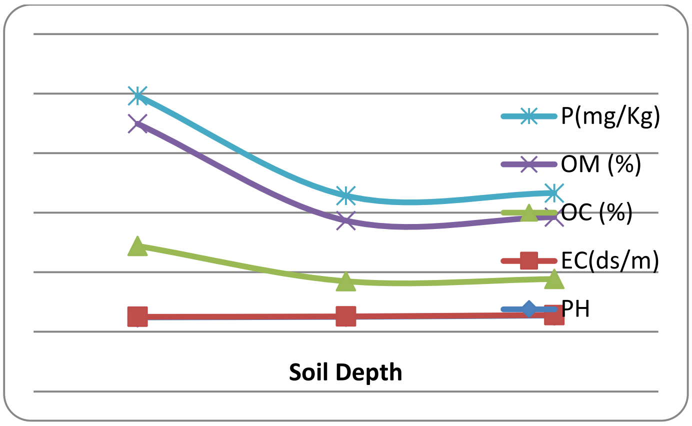


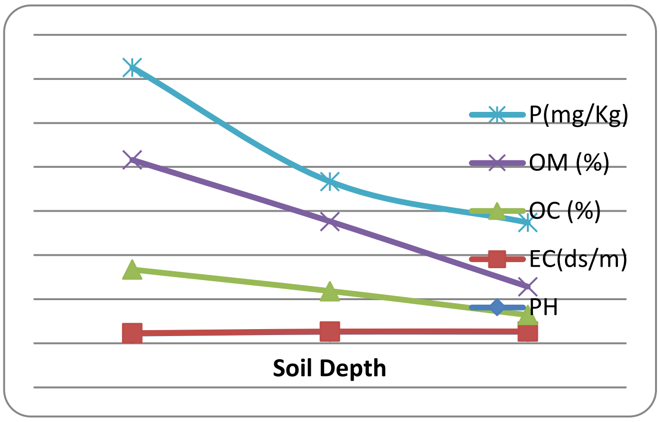
j) Robe crop land use system



k) Robe *Eucalyptus camaldulensis* plantation

l) Goba crop land use system





m) Goba *Eucalyptus globules* plantation

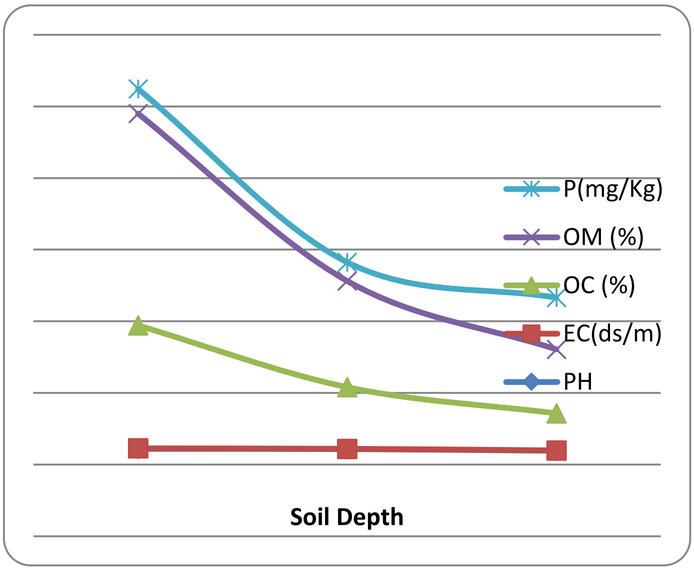


Figure 5. Physico-chemical properties of under different depth of Eucalyptus plantation and crop land

Table 5. Chemical properties of soil under Eucalyptus plantation and crop land systems

a) Agarfa

b) Dello Menna

Land use	PH(±SD)	EC(±SD)	OC(±SD)	OM(±SD)	P(±SD)
Eucalyptus globules-1	6.25(±0.04)^{b}	0.04(±0.003)^{a}	5.30(±0.71)^{a}	9.14(±1.23)^{a}	2.86(±0.62)^{a}
Eucalyptus globules-2	6.08(±0.06)^{c}	0.03(±0.004)^{a}	5.09(±0.77)^{a}	8.77(±1.33)^{a}	1.83(±0.35)^{a}
Crop land	6.41(±0.04)^{a}	0.04(±0.001)^{a}	3.21(±0.29)^{b}	5.53(±0.50)^{b}	2.89(±0.63)^{a}
Overall Mean	6.24(±0.03)	0.04(±0.002)	4.53(±0.38)	7.81(±0.66)	2.53(±0.32)
P- Value	< .0001	0.0501	< .0001	< .0001	0.2793

Land use	PH(±SD)	EC(±SD)	OC(±SD)	OM (±SD)	P(±SD)
Eucalyptus saligna	7.05(±0.14)^{a}	0.04(±0.01)^{b}	2.92(±0.56)^{bc}	5.03(±0.97)^{bc}	1.94(±0.07)^{b}
Eucalyptus citrodora	7.11(±0.06)^{a}	0.07(±0.01)^{a}	4.84(±0.79)^{a}	8.34(±1.36)^{a}	2.09(±0.07)^{ab}
Eucalyptus camaldulensis	6.47(±0.06)^{b}	0.03(±0.01)^{b}	3.71(±0.58)^{ab}	6.39(±0.99)^{ab}	2.03(±0.07)^{ab}
Crop land	6.56(±0.04)^{b}	0.02(±0.00)^{b}	1.68(±0.22)^{c}	2.89(±0.38)^{c}	2.15(±0.07)^{a}
Overall Mean	6.80(±0.06)	0.04(±0.00)	3.28(±0.32)	5.66(±0.55)	2.05(±0.04)
P-value	< .0001	0.0003	< .0001	< .0001	0.0001

c) Goba

Land use	PH(±SD)	EC(±SD)	OC(±SD)	OM(±SD)	P(±SD)
Eucalyptus globules	6.04(±0.07)^{a}	0.03(±0.00)^{b}	5.16(±0.75)^{a}	8.89(±1.29)^{a}	2.21(±0.72)^{a}
Crop land	6.23(±0.08)^{a}	0.04(±0.00)^{a}	4.56(±0.69)^{a}	7.85(±1.19)^{a}	7.42(±3.28)^{a}
Overall Mean	6.14(±0.05)	0.04(±0.00)	4.86(±0.50)	8.37(±0.87)	4.82(±1.72)
P- Value	0.2753	0.0284	< .0001	< .0001	0.4188

d) Goro

Land use	PH(±SD)	EC(±SD)	OC(±SD)	OM(±SD)	P(±SD)
Eucalyptus camaldulensis	7.19(±0.18)^{a}	0.25(±0.06)^{a}	5.01(±0.62)^{a}	8.63(±1.08)^{a}	0.91(±0.36)^{a}
Crop land	7.35(±0.11)^{a}	0.05(±0.00)^{b}	4.83(±0.21)^{a}	8.32(±0.37)^{a}	4.75(±2.01)^{a}
Overall mean	7.27(±0.10)	0.15(±0.03)	4.92(±0.32)	8.47(±0.56)	2.83(±1.07)
P-value	0.7097	0.0106	< .0001	< .0001	0.2264

e) Robe

Land use	PH (±SD)	EC(±SD)	OC(±SD)	OM(±SD)	P(±SD)
Eucalyptus camaldulensis	6.29(±0.06)^{a}	0.04(±0.00)^{a}	3.9(±0.55)^{a}	6.85(±0.95)^{a}	2.15(±0.04)^{a}

Crop land	6.31(±0.05)[a]	0.03(±0.00)[a]	2.86(±0.39)[b]	4.94(±0.67)[b]	1.62(±0.45)[a]
Overall mean	6.30(±0.04)	0.04(±0.00)	3.42(±0.35)	5.89(±0.60)	1.89(±0.23)
P-value	0.1048	0.2604	0.0036	0.0036	0.3037

Discussion

According to different studies monoculture plantation forestry may affect soil physical and chemical properties in two different ways. That through direct depletion from the soil into the tree component, and changes in the chemical status of the soil surface as the litter layer is dominated by leaf fall derived from one species. In the case Moisture content, even if the statically difference for most of the location, except for Goro district, for the other districts (Agarfa, Dello Menna, Goba, Robe) the amount of moisture content is higher in the soil under Eucalyptus plantation land uses than crop land.

When we see the overall mean depth wise comparison of the whole land uses (Agarfa crop land use system, Agarfa *Eucalyptus globules* plantation-1, Agarfa *Eucalyptus globules* plantation-2, Dello Menna crop land use system, Dello Menna *Eucalyptus camaldulenis* plantation, Dello Menna *Eucalyptus citrodora* plantation, Dello Menna *Eucalyptus saligna* plantation, Goro crop land use system, Goro *Eucalyptus camaldulenis* plantation, Robe crop land use system, Robe *Eucalyptus camaldulenis* plantation, Goba crop land use system and Goba *Eucalyptus globules* plantation) as the depth increases the overall mean potential of soil physiochemical properties in PH, OC%, OM% and available P is decreases . But in the case Electronic conductivity (EC) as the depth increase the concentration is slightly increases.

In Agrfa district, when we compare the Eucalyptus land use with the crop land, the overall PH mean value is statistically different. In this district the PH level of the whole land uses are varied from 6.08-6.41. This shows that the soil of the area is categorized under slightly acidic soil type in nature. Even if there is statically difference between the land uses, the highest PH value (6.41) is recorded in crop land than Eucalyptus land which is more nearest to neural. For EC there is no statically difference between the land uses. The overall mean EC of the district 0.04ds/m which grouped under non saline soil type. In terms of %OC and %OC there statistically difference among the land uses and the highest value is observed in the soil under Eucalyptus plantation than crop land. For OM the value of the district is ranged from 5.53% - 9.14% which is rating under high level concentration. For available phosphorus (P) there is no difference between the land uses and the observed available P potential of the whole land uses are grouped under very low class.

In Dello Menna district there is statistical difference for PH and the highest value was recorded in *Eucalyptus saligna* (7.05) and *Eucalyptus citrodora* (7.11) which is base in nature. When we categorize the PH level of the whole land uses, they are grouped under neutral PH level. In terms of EC, the soil around the area is categorized under non-saline soil type and the highest EC value was recorded in the sol under *Eucalyptus citrodora* plantations (0.07ds/m). But there is no statistical difference among the other land uses. In the OM and OC% the high concentration level is observed in the soil under Eucalyptus plantation land uses than crop land. In the case of available P level, even though there is statistical different, the area is grouped under a very low concentration level. For OC and OM the highest percent is observed in the soil under *Eucalyptus citrodora* plantation. Generally overall OM% and OC% potential of the district is grouped under high concentration level. When we see the available P, they have very low in terms of the concentration level and the highest value is in the crop land uses (2.15mg/Kg).

In Goba district there is no statistical difference in PH, OM% and OC% among the land uses. The PH level shows that the soil is grouped under slightly acidic type. For EC they are grouped under non-saline soil type. In terms of OM and OC% even though there is statistical difference between the land uses as the other district the highest concentration is recorded in the eucalyptus land uses than crop lands. In the case of OM and OC percent as the other location of Bale district they have high potential in organic matter and organic carbon percent. For EC and P the largest value is recorded in crop land uses than in the soil under *Eucalyptus* plantation land uses. Generally the available P of the district is grouped under a very low level.

In Goro district there is no statistical difference in PH, OC and OM soil chemical characteristics. The PH level of the area is grouped under neutral soil class level. In terms of EC there is statistical difference between the land uses and they are grouped in non- saline soil class. For EC the highest value is in the soil under *Eucalyptus camaldulensis* than crop land uses 0.25ds/m. For OM% and OC% even if there is no statistical difference between the land uses, the highest percent of concentration is estimated from the soil under eucalyptus plantation than crop land uses. The overall OM and OC percent the soil type of the area is categorized in higher level. In the case available P there is statistical difference between the land uses and the concentration level is grouped under very low class level. Due to several factors the largest values is recorded in crop land uses (4.75mg/Kg) than the other system.

In Robe district there is no statistical difference among the land uses in all soil chemical properties. Except for available P for the remaining parameter (PH, EC, OC, OM) there is no statistical difference between the land uses. The PH level of the district is categorized under slightly acidic soil level. For EC the soil is categorized in the non-saline soil type. For OC% and OM% even if there is no difference between the land uses the amount of OM% in the Eucalyptus plantation is categorized in the high concentration level. For OM and OC percent the concentration is ranged from moderate up to high potential. But for available P even if there is a difference between them both land uses are grouped in a very low level.

Conclusion and Recommendation

When we see the overall mean wise comparison of the whole land uses as the depth increases the overall mean potential of soil chemical properties in PH, OC%, OM% and available P is decreases. But in the case Electronic conductivity (EC) as the depth increase the concentration is slightly increases. In the case moisture content, except for Goro district, for the other districts (Agarfa, Dello Menna, Goba, Robe) the amount of moisture content is higher in the soil under Eucalyptus plantation land uses than crop land. This may be due to deep rooted and huge amounts of lateral root nature of the species which contributed to the strong moisture attraction capacity of the species.

When we see the general overview of the land uses, there is no significant differences are observed between Eucalyptus plantation land uses and agricultural land use. Even in most of the parameter especially in soil organic carbon and soil organic matter the highest value were recorded in Eucalyptus plantation land uses than agricultural land use. This is due to the recycling of nutrient through decomposition of different tree parts. In terms of agricultural land due to cereal crop intensive agriculture, most the soil nutrient is depleted.

When we see the nature of Eucalyptus trees species, they have the capacity of extracting large amounts of soil nutrient and moisture from the soil. At the same time they have the potential of building large amounts of biomass than any other tree species. But if the rotation age of the tree is not properly managed the rate of biomass construction is reduced and they loss huge amount of soil nutrient and moisture. In addition to this due to its large amounts soil nutrient and moisture attraction capacity of Eucalyptus trees species the place where the tree was planted also take in to consideration and it must be far from the crop field.

Generally due to its large computation capacity of the Eucalyptus species, even if it is based on the agro ecology it is not recommended for intercropping, adjacent to crop filed and it must be far from river banks. Therefore when we conclude this study, if we are planting Eucalyptus tree species in appropriate place and if we are mange properly(silvicultural practices and timely cutting), Eucalyptus plantation have positive impacts on soil physical and chemical property through decayed litter than intensively cultivated crop land.

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Evaluation of Coffee growth, yield and quality under coffee shade trees at Mechara on Station, West Hararghe zone, Ethiopia

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Abstract

Coffee production with shade trees is important to improve growth and quality of coffee, sustain and restore agroecology and nature based agroforestry practices. The trial was conducted at Mechara Agricultural Research Center (on station) in DaroLebu District of West Hararghe Zone, Oromia, Ethiopia. The study was intended to evaluate the influence of coffee shade trees on growth performance, yield and quality of coffee (Coffea arabica L.) under the canopy of Erytherina absinica, Cordia africana and Acacia sieberiana. The design was Randomized complete block design with three replications. The outcome had been observed a significant value at ($p<0.05$) probability level, non- significant value at ($p>0.05$) probability level and highly significance value at ($p<0.01$) probability level between treatments. Statistically significant and non- significant differences were observed between shaded and unshaded as well as within shaded effect based on the given parameters. Integration of shade in coffee farming system created creditable promising in producing organic coffee. Shade utility could be confirmed as to be ecologically sustainable, economically viable and socially acceptable practice. In so doing that, the effect of Erytherina absinica, Cordia africana shade trees illustrated the highest mean value in most parameters, while the least one is under the Acacia sieberiana shade tree. So the effect of Erytherina absinica mean observed with the highest value on total bearing plants 60%, thousand seed weight 59% and yield in Quintal per hectare 47.4% greater than the least treatments' mean value based on growth parameters. On the other hand, the effect of Erytherina absinica mean observed with the higher value on aromatic intensity 46.4%, aromatic quality 87.2%, acidity 92.4%, body 93.5%, flavors 88.6% and overall quality 88.6% than the least treatments' mean value, and also the effect of un-shade mean observed with the higher value on astringency 68.8% and bitterness 93.5% than the least treatments' mean value based on organoleptic parameters. The highest mean value of Erytherina absinica observed on total bearing plants 12.1, thousand seed weight 130 gram and yield in Quintal per hectare 5.7 based on growth parameters, while based on organoleptic parameters, the highest mean value observed under the effect of Erytherina absinica shade tree on aromatic intensity 4.5, aromatic quality 3.9, acidity 7.9, body 7.7, flavors 7.9 and overall quality 7.9. Therefore, based on the most treatments' parameters, to be the best shade tree was Erythrina abyssinica followed by cordia africana. Commonly, the dynamic indication of the treatment's means difference were indicated between shaded and unshaded rather than within shaded means variation at most treatments' parameters.

Keywords: *Coffee-based agroforestry system, Coffee shade value, coffee growth and Coffee quality attributions.*

Introduction

Coffee is originated in the forest of East Africa that is in Ethiopia. It is adapted traditionally under the shade in order to pretend its natural habitat accounting for the fact that it has evolved to fit the normal physiological and structural characteristics. Coffee (*Coffea arabica L.)* is the most important agricultural shade lover goods and half of world's people take it in daily life process that more than 400 billion cups of coffee are consumed each year, which is exported from developing nations as to be the major source of foreign currency earnings (Illy E, 2002; Grades, 2007; Ferrell, J. and Cockerill, K, 2012). The value of coffee for producers' country about $ 14 billion annual income generator and more than 18 countries, including Ethiopia, export coffee product to more than 165 countries providing a livelihood for an estimate of 100 million people around the world (ICO, 2001). Thus among 25 coffee producers, from African continent, Ethiopia is the first largest producer and the fifth of the world after Brazil, Vetinam, Indonesia and Colombia (AfDB, 2010).

Recently, coffee production with shade tree is the best example of agroforestry practice, which is to be improved environmental function and non-marketable ecosystem services such as recycling nutrients, providing habitat of biodiversity, maintaining natural resource as well as improving growth and quality of coffee, fodder for livestock production and increasing alternative income to the society from the sale of timber and non- timber forest products (Michiel *et al.,* 2004; Soto-Pinto *et al*., 2010; Geta *et al.,* 2014; Ríos and Ferguson, 2015; *et al.,* 2016).

Therefore coffee plant needs shade naturally on behalf of sustaining its production with reduces over-bearing, avoids branch die-back, disallows disease, and maintains growth parameter or physical yield and improves organoleptic quality. Coffee shade had an effect on physical yields of coffee plant such as number of branch, number of node per branch and number of fruit per node, and organoleptic qualities such as shape and make, color, bean size, aromatic intensity, aromatic quality, acidity, astringency, bitterness, body, flavor and overall quality (Mark, 2005; Alemayehu *et al.*, 2017; Alemayehu, 2017).

In the reverse, sun grown coffee increase the level of metabolism and improper morphological growth which are exposes for premature death of coffee plant, branch dieback, over bearing of fruits, fluctuation of fruit bearings, intensive use of chemical fertilizers, insecticides, herbicides, fungicides and need more management. These could be resulted for undermine of organic coffee yields and decreased the leading perineum price of coffee market (Mark, 2005).

However; coffee production in Ethiopia is high, the immense human pressure consumes forest coffee for different socio-economic utilities and mainly because of unsustainable resource use is one of the constraints for coffee production in the country. Hence farmers have cleared natural forest and around their farms for timber, firewood, construction, cultivation of other crops, settlement and establishment of plantations is also causing a reduction of the forest cover leading to destruction, fragmentation and degradation of the coffee habitats. On the other hand, only a few shade tree species are used in a limited area of coffee producers (Grades, 2007: Tadesse et al, 2008).

Generally, in Ethiopia as population number has been increasing, while cultivable land shortage is creating then many coffee grower farmers abandoning their traditional system to intensive production through integrating of food crops with coffee production without shade trees. Especially this scenario has been appearing truly in west Hararghe zone of coffee producer districts. Thus, gradually the genetic resource of *Coffe*a *arabica* which is shade lover has been disappearing at an alarming rate from the area, this rendering it for premature death of coffee plant, branch dieback, disease, over bearing of fruits, fluctuation of fruit bearings and undermines organic coffee quality (Gole *et al.*, 2002; Bote and Struik, 2011; Alemayehu *et al*., 2017).

Therefore, to change these trends; evaluation of coffee shade tree species and its effect on coffee growth parameters, raw and cup coffee beans' quality had been evaluated in order to amend the value of coffee shade trees based on the following objectives.

Objective:

- To select the suitable coffee shade tree species
- To evaluate the effect of coffee shade trees on coffee growth, yield andOrganoleptic coffee beans' quality

Materials and Method

Description of the study area

The trial was conducted at Mechara Agricultural Research Center (on station). The center is located at 431 Km west of Addis Ababa. The altitude is 1780m a.s.l. Rainfall pattern in the area is bi-modal; *kiremt* rainy season (June, January, August and September) and *belg* rainy season (February, March, April and May). Average annual rainfall amount is 1145 mm.

High amount of rainfall is received in the April (l188 mm) and May (1395 mm) during the *belg* rainy season whereas high amount of rainfall is received in the month of July (1180 mm) and August (1462 mm) in the *kiremt* rainy season. Mean annual temperature is 21°C with mean annual minimum temperature of 13°C and maximum 27°C (Mechara agricultural research center, meteorological station 2009-2017 intervals) Figure 2. Soil of study 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. The vegetation cover of the area is woodland and open wooded grassland types.

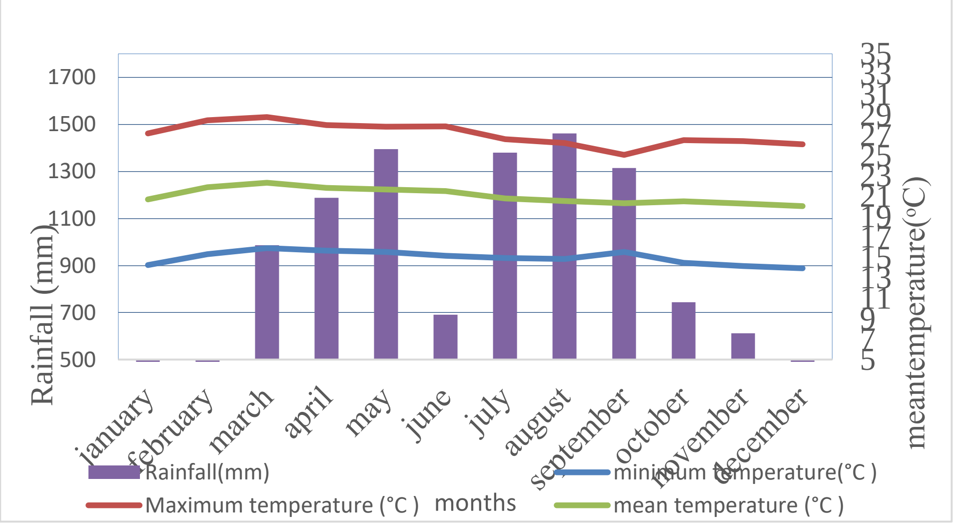

Fig.1. Rain fall and temperature of the study area from 2009-2017 years

Source: (*Mechara Agricultural Research Center, meteorological station data)*

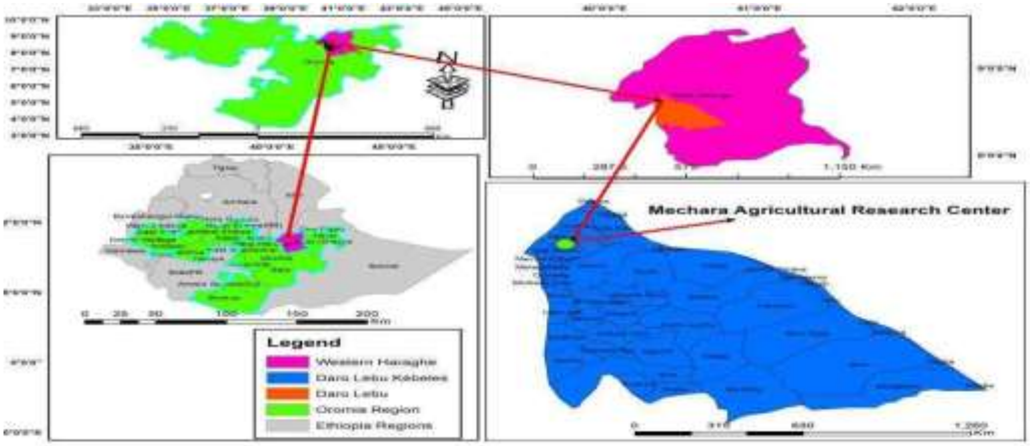

Figure 2, Map of the study area

Treatments and Experimental Design

The selected coffee seed was (Mechara-1 Varity) that secured from Mechara Agricultural Research center. Coffee shade seeds were collected from surroundings Mother Trees. The collected seeds were sown directly on seed beds with polythentub plastic bags that were filled with 3 part local soil: 2 part sand: 2 part farmyard manure based on its time taken. The seedlings were raised at coffee nursery site of Mechara Agricultural office following the expected nursery recommendation practices. Seedlings of coffee shade trees (*Erytherina absinica, Cordia africana* and *Acacia sieberiana*) were planted in spacing of 4m distance from each other before one year of coffee seedlings plantation. Then, the planting pits of coffee seedlings were prepared on experimental site with 2mx2m space gap between coffee plants and rows, and 4m gap between each plotsand between reps. The total number of plot was 12 in 3 replication with 3 shade tree species.

Finally, when the seedlings were reached for planting with the size of (25-35cm) and they were transplanted towards the experimental field in Randomize Completely Block Designed (RCBD) in three replications. One plot had 16 coffee plants and 4 shade tree plants; one shade tree to be shaded for 4 coffee plants. A plot was contain only the same shade tree species. As a control, three plots were planted with 48 coffee seedlings without coffee shade tree species.Whereas 144 coffee plants were planted under 36 shade trees (12 shade trees species in one rep from each species). The plantation area was 1672 m^2 that 38m *44m.

Coffee Sample Process

The necessary data was collected starts the planting of coffee plants up to the coffee beard the beans. There was twelve representative coffee plants were demarked from each plot of shaded and unshaded part that purposively selected and assigned for sample collection. Then, six coffee branches were selected and marked from the lower, middle and upper stick branch from west and east directions for each sample of coffee plants. The cherries were collected at the time of full ripping period, after planting of 5 years old. The coffee was too let to give a yield due to drought problem for three years of growing time, so the true yield was collected after six years ago.

The sampled branches were counted and the number of fruits per node per branch was identified, which had been used to estimates yields of coffee per plant per hectare. The yield estimation was done based on sensibly with the logic of conversion factor that changing red cherries yield to clean coffee yield. Hence, the reasonable suggestion was taken based on the yield had been gained by correction factors (Hernández, 1995). 4kg of fully ripe coffee cherry beans were collected from each sampled plot and branch of coffee plants. Under both shaded and unshaded coffee trees, there were 36 samples of coffee bean were collected. The harvested coffee bean was dried until a constant moisture content of 12%. Then dry coffee beans were weighted using digital measuring balance on basis of 1000 seed weight of shaded and unshaded coffee plants from each coffee bean samples based on the procedures of (Siles *et al.,* 2010; Bote and Struik, 2011).

Coffee Cherries Drying and Packing

The oldest and simplest method producing' natural' coffee is 'sun drying' that has been adopted throughout all coffee growing areas in Ethiopia, and this system was the only processing method. The cherries were spread out evenly on mesh wire to dry in the sun. Each sample cherries were dried until the recommended moisture content of 11-12% was attained. Then after, the sample cherries were hulled with mortar as farmers have been practicing carefully and cleaned. Finally, the green coffee beans were labeled and packed in transparent polyethylene bags where berries stabilize their moisture content and quality attribute. The packed dry coffee bean was then transported to Jimma Agricultural Research Center for determination of the raw and cup coffee quality. The packed and collected samples were prepared using proper method of processing and arbitrary code (identity letter) was assigned to secure unbiased judgment. The packed dry coffee bean samples were transferred to coffee quality laboratory at Jimma Agriculture Research Center to evaluate the quality, based on the physical, raw, aroma and cup attributes.

Screen Size of Coffee Beans

Bean sizes were determined by conventional screen analysis of perforated plate screen sizes of 14 with respective whole diameter of 5.55mm (Wintgens, 2004). 300g of each coffee samples were replicated three times and measured using digital beam balance.

The coffee beans were graded by 'size using standard screen' that have different screen size, with 'round holes' as defined by (ISO, 1991). The normal sizes of coffee beans were remained over the screen in order to determine their normality percentage while undervalued and broken beans were separated from each sample. Finally, the defect count percentage was recorded as per national fixed standard (JARC, 2008).

Raw coffee quality grade evaluation

During physical quality analysis; 300g of green bean was used for each sample for their qualities attribute such as 'shape and make', color and odor. These quality attributes were measured according to the Ethiopian standard that based on raw quality parameters' grading was done in account of 40% as per ((ES, 2001; ECX, 2009).

Aroma and Cup Quality Grade Evaluation

Three cups per treatment in three replications were prepared for each tasting session. The evaluation had been carried out by a panel of Jimma Agricultural Research Center panelist who formed a team of trained, experienced and certified quality Graders and Cuppers in order to get aroma and cup quality values in account of 60%. In this case, three experienced tasters participated in a panel to evaluate coffee bean samples' aroma and taste characteristics of each treatment of coffee brew involving olfaction, gestation, and mouth feel sensation. For each sample using the round soup spoon raise six to eight cc of liquid to just in front of the mouth and forcefully slurp the liquid. Aroma was evaluated by sensation from brewed coffee that released gasses.

The released gasses were inhaled through the nose by sniffing and briskly/quickly aspiring, the coffee. In this way, spread evenly over the entire surface of the tongue. Sensory evaluation was done using the following quality criteria in scale range of (AI, AQ, AC, AS, BI, BD, FL and OAQ) value. Based on these measures, the scale comprised the point ranged from 1-15 was used. The sensation was obtained from the gases released from roasted and ground coffee beans as aromatic compounds. In order to evaluate sample of ground coffee quality, the gasses were inhaled through the nose with sniffing/smelling aroma and the inhaling process revealed the nature of coffee bean taste /typicity such as floral, moca, spicy, etc.

Data collection

Table 1, Data of coffee shade trees, growth and yield of coffee, and quality of raw and cup coffee beans

Growth and yield parameter of coffee plants	**Aroma and cup coffee beans' quality parameters**
Number of branch	Aromatic quality
Number of node per branch	Aromatic intensity
Number of branch dieback,	Acidity
Number of fruit per node, Number of bearing coffee plants	Astringency Body and Bitterness
1000 seeds weight in gram,	Flavor
clean yield in quintal per hectare	Overall quality
The growth parameter of shade trees:	**Raw coffee beans' quality parameters**
Canopy coverage	Screen size of coffee beans
Diameter(DBH)	Shape and make
Height	Color and odor

Data analysis

The collected data was analyzed with analysis of variance (ANOVA) following the General Linear Model (GLM) procedure using SAS statistical software of 9.1.3 versions. The important variation, mean separation using LSD was conducted at 5 % point of significance level.

Result and Discussions

Canopy Coverage, Height and Diameter at Breast Height of Coffee Shade

Table 2: The mean value of Coffee shade tree growth parameters

Coffee shade	Ccrg (m)		DBH(cm)
Acacia sieberiana	6.8a	4.4a	13.9a
Cordia africana	5.1b	3.9a	8.4b
Erythrina abyssinica	2.6c	2.7a	7.1b
LSD (5%)	1.5	2.3	5
CV (%)	13.5	27.9	22.6
Ccrg= Canopy coverage, PH= plant height in meter, DBH= Diameter at breast height=meter; cm=centimeter			

The highest mean of *Acacia sieberiana* greater than the lowest mean of *Erythrina abyssinica* (61.8%) based on the Canopy coverage parameter (Table 2). Under the plant height, the height value greater than the lowest mean with (38.6%) on treatment of *Cordia africana* and Erythrina *abyssinica* respectively (Table 2). The highest and lowest means difference is (48.9%) that recorded under *Acacia sieberiana and Erythrina abyssinica* based on Diameter at breast height respectively (Table 2).

Generally, the higher yield could be found under the lowest canopy coverage that is Erythrina *abyssinica* shade tree, inversely the lowest yield also found under higher canopy coverage of *Acacia sieberiana* shade tree (Table 2). Similarly, canopy of shade has a positive effect on yield of per coffee plant, if the canopy coverage is between 15% and 54, otherwise less than or greater than these range, it has a negative effect on yield of per coffee plant (Gao, Yixuan, 2018).

Effect of Coffee Shade Trees on Growth and Yield of Coffee Plant

Number of Branch per Coffee Plants

Table 3, the mean value of coffee growth and yield under the effect of shade trees

Trt	Parameters						
	Nbrch	nndprbch	brcdbk	frtprnd	ttbplt	Sswt(gm)	yldQtl/ha
E.abyssinica	26.7ab	10ab	2b	6.7a	12.1a	130a	5.7a
C.africana	24.3ab	10ab	2.7b	6.7a	7.7a	119.3ab	5.3a
A.seiberina	20b	8.7b	3.7b	4.3a	7.3a	76.7b	2.7a

Un shaded	29a	11.3a	7a	7.3a	8a	106.7ab	3.8a
LSD (5%)	8.7	2.6	5.2	3.3	5.2	55.2	3.1
CV (%)	17	12.8	28.5	31	33.7	23	36
Nbrch=number of branch; nndprbch=number of node per branch; brcdbk=branch dieback; frtprnd=fruit per node; ttbplt=total bearing plants; Sswt(gm)=1000 seed weight; yldQtl/ha=yield in quintal per hectare							

The highest mean value of branch per coffee plant was observed at unshaded coffee plants, while the least mean value of a given treatment showed under *Acacia sieberiana* shade tree (Table 3). The mean value of number of branch per coffee plants showed statistically non-significant difference; but there is a variation between mean values numerically. So, the highest mean of unshaded coffee greater than the lowest mean of *Acacia sieberiana* is 31% based on the given parameter (Table 3). However; higher number of branches and number of node per coffee plant were recorded under unshaded coffee plants, the coffee plants physiologically stunted and deformed which were affected with branch dieback at the tip. Unlikely to other coffee shrubs which are found under shade trees effect.

In the contrary; the highest mean value of branch per coffee plant was observed under shaded coffee plant that due to a higher content of organic matter under the tree canopies than in the open area as higher addition of the litter falls, dead roots from the shade trees accumulated under the canopies then altered soil properties (Alemayehu *et al.,* 2017).

In general, this finding might be due to the effect of vary with age of shade, climatic variation, density, site conditions, management and particularly with soil fertility to modify light availability for specific requirements of both plants.

Number of Branch Dieback per Coffee Plants

The highest mean value of branch die back observed at unshaded coffee plants, while the least mean value of a given treatment showed under *Erythrina abyssinica* shade tree (Table 2). The mean value of number of branch dieback per coffee plant showed highly significant difference at ($p<0.01$) probability level based on the given parameters; therefore there is a variation between mean values statistically. So, the highest mean is greater than the lowest mean with 69% between treatment of unshaded coffee and *Acacia sieberiana* coffee plants (Table 3).

Similarly, unshaded coffee stands exposed to excessive evapotranspiration and sever water stress, death of actively growing branch, seasonal crinkling of leaves and subsequent yield reduction due to frost damages "hot and cold as well as bio-physiochemical disorder of coffee plants" (Taye *et al.,* 2007).

Generally, the number of branch dieback of per coffee plant was higher under unshaded coffee plants, while the least number of branch dieback was recorded under *Erythrina abyssinica* shade tree. This effect indicated that the shade tree might be increased the number of microorganism to decompose litter fall inputs in addition to other factors, which are to be a better attributers of positive effect for normal physiology of coffee plants.

Number of Node per Branch

The highest mean value of number of node per branch observed under unshaded coffee plants, while the least one showed under *Acacia sieberiana* shaded coffee plants (Table 3). The mean value of number of node per branch showed statistically non-significant difference between treatments based on the given parameters; but there is a variation between mean values mathematically. So, highest and lowest means difference is (24%) and that recorded the difference between under unshaded coffee plants and *Acacia sieberiana* shaded coffee plants based on number of node per branch (Table 3).

Number of Fruit per Node

The available mean value of number of coffee fruit per node showed statistically non- significant difference between a given treatments. But based on the mean difference, there is a variation between treatments that is 69% difference between the highest and the lowest value of number of fruit per node due to shade effect (Table 3). The shade has a positive effect on the yield of per coffee plant, if the canopy of shade tree is between 15% and 54% coverage unless it has negative effect on coffee yield (Gao Yixuan, 2018). Similarly the study of (Pinto *et al.*, 2000) approved that, when the canopy coverage exceeds the threshold ranges, it may decrease on the number of fruit per node or per coffee yield. Therefore; the lowest value of a given treatment is recorded from *Acacia sieberiana* which has dense canopy coverage over the coffee shrubs (Table 3).

In general, canopy of coffee shade tree might be beneficial to coffee yield components within a certain range, likely due to the competition between shade trees and coffee shrubs for soil water retention, soil fertility and ecosystem services specially provided by the shade trees.

Total Number of Bearing Coffee Shrubs

In this study, the mean value of total number of bearing coffee shrubs revealed statistically non- significance differences between a given treatments. But there is a difference between mean values. Therefore, the highest and lowest means difference is (39.7%) recorded between *Erythrina abyssinica* and *Acacia sieberiana* shaded coffee plants based on the number of bearing coffee shrubs (Table 3).

Various researches conducted previously at different places came up with results that are somewhat related ideas to the present study. These related ideas narrate to this thought that higher shade density had a negative effect on coffee bearing trees. However; some studies showed higher yields of coffee can be obtained from intensively managed of unshaded coffee plants, probably because of widely varying site conditions, management and other factors. When comparing shaded versus unshaded coffee or comparing different shade species, a group of factors vary rather than just the factor 'shade tree species (Somarriba et al., 1996).

In this study, the variation in "number of bearing coffee shrubs" between shaded and unshaded effect was quite logical as a result of the above reasons. Generally shade makes a coffee plant to persist fruit bearing condition with sustainable manner without any physiological and morphological problems.

Thousand Coffee Fruits' Weight

The study revealed that available mean value of '1000 seed weight in gm' showed statistically non-significance difference between a given treatments. But there is a variation between means. The highest mean value of 1000 seed weight in gram was observed under *Erythrina abyssinica* shaded coffee, while the least mean value was under *Acacia sieberiana* shaded coffee plants that with 40% mean difference (Table 3).

The highest weight of coffee fruits observed under medium shaded coffee plants that might be due to shade tree species effect which is donated the highest amount of nutrient availability from the litter fall for improved nitrogen mineralization rates with the exception of other factors. Similarly, Ebisa (2014) report, there was an observed relatively higher coffee weight of 1000 beans in gram under shaded zone than under unshaded zone of coffee plants even if the difference was not statistically significant. Similarly, the finding of Geromel *et al*. (2008) indicated that coffee weight was significantly higher in shade zone.

Therefore, 1000 seed weight of highest coffee fruit yielder showed under *Erythrina abyssinica* shaded coffees which can be taken as to be the superlative coffee shade tree based on its effect (Table 3).

Clean Yield of coffee in Quintal per Hectare

The mean value of clean coffee yield observed non-significant difference between a given treatments. But there is a difference between the observed means, that the highest mean value of a given treatments observed under *Erythrina abyssinica* shaded coffee, while the least mean value is under *Acacia sieberiana* shaded coffee (Table 3). Therefore, between the highest and lowest mean difference of a given treatment is 87.7% vary.

Similarly, coffee productivity under the shade of *Erythrina abyssinica* had a much higher productivity than other shades (Hergoual'ch *et al.,* 2007). According to Hernández (1995) report specified that yield of green coffee beans was 0.6% higher under shaded than open one, which translated in to an additional of 44 kg ha-[1] green coffee beans. Earlier st

udy of Muleta *et al.* (2011) from south west Ethiopia was also confirmed higher coffee yield from shade grown coffee. In the contrary, coffee beans yield was reported to be relatively higher in unshaded coffee zone (Bote and Struik, 2011).

Generally, in this result, truly imitated other's idea that canopy of coffee shade has a positive effect on the coffee yield of per coffee plant, if the canopy range is between 15% and 54% coverage unless it has negative effect on the yield of per coffee plant (Gao Yixuan, 2018). This might be the result of improved nitrogen mineralization rate under the optimum shade effect of *Erythrina abyssinica* tree, related to the higher level of biomass recycling and nitrogen fixation with the exception of other factors.

Effect of Shade Trees in Organoleptic coffee Beans' Quality

Table 4- The mean value of raw coffee beans under the effect of shade trees

Treatments	Shape and make	Color	Odor
	15%	15%	10%
Erythrina abyssinica	13a	13.1a	10
Cordia Africana	12.7a	13.2a	10
Acacia sieberiana	11.1b	11.2b	10
Un shaded	11b	11.1b	10
LSD (5%)	1.7	2.2	0
CV (%)	2.5	4.5	0

Effect of Shade Trees on Raw Coffee Beans in Shape and Make Quality

In this study, the mean value of parameter observed to have significant difference (P<0.05) between a given treatments effect in the availability of shape and make of raw coffee quality test. The highest mean value of the given treatments' parameter was observed under Erythrina abyssinica shade tree influence but under unshaded effect. According to Bote and Struik (2011), research report, shaded coffee resulted in heavier and larger coffee beans and a good "shape and make" than unshaded coffee fruits. This research report, confirmed with the present study. This might be mainly due to its effect on temperature and the duration of the ripening period.

Effect of Shade Trees on Raw Coffee Beans in Color Quality

The mean value of treatments indicated significant difference (P<0.05) between shade tree species as well as open areas' effect on the availability of color at raw coffee quality test. The highest mean value on the treatments' parameter was Erythrina abyssinica shade trees, while the lowest mean value of the given treatments' parameters was observed in unshaded coffee plants. Color is the visual appearance of the brewed

Treatments	AI	AQ	AC	AS	BI	BO	FL	OAQ
	5%	5%	10%	**5%**	5%	10%	10%	10%
Erythrina abyssinica	**4.5a**	**3.9a**	**7.9a**	4.4a	4.4a	**7.7a**	**7.9a**	**7.9a**
Cordia africana	4.1a	3.8a	7.3a	3.4b	4.3a	7.4a	7.3b	7.3ab
Acacia sieberiana	2.9b	**3.6a**	**7.5a**	3.1b	4.5a	7.3a	7a	7.1a
Un shaded	3.5b	3.4a	8.2a	**4.5a**	**4.6a**	7.2a	6.9ab	7b
LSD (5%)	1.2	1.7	1	1.2	0.3	0.7	1.8	1.8
CV (%)	13	20	5	4.8	9.2	4.6	4.8	5
Note-AI=Aromatic intensity; AQ=Aromatic quality; AC=acidity; AS=astringency; BI=bitterness; BD=body; Ttlgrad=total gradeFL=flavors; OAQ= overall quality								

cup of coffee. Ones' aspect of visual appearance indicates color and the direct effect of caramelization power of the sugar beans based on roasting degree. The roasting degree also depends on the size and 'shape and make' of green coffee beans. So the shade may have an influence on color availability indirectly hence and Categories of the rate of results were found under the rooted in its referred scales similarly in (Table 4).

Effect of Shade Trees on Cup Quality of Coffee Beans in Aromatic Intensity

Table 5, The mean value of aroma and cup coffee beans under the effect of shade trees

The mean value of treatments showed significant difference (P<0.05) between shade tree species and unshaded areas' effect in the availability of aromatic intensity at cup coffee quality (Table 5). The highest mean value of aromatic intensity was observed under *Erythrina abyssinica* shade tree effect, while the lowest mean value of the given parameters was also displayed at unshaded coffee plants (Table 5).

Aromatic intensity, the gaseous natural chemical components of roasted and brewed coffee is given off when coffee is roasted and brewed. Aroma is a responsible for all coffee flavor attributes. The shade may have indirect effect on availability of aromatic intensity. According to results' discussion was stated at different tables in this study, the shade trees might be have a direct and indirect effect on coffee production through the process with buffering the physiological part of coffee plants, from natural phenomenon. Thereby the coffee beans made uniform bean size due to indirect effect of shade trees and the rate of parameter was based on its description of the scale in (Table 5).

Effect of Shade Trees on Cup of Coffee Beans in Aromatic Quality

The mean value of treatment observed non-significant difference at ($P>0.05$) probability level between a given treatments based on the parameter that on aromatic intensity (Table 5). However, statistically it showed non-significant difference at ($P>0.05$) probability level; there is aviation between the means. So the highest mean value of treatment was recorded under *Erythrina abyssinica* shade tree, while the lowest mean value of the given treatments' parameter was recorded under unshaded coffee (Table 5).

Similar outcome was reported by (Alemayehu, 2017). Aromatic quality indicates smell of the liquor sensed either by direct inhaling of the vapors arising from the cup or by nasal perception of volatile substance evolving in the mouth found as multiple aromatic compounds' quality. So the shade tree'sresult designated to have typicity values of the given parameter to be 'slightly moca and spice' perfume by professional cup liquor panelist of (JARC, 2008) group and the rate of parameter was based on its description of scale in (Table 5).

Effect of Shade Trees on Cup of Coffee Beans in Aromatic

The mean value of treatment effect observed statistically non-significant difference ($P<0.05$) between the given treatments based on this parameter, in the availability of acidity at cup coffee quality test but there is aviation between their mean differences (Table 5). The highest mean value of acidity was recorded under *Erythrina abyssinica* shade tree, while the lowest mean value of the given parameter observed from unshaded coffee plants (Table 5). The literatures reflected that high acidity of cup coffee quality had reported defiantly from shaded areas of the coffee farm than open areas (Siles *et al.*, 2010; Souza *et al.*, 2012). According to Agawanda (1999), acidity of coffee cup tests are reliable and suitable quality attributes that can be used as selection criteria for the genetic improvement of the overall liquor quality had got from shaded coffee beans than unshaded beans.

The higher value of acidity percentage in cup quality test was found under shaded coffee beans, while the least mean value under open coffee beans. This might be, due to high pH value under the shade, which influences acidity of coffee bean cup quality test under the canopies (Alemayehu, 2017). Acidity indicates the bitter or acidic balance that a sweet car melic after taste which could be affected by roast degree and phonology of coffee fruit that means shade may have indirect effect on coffee cup quality test.

Effect of Shade Trees on Cup of Coffee Beans in Astringency Quality

The mean value of treatment observed a significant difference ($P<0.05$) between a given treatments in the availability of astringency at coffee cup quality test (Table 5). Many researchers reported that the higher content of astringency of the coffee beverage may be due to higher content of sucrose and chromogenic acid in green coffee beans based on its size and ripping paired. This chromogenic acid is reduced to organoleptic quality especially under unshaded beans than shaded ones (Morais *et al.*, 2006). Shade tree play a great role in producing heavier and larger coffee beans size which is depends on temperature effect and the duration of ripening period to have quality physiological fitness of coffee beans (Siebert, 2002). So in this study the higher value of astringency was observed under unshaded part of coffee plants (Table 5) and the rate of parameters ware based on scale description in (Table 5).

Effect of Shade Trees on Cup of Coffee beansin Acidic quality

The mean value of treatments effect did not show significant difference (P>0.05) in the availability of bitterness at the given treatments' parameter between the given treatments (Table 5). But the highest mean value of the given treatment was observed unshaded coffee beans, while the least mean value was observed under shade tree effects (Table 5).

The higher content of bitterness of the coffee beverage may be due to higher content of sucrose and chromogenic acid in green coffee beans based on its size and ripping paired. This chromogenic acid optimally influences organoleptic quality especially under unshaded than shaded ones (Morais *et al.*, 2006). So in this study, the highest mean value of bitterness was observed under unshaded coffee beans, than that of shaded coffee beans' quality. This may be due to its size and ripping paired beside other factors that due the direct sun light could be predisposed the chromogenic acid which is optimally influences organoleptic quality especially under unshaded coffee beans and the rate of parameters was based on description in (Table 5) scale rages.

Effect of Shade Trees on cup of Coffee beans in body Quality

The mean value of treatment effect had non- significant difference (P>0.05) in the availability of body at cup coffee quality test between but there is a difference between there means. The highest mean value of treatments' parameter was observed under Erythrina abyssinica shade trees, while the lowest mean value observed at open coffee beans (Table 5). Available of body in a cup of coffee quality test indicates viscosity or thickness of coffee brewed. It is the physical property of beverage that the result in tactile sensations perceived on the skin in the mouth during that after ingestion based on beans quality (JARC, 2008).

According to Agawanda (1999), body of coffee cup tests are reliable and suitable quality attributes that can be used as selection criteria for the genetic improvement of the overall liquor quality had got from shaded coffee beans than unshaded beans. Shade alter directly and indirectly organoleptic result in coffee quality aspect beside to other factors that dark roast enhance the body while light roast emphasize acidity (Muschler, 2001; ITC, 2002). The study was also confirmed the above ideas that the higher mean value of the given treatments' parameter was observed under the shaded coffee plants' beans (Table 5) and the rate of parameter s ware submitted by description of (Table 5) scale rages.

Effect of Shade Trees on Cup of Coffee Beans in Flavour Quality

The mean value of treatments indicated statistically non-significant difference (P<0.05) in the availability of flavor at cup of coffee test between a given treatments. The mean value of flavor at cup quality test that influenced by shade tree canopy was higher than that of open area under *Erythrina abyssinica* shade tree effect (Table 5).

Flavor is the simultaneous sensation in the test of aroma and taste. Coffee aroma is composed of the gaseous natural chemical components of roasted and brewed coffee beans, which escape as vapors after the coffee grounds are brewed. The perfume of the ground roasted coffee before water is added, it gives fragrance/aroma and one can smell the aroma, evaluate the body then perceive the taste and flavors (Muschler, 2001). The higher mean value of treatments' parameter was observed under the shade, while the lowest mean value was observed under unshaded coffee plants. This may be due to indirect effect of shade trees and the rate of parameters ware submitted by description of (Table 5) scale rages.

Effect of Shade Trees on Cup of Coffee Beans in Overall Coffee Quality

The mean value of treatments observed statistically non- significant difference ($P<0.01$) between the given treatments. But there is varies between mean value on availability of the given treatments' parameter (Table 5). The highest mean value of the given treatments was observed under shaded coffee beans, while the least mean value observed from unshaded coffee beans (Table 5). The total quality of coffee, based on overall quality attributes was used to determine quality potential (Muschler, 2001). The higher value of the given treatments' parameter was observed under the shade trees effect.

Coffee Grading Based on Raw and Cup Coffee Beans' Quality Evaluation

Table 6: Grading value of raw, aroma and cup coffee beans quality

Table 5: Standard and respective mean values used for unwashed raw coffee beans, and cup and aroma coffee beans value

Trt	p & mk	olor	dor	RQ	I	Q	C	S	I	O	L	AQ	CPQ %	tlgrd %
	5%	5%	0%	0	%	%	0%	%	%	0%	0%	0%	0	00
Erythrina abyssinica	3	3.11	0	6.11	.5	.94	.89	.44	.44	7.72	.94	.89	8.78	5
Cordia Africana	2.67	3.17	0	5.83	.17	.83	.33	.33	.33	.17	.33	.33	5.83	2
Acacia sieberiana	1.1	1.2	0	2.3	.9	.6	.5	.1	.5	.3		.1	3	5.3
Un shaded	1.67	1.08	0	2.75	.58	.42	.17	.5	.67	.33	.92		5.58	8

Note; Scale of Sp&mk=shape and make:- v. good=15; Good =12; Fair good=10; Average=8; Mixed =6; Small =4"
Scale of Color:-Bluish =15; Grayish =12; Greenish =10; Coated =8; Faded=6; White =4"
*" TCPQ=Total cup quality; AI=Aromatic intensity; AQ=Aromatic quality; AC=acidity; AS=astringency; BI=bitterness; BD=body; Ttlgrad=total grade; FL=flavors; OAQ= overall quality; TCPQ=total cup quality **
"The first grade coffee sample was determined as slightly moca and slightly spicy flavors as per (JARC, 2008)"; "After the raw and cup quality values summed the: 1rst grade =81-100%, 2nd grade =63-80%, 3rd grade =50-62%, 4th grade =31-49%"

The raw coffee quality evaluation based on their "shape and make", color and odor were computed along with the set of (ES, 2001; ECX, 2009). The highest mean value of raw quality analysis was found from the *Erythrina abyssinica* shade tree’s effect followed by *Cordia africana* based on the given parameters, relatively. The summations of parameters were given its grading value as per (JARC, 2008) standard with 40% accounting shown as (Table 6).

The highest mean value of aroma and cup quality analysis of a given parameters was found from Erythrina abyssinica shade tree’s effect followed by Cordia africana in the given parameters, relatively. Each quality attribute, after laboratory processing was subjected to statistical descriptive analysis, which was based on treatment effect. The total of raw quality (40%), and aroma and cup quality (60%) summation values ware used for final quality grading judgment in accounting of (100%) based on (ES, 2001; ECX, 2009) procedure as per (JARC, 2008) standard.

The highest quality grade range and typicity sense of ‘moca’ and ‘spice of a given quality attributer were observed under shade tree effect in the given parameters (Table 6).

Conclusions and Recommendations

In Ethiopian coffee production become deteriorates from time to time because of daily and annual climatic variation due to deforestation of natural forest and integration of food crops with coffee production without shade trees. Coffee growers encountered up normal growth of coffee plants which have negative impact on coffee yields due to sun grown coffee. Moreover, un shaded coffee plants have wilted and stunted coffee growth, branches, and needs more management and input is required for coffee plants.

The pressure from rapidly growing human population has been directly and indirectly shrinking welfare natural resources by means of deforestation. So production of coffee with shade tree is an agroforestry practice to improve production quality and sustain environmental biodiversity. This practice should have to be promoted and demonstrated in most districts of Hararghe zone for the place where coffee farmlands nearly wiped out and have been replacing with Khat and food crops.

Therefore, *Erythrina abyssinica* can be taken as the best shade tree for coffee production at the ideal level of canopy coverage in the aspect of optimizes the competition between shade trees and coffee shrubs in resource utilization. Successively, in almost all parameters, the best results were found under *Erythrina abyssinica* shade tree’s effect followed by *Cordia africana*. So *Erythrina abyssinica* shade tree’s outcome has to be designated to have better effect than other shade trees’ effect. So, based on the investigated effect of treatments, it can be recommended that the remarkable coffee shade tree.

In general, the present study indicates that a substantial contribution of coffee shade trees for coffee production improvement, this could not be an end itself. Much more research work needs to be done in the following hesitation area of research potential:

The further schoolwork should be conducted towards scientific research study of shade trees’ spaces for coffee plantation. Additionally, should be investigated associations of *Erythrina abyssinica* and *Cordia africana* shade trees with micro floral population of *Rhyzobia* and *mycorrhizal fungal* species are a principal importance, if being correlated with them which is may be good for production quality.

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Soil and Water Conservation and watershed Management Research

Socio-economic and Bio-physical Resources Characterization of Warja Watershed in Adami Tulu Jido Kombolcha District, East Shewa Zone, Oromia, Ethiopia.

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Abstract

Watershed development is an important component of rural development and natural resource management strategies in many countries. The study was conducted to investigate the current situation of Warja watershed for further improvements to promote Sustainable and productive livelihood through the integration of different watershed components in participatory approach. Household interview and biophysical resources assessment followed by watershed mapping techniques were used for the data collection. Purposive sampling methods were used to select 63 households and Warja watershed boundary was delineated and its map was developed based on the preliminary outlet identified with the help of GPS reading. Descriptive statistics and diversity indices were used for data analysis. The results of the study indicated that Agriculture was the principal occupation (98.4 %) of the population of Warja watershed. The average farmland size was 1.9 hectares while 25% of the households have farmland ranging from 0.25 to 1 hectare.The minimum and maximum family size of the sample farm households was 2 and 16 respectively.The common types of off-farm income generating activities are petty trade and working as daily labor. Slope gradient of Warja watershed ranges from 0 to more than 30 and the slope gradient of 2-5 and 5-10 cover the greatest in area coverage representing 204ha and 145ha respectively. Soil laboratory analysis result showed that sandy loam was the major soil type of Warja watershed.Overall results concluded that land degradation and biodiversity loss were a serious concern and watershed management programs could be strengthened. Awareness creation and strengthening capacity of rural communities on integrating crops, livestock and natural resource management technologies for effective soil and water conservation measure should be enhanced through participatory integrated watershed management approach.

Keywords: *Characterization, constraints, mapping, soil properties, species diversity, use value index.*

Introduction

In Ethiopia Watershed management programs commenced in a formal way in the 1970s. From that time up to the late 1990s, it was a government-led, top-down, incentive based (food-for-work) approach that prioritized engineering measures that focused primarily on reducing soil erosion. Since then the government, nongovernmental organizations and local community efforts on rural development have been based on watershed development program (Holden, 2005; Pathak, 2007; Assefa, 2011). In the early 2000s, community-based integrated watershed development was introduced to promote watershed management as a means to achieve broader integrated natural resource management and livelihood improvement objectives within prevailing agro-ecological and socioeconomic environments (Gebregziabher*et al*., 2016).

A watershed is a topographically delineated area that is drained by a stream system i.e. all of the land draining its rain, snowmelt and ground water into a stream or river (Corn, 1993; Swallow et al., 2001). At the earlier watershed management had a narrow focus primarily for controlling erosion, floods and maintaining sustainability of useable water yield. However, recently watershed management is not only for managing or conserving natural resources in a holistic manner, but also to involve local people for betterment of their lives. Its management is more people oriented and process based, than only physically target oriented (Abbaspour*et al.*, 2015).

Factors that contribute to the success of watershed management are multidimensional, including biophysical, institutional and socioeconomic elements. The presence of supporting institutional structures and the extent of community participation were also other factors found to significantly influence the 'success' of watershed management (Gebregziabher*et al*., 2016).The lack of integration from the different disciplines, sectors and limited level of participation of the stakeholders are among the limiting factors contributed to low level of success (Anantha*et al*., 2009).

Baseline characterization helps understand the initial livelihood condition of the people in the watershed before intervention. It builds necessary foundation for the plan and obtains proper information for effective planning, implementation and monitoring (Anantha*et al*., 2009). Due to demographic pressure the average landholding in the Ethiopian watersheds is often fragmented and less than one ha (Zenebe, 2005). The fragmented landholding (3-5 parcels) coupled with the improper land use system, nutrient depletion, drought and drainage problem, low crop and livestock productivity worsened the situation. Deforestation for cultivation, wood for fuel and construction, overgrazing, conversion of marginal lands to agriculture is escalating the problem of soil erosion and land degradation than ever (Zenebe*et al*.).

Some impact studies have showed that investments in watershed management in the developing world do pay off in economic terms. However, such impact studies do not typically include detailed socio-economical components (Holden, 2005, Pathak, 2007 and Assefa, 2011). Similarly, Watersheds management in East Shewa including Warja watershed has got attention for more technical interventions to restore degraded lands and improve livelihood benefits. Before that a detail biophysical and Socio-economic characteristics of the watershed must be known for accurate problem solving. Several challenges that threaten the efficiencies of watershed for local community livelihood improvement exist in the in area. These include the lack of technical provision and information to support the selection of interventions suitable for the local context; uncoordinated interventions, institutions and actors within a watershed. This watershed is among the watersheds that discharge water to the big out late i.e. Dambal Lake. Managements of this and other surrounding watersheds help improve and sustain the lifespan of the lake while reduce its vulnerability to the changing climate. The managed water sources are buffer for productive ecosystem. Therefore, the analysis frombiophysical and socioeconomic information in the watershed helps prioritize the problems with their appropriate management options and technologies which in turn leading to the implementation phase so that all the community in the watershed will be benefited

General Objective

- To investigate the current situation of Warja watershed for further improvements to promote Sustainable and productive livelihood through the integration of different watershed components in participatory approach.

Specific Objectives

- To delineate and map the selected watershed based on existing land uses.
- To characterize biophysical resources of the watershed with basic livelihood aspects of the surrounding society.
- To describe and evaluate the present resource use, management practices and socio-economic conditions in the watershed

Materials and Methods

Description of the Study Area

Geographical Location

The study was conducted in Adami Tulu Jido-Kombolcha (ATJK) district of East Shewa of Oromia, Ethiopia, where soil degradation, gully formation and loss of agricultural land are a serious problem. Adami Tulu Jido Kombolcha (ATJK) district is located between 7.58ºN and 38.43ºE longitudes. It is bordered to the North by Dugda Bora Woreda, in the west by Southern Nations Nationalities Peoples Region (SNNPR), Arsi Negele to the south and Arsi zone to the East. Batu is the capital of the Woreda, which is 160 km away from Addis Ababa and 40 km from ASLNP (ATARC profile, 2004).

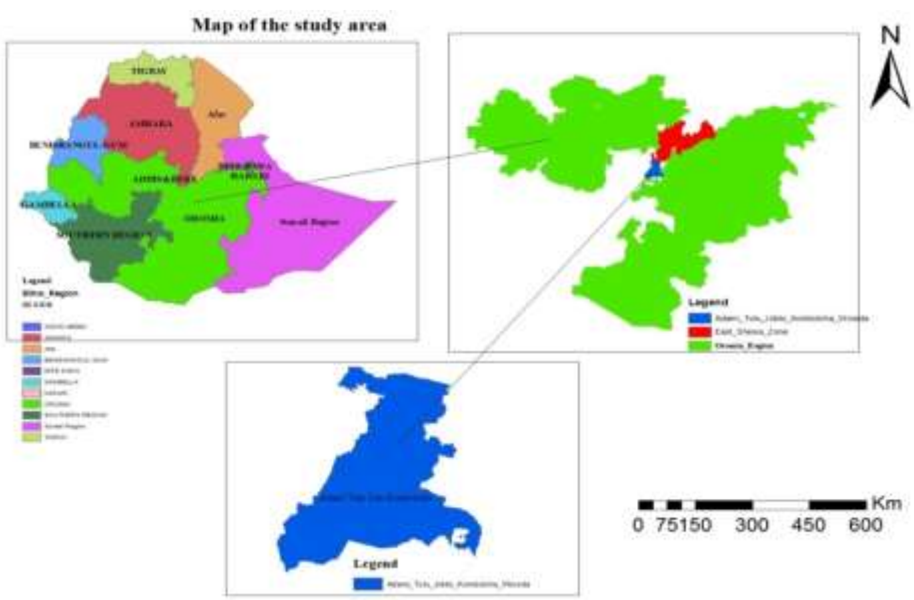


Figure 1: Location Map of Adami Tulu Jido Kombolcha District

Topography and Climate

The area is characterized by plain and flat lands of volcanic origin with small mountains, hills and gorges extending from the most northern part of Central Rift Valley. The altitude ranges from 1500-2300 m.a.s.l. Adami Tulu Jido Kombolcha Woreda has semi-arid and arid agro-climate zones. The Woreda receives an average annual rainfall of 760 mm. The mean monthly temperature varies from 18.5ºC to 21.6ºC with mean annual temperature of 20ºC. Rainfall extends from February to September with a dry period in May to June, which separates the preceding short rains from the following long rains (ATARC profile, 2004).

Vegetation, Soil and Land Uses

The vegetation is characterized by scattered acacia wood land is categorized as tropical savannahAcacia trees are dominant and important means of livelihood for the local people *(kasahun& Tesfaye, 2014)*. The pH of soil is 7.88 fine sandy loams with the highest sandy proportion (ATARC profile, 2004). Most of the area is topographically flat having sandy loam and andosol soil types *(kasahun& Tesfaye, 2014)*.Three land use systems: (a) croplands under small holder subsistence farming system (b) controlled grazing lands with closed areas (i.e., the Abernosa Ranch now days partially converted to private owners big farms), and (c) communal open access grazing land exist in the study area. Soil texture at these land uses is sandy loam with greater proportion of sand fractions. PH of the soil in a scattered acacia farm land is less alkaline than other land uses (Zeleke, 2017).

Population

According to the Woreda agriculture and rural development office, the total population of the Woreda is estimated at 164,321 for the year 2006 (computed from 1994 CSA population and housing census which accounts a 3% population increase every year) of which 14.5% urban and 85.5% rural dwellers. The average household size was 4.6 with 4.9 and 4.2 for rural and urban areas, respectively. The population density was 99 persons per square kilometer. With regard to ethnic and religious composition 78.7% are Oromos, 21.3% are other ethnic groups. Muslims are 72.4%, 27.4% Christian and 0.2% others (CSA, 2007).

Methods of Data Collection

Before data collection started, different stakeholders, roles and responsibilities of each stakeholder were identified. The interdisciplinary team was formed from the research divisions of Adami Tulu Agricultural Research Centre for site characterization, planning and implementation of the watershed research. The followings disciplines were considered for team formation: socio-economics, livestock, and geographic information system (GIS).

Watershed Delineation and Mapping

Sample points Design and Technique

Initially reconnaissance survey was conducted with community leaders and government administrators to identify the watershed boundary. Based on the preliminary outlet identified during the site selection process, the watershed boundary was delineated using primary data (GPS readings), secondary data (topographic map) and in consultation with the local community. The delineated watershed was geo-referenced and digitized for its contour, roads, rivers, and other features. The preliminary delineated boundaries were verified in the field using GPS and establish reference benchmarks for future operations. Finally, map of the watershed was produced; other information such as elevation ranges, area, slopes and aspect was extracted. After delineation, the Digital Elevation Model was derived. 18 points three each from all slopes were selected systematically. Map of the Warja watershed was developed and delineated from 1:50,000 scale topographic map and aerial photographs/satellite images. This was employ GIS tools like aerial photo interpretation using Stereoscope or satellite image interpretation using different software.

Socio-economic data collection

Local institutions and social and administrative boundaries were identified, described and analyzed with respect to the watershed boundaries. Then, the existing local livelihood constraints of production were identified. Important parameters for Socio economic database were collected. Also any factors expected to influence farmers' land management practices were also examined. In addition, production constraints were analyzed and prioritized with the whole community participation. PRA tools like group discussion, trend analysis, problem ranking was employed to generate information and questionnaires were used to quantify important variables. SPSS computer software v.20 was used for socioeconomic data analysis. Based on the data obtained, statistical tools like cross tabulation, percentages, graphs, etc were used to analyze quantitative data.

Household survey

25 % (1/4) of population of watershed (n=63) was selected according to Anantha*et al*. (2009) stated the ideal sample should cover 20-25 % of the households in the Watershed as representative of socio economic aspects. Warja watershed and households from the area were selected through purposive and random selection methods respectively. FGD (containing 6-8) members and 10 key informants were selected purposefully.

Table 6: Total population characteristics of Warja Kebele and Warja watershed society

Warja Kebele			Warja watershed	
Sex category	HH heads	Total	HH heads	Total
Male	282	1,550	196	621
Female	250	1,601	53	733
Total	532	3151	249	1354

Source: Warja Kebele Office, 2017

Biophysical Resource Survey

The current land use/land cover of the watershed was assessed and mapped depending upon the availability of historical data (existing maps, aerial photographs, knowledge of the local community and satellite images) and GPS respectively. The map produced by image interpretation was cross-checked and verified by field observation. The boundary coordinates was collected using GPS. Then each land unit was characterized in terms of different parameters (quality indicators). This includes soil Physical, chemical and biological parameters, vegetation and topography. The seasonal climate pattern of the watershed was determined using data collected from the nearest weather station. 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. Similarly, the most important drought characteristics (frequency, intensity, severity and magnitude) were determined using standardized precipitation index (SPI). Temperature data was also analyzed.

Vegetation data collection

A 10mx10m quadrant was used to collect vegetation data across slopes. Quadrants were set three times at each slope randomly. Seedlings with height below 0.3 m were not included in the study as they were difficult to identify and are known to have very high mortality (Otsamo, 2000).

Soil sample collection

18 Soil samples were taken from every systematically selected point across the slope. During systematic sampling points allocation all slopes in three land uses (Crop land, protected area and grazing land) were purposively selected. Points were loaded to GPS and navigated until the destination. Then samples were collected using 20 cm auger to analyze important soil physical chemical properties.

Erosion Assessment and Detection

Availability of erosion was detected by using field observation indicators used by National Range and Pasture Handbook and Erosion (190-VI-NRPH, December 2003). Some of these factors are accounted for in the range land health and pasture condition scoring models. After the availability of the erosion detected Gullies were digitized by using GPS.

The indicators include:

- Pedestalled plants and rocks
- Base of plants discolored by soil movement from raindrop splash or overland flow
- Exposed root crowns
- Formation of miniature debris dams and terraces
- Puddled spots on soil surface with fine clays forming a crust in minor depressions, which crack as the soil surface dries and the clay shrinks
- Rill and gully formation
- Accumulation of soil in small alluvial fans where minor changes in slope occur
- Surface litter, rock, or fragments exhibit some movement and accumulation of smaller fragments behind obstacles
- Eroded inter space areas between plants with un natural gravel pavements
- Flow patterns contain silt and/or sand deposits and are well defined or numerous
- Differential charring of wood and stumps indicating how much soil has eroded after a fire

Climatic Data Collection

Five years secondary data were taken from Adami Tulu Agricultural Research Center weather station. ATARC weather station is one of the nearest stations to the study area. This is because in principle climate data can be taken from the nearest weather station to the study area and it is around 7 km from the study area.

Methods of Data Analysis

Household survey data analysis

The qualitative data collected through questionnaire based survey were entered into Statistical Package for Social Sciences (SPSS V 20) computer program and analyzed using descriptive statistics and Frequencies.

Soil Data Analysis

The most common method of measuring soil BD is by collecting a known volume of soil using a metal ring pressed into the soil (intact core), and determining the weight after drying (McKenzie et al. 2004). Other soil physical and chemical properties were analyzed using standard Laboratory procedures at Batu Soil Research Center. The samples are then prepared for analysis following standard sampling and lab procedure. Finally prepared soil samples were analyzed for Organic Carbon (OC) using a *Walkley and*

Black method, Total Nitrogen (TN) using *Kjeldhal method*, Available Phosphorus (Av.P) using *Olsen metal method*, Available potassium (Av.K) using *Morgan's extraction method*, PH using *PH meter* in water suspension with soil to water ratio 1:2:5, EC (Electrical conductivity) using *electro conductivity meter*, CEC (Cat ion exchangeable capacity) using *Ammonium Acetate (1 M NH4OAC).*Bulk density is usually expressed in mega grams per cubic metre (Mg/m3) but the numerically equivalent units of g/ cm^3 and t/m^3 are also used (1 Mg/m^3 = 1 g/cm^3 = 1 t/m^3) (Cresswell and Hamilton, 2002).

Soil volume

Soil volume = ring volume

To calculate the volume of the ring:

i. Measure the height of the ring with the ruler in cm to the nearest mm.
ii. Measure the diameter of the ring and halve this value to get the radius (r).
iii. Ring volume (cm3) = π x r^2 x ring height……………………………(1)
Ring radius = 5.73 cm and ring height = 8 cm
Ring volume = 3.14 x 5.73 x 5.73 x 8 = 824.7 cm3

Dry soil weight

To calculate the dry weight of the soil:

i. Weigh an ovenproof container in grams (W1).
ii. Carefully remove the all soil from the bag into the container. Dry the soil for 10 minutes in the microwave, or for 2 hours in a conventional oven at 105ºC.
iii. When the soil is dry weigh the sample on the scales (W2).
iv. Dry soil weight (g) = W2 - W1 ………………………………………… (2)

Finally, Bulk density was calculated as follows;

$$\boldsymbol{Bulk\ density\ (g/cm^3) = \frac{Dry\ soil\ weight\ (g)}{Soil\ volume\ (cm^3)}} \quad \text{……………………………... (3)}$$

Tree uses analysis

Use value index technique was used to identify and prioritize the important trees based on the uses mentioned by the farmers (Phillips and Gentry, 1993).

UV = ΣUi/n ……………………………………………………………..... (4)

Where: Ui is the number of uses mentioned by each respondent for a given species, n is the total number of respondents and stands for summation. The species will be then ranked basing on the overall use value.

Important diversity measurement indice, Shannon index was used to calculate richness and abundance of the vegetation respectively. Shannon diversity indices will be estimated as Magurran (1988);

H' = - Σpilnpi ……………………………………………………….. (5)

Where, pi is the proportion of individuals composed of species i.

Shannon diversity index (H') is high when the relative abundance of the different species in the sample is even, and decreases when few species are more abundant than the others. It is based on the theory that when there are many species with even proportions, the uncertainty that a randomly selected individual belongs to a certain species increases and thus the diversity. As a measure of heterogeneity, Shannon's index takes into account the evenness of abundance of species (Peet, 1974).

Finally soil data's, tree utilization data's and diversity data's were adjusted to MINITAB 17 and analyzed with appropriate analytical methods.

Results and Discussion

Socio-economic Characteristics of Warja Watershed

Household characteristics of the respondents

The results of these socioeconomic characteristics of households are helpful in exploring the communities' infrastructures and resources need for planning future intervention of watershed management and could determine the extent to which the community could adopt the future intervention that might be useful in developing a plan for commencing community development work. The results from household survey revealed the average age of the respondents was 45 with a standard deviation of 15.09. The family size of the sampled households on average was six. The largest frequency in family size is four family members per household, which was about 5% of the sample households' family size. The sampled household education level in the study area ranges from illiterate to complete secondary school. The total land size of each household mostly consists of the cropland, grazing land, and homegardens. The average farmland size was 1.9 hectare with the range of 0.25 to 4 hectare whereas about 25% of the households have farmland ranging from 0.25 to 1 hectare (Table 2).

Of the total respondents of the watershed 42.97% are occupants. According to the survey result, the minimum and maximum family size of the sample farm households was 2 and 16 respectively (Table 2).

The respondents are divided into three age groups (i.e. up to 15, 16 to 64, and above 64 years of age). The idea behind these classes is that the middle group (16-64 years) is the most productive age group in farming. As age is one of thevital characteristics of the society which plays a significant role in any type of employment pattern, mobility and any kind of activity performances, particularly in agriculture, as the use of child labor on farm activities mostly prevail.

Table 7: Household respondents age characteristic in the Warja watershed (N= 63)

Household characteristics	Unit of Measurement	Observed range	Average age
Age	Year	22-75	45
Household family size	Numbers	2-16	6
Household family by age categories			
1-15 male	Numbers	0-6	1.76
1-15 female	Numbers	0-7	1.62
16-64 male	Numbers	0-8	2.25
16-64 female	Numbers	0-12	1.83
Greater than 64 male	Numbers	0-1	0.64
Greater than 64 female	Numbers	0-1	0.11

Majority of the sample farmers (98.5 %) owned farm lands with varies size ranging from 0.25 to 4 hectare, and on average 1.9 hectare of land holding (Figure 1 and Table 3).

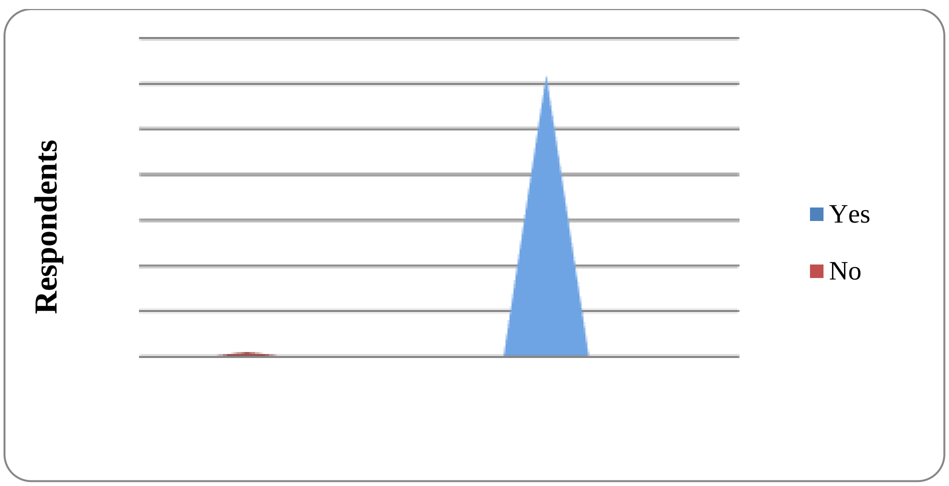


Figure 6: Households owing agricultural land

Table 8: Household land holding, (N=63)

Household characteristics	Unit of measurement	Observed range	Average
Total land size	Hectare	0.25-4	1.9
Education	Grade	0-12	4

Agriculture (Working on farm) was the principal occupation of 98.4% of the economically active population of Warja watershed in 2017, although only about 22.4% of the respondents Work on farm as a Secondary occupation. Working on the farm includes crop production activities and rearing of the livestock's. Few households were also engaged on off-farm activities, another livelihood for the farmers in the watershed. The common types of off-farm income generating activities are petty trade and working as daily labor. About 17.9 % of households in the area were involved in these income generating activities in addition to agricultural practices.

Table 9: Households means of livelihoods in the Warja watershed (n=63)

Occupation category	Frequency	Percentage (%)
Primary occupation	Working on farm	98.4
	Casual farm labor	1.6
Secondary occupation	Working on farm	22.4
	Casual farm labor	6.1
	Salaried/Wage labor(formal employment)	20.4
	Other	12.2
	No secondary occupation	38.8

Trends and constraints of Crop production in the Warja watershed

Crop production is one of the major agricultural activities undertaken by community in the Warja watershed (Table 5). The crops grown in the watershed were Maize, Wheat, Teff and Barley, Harricotbean and Sorghum. Maize and wheat were the major grown crops while sorghum was the Lesley grown one.These crops have been produced for the purpose of home consumption and seed at most while a few are sold in local markets as they came after threshing. The assessment conducted for the two cropping years showed there has been no common use of the crops varieties with their recommended technology package. In addition to these gaps, other external factors of production worsened the expected crops yield.

Table 10: Major crop types grown in two cropping year in the Warja Watershed

Crops grown	Cropping Year							
	2007/8				2008/9			
			Farmer grown				Farmer grown	
	Area	Yield	Frequency	%	Area	Yield	Frequency	%
Maize variety								
BH-540	1.01 ± 0.51	14.5 ± 12	36	57.1	0.9 ± 0.4	13.1 ± 11.2	35	55.6
BH-543	0.9 ± 0.3	10.2 ± 9	13	20.6	1.1 ± 0.4	15.9 ± 9.1	18	28.6
SHALLA	0.9 ± 0.2	6.3 ± 4.8	6	9.5	0.8 ± 0.0	8.5 ± 5.0	3	4.8
NOT KNOWN	0.8 ± 0.4	14.8 ± 6.6	8	12.7	0.6 ± 0.1	9.0 ± 6.6	7	11.1
Teff variety								
WHITE	0.4 ± 0.1	1.8 ± 1.7	4	36.4	0.4 ± 0.13	0.50 ± 1.0	2	25
RED	0.4 ± 0.1	2.5 ± 2.5	5	45.5	0.3 ± 0.0	1.0 ± 0.0	3	37.5
SERGAGNA	0.3 ± 0	1.0 ± 0	1	9.1	0	0	1	12.5
NOT KNOWN	0.4 ± 0.2	3.0 ± 4.2	1	9.1	0.5 ± 0.4	1.0 ± 0.0	2	25
Wheat variety								
BAFANI	0.8 ± 0.5	9.1 ± 6.9	29	53.7	0.8 ± 0.5	9.2 ± 9.5	25	50
HAWI	1.3 ± 0.9	6.6 ± 8.7	12	22.2	0.9 ± 0.5	7.9 ± 7.2	12	24
QUBSA	1.0 ± 0.7	4.5± 0.707	3	5.6	0.75 ± 0.4	14.0 ± 5.7	2	4
NOT KNOWN	0.5 ± 0.4		10	18.5	0.6 ± 0.4	5.8 ± 4.7	11	22
Barley variety								
ARUSO	0.4 ± 0.2	6.7 ± 3.8	3	21.4	0.4 ± 0.1	2.4 ± 2.5	3	37.5
BEKA	0	0	2	14.3	0.3 ± 0.1	4.8 ± 6.5	1	12.5
NOT KNOWN	0.4 ± 0.5	2.9 ± 2.6	9	64.3	0.4 ± 0.1	0	4	50
Haricot bean variety								
MARTA	0.3 ± 0.0	2.5 ± 2.1	2	3.2	0.3 ± 0	0.8 ± 0		
UNKNOWN	0.3 ± 0.0	3.5 ± 5.7	4	6.3			1	100
Finger millet variety								
RED	0.5 ± 0	3.0 ± 0			0.3 ± 0	2.0 ± 0		

The results (Table 6) showed that the major constraint for crop production as ranked by farmers in the area were high cost of inputs, climatic problems, land infertility, lack of improved agricultural technologies, high cost of labor force and others listed were contributed significantly to the low yield in the watershed.

Table 11: Constraints of crop production in the Warja watershed

Constraints	Percentage (%)	Rank
High cost of inputs	65.08	1
Climatic problem	58.7	2
Lack of improved agricultural mechanization technologies	19.0	4
High cost of labor force	17.46	5
Poor access to extension services	15.87	6
Land infertility	11.1	3
Unavailability of inputs on time	6.3	7
Disease and pests	4.80	8
Lack of access to credit services	3.20	9

Table 12: Other major constraints related to crop production

Constraints list	Percentage(%)	Rank
Constraints of Crop marketing		
Lack of market information	52.4	1
Market fluctuation	38.1	2
Lack of access to inputs (improved seed/seedlings, fertilizer)	4.8	3
Constraints of crop storage and facility		
Lack of improved storage facility	42.9	1
Poor access to extension services	11.1	2
Pests	9.5	3

The majority of household respondents' perceived that crop production in the area is decreasing due to lack of access to inputs and climatic problem (frequently changing weather condition) (Figure 2 and Table 6).

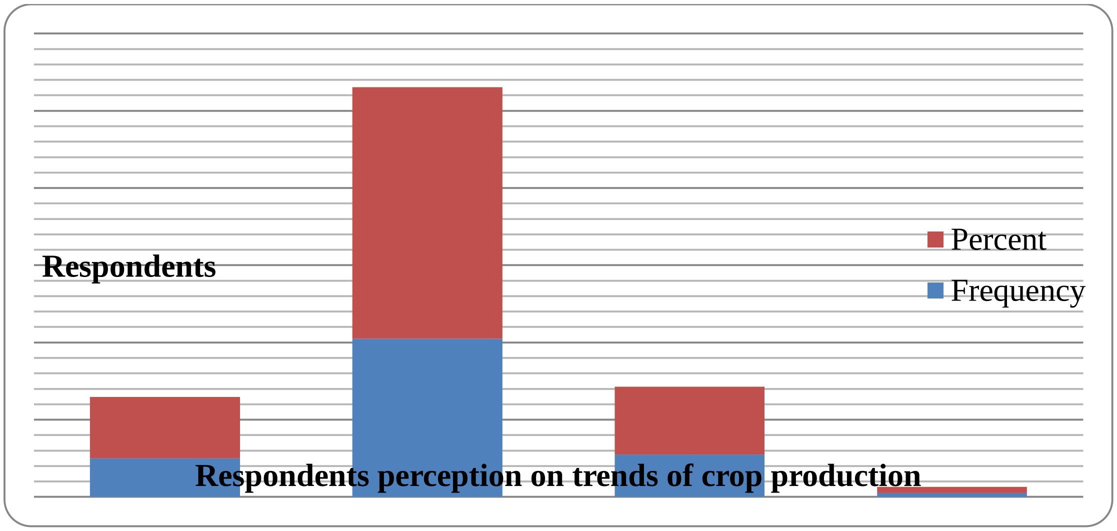


Figure 7: Trends of crops in the selected Warja watershed

Livestock Production and Feeding Source Characteristics in the Warja Watershed

Farmers in the watershed have low to moderated livestock population. Accordingly Local breed cow ranged from 1-7 and 0-12 with the average of 2 and Local breed sheep and goat ranged from 1-10 and 1-20 and with average of 4 and 5 respectively although very few number of cross breeds livestock population is observed (table 8). The major livestockfeeding source in the selected Warja watershed are grazing land and aftermath of croplands, although it exceeds thecarrying capacity of the existing livestock population they are available in the area. Various food crops, mainly cereals and pulse crop residues were also the commonly used feed sources for all livestock categories during the dry season and private grazing land near the farmers' homestead and small plots of grazing lands at the edge of croplands were the main source of feed for their livestock at wet season. Animals were restricted to the smaller area near the homestead during the wet season because it overlaps with rain-fed crop growing seasons. Besides, animals were primarily fed on weeds harvested from within the cropland, green grasses and thin out crops, as it is also confirmed by the secondary information (Table 9). Industrial by-products have not been used by farmers in mostly in the area during wet seasons because this time is characterized by availability amble feed sources. Due to challenges related with unaffordable prices of industrial by-products by smallholders, they have rarely used it for animals affected by feed shortage during the dry season.

The feeding source in the study watershed was dominantly pasture land, vegetable waste, fodder trees/shrubs, weeds, thin out crops and crop residue (93.65%) followed by all industrial by products and concentrate feed which cover 6.35% of the total feed source in the area. The contribution of communal grazing land sole was lower as result of shortages of grazing land (bush and scramble tree covered) occur due to expansion of crop lands due to increased population as well as degradation of the land current local community holds.

Table 13: Farm animals' resources in the Warja watershed

Livestock type	Total number owned by the household		
	Mean	Minimum	Maximum
Local breed cow	2.22	1	7
Local breed oxen	1.84	1	5
Local breed calves	1.87	0	7
Local breed heifers	1.68	0	6
Local breed bull	1.18	0	3
Local breed goat	4.92	1	20
Local breed sheep	4.08	0	10
Local breed chicken	5.95	1	12
Donkey	2.14	1	15
Horse	1.00	0	2
Mule	.00	0	0
Cross breed cow	.50	0	1
Cross breed oxen	.33	0	1
Cross breed calves	.75	0	2
Cross breed heifers	.33	0	1
Cross breed bull	.00	0	0
Cross breed goat	1.00	0	3
Breed sheep	.67	0	2
Cross breed chicken	.00	0	0

Table 14: Characteristics of respondent on livestock feed system in the Warja watershed

Categories	Frequency	Percent (%)
Own grazing land		
Have pasture land	8	12.7
Don't have pasture land	55	87.3
Source of animal feed		
Industrial by-products and Concentrate feed	4	6.4
Pasture land, vegetable waste, fodder trees/shrubs, Weeds, thin out crops and crop residue	59	93.7
Feel no enough animal feed	63	100
I believe that feed is enough	0	0

Farmers have mentioned some constraints affecting livestock production in their area and ranked them based on their severity. Accordingly, the most common constraints of animal production in the area were lack of improved breed and un availability of feed because of drought and lack of improved forage and/or fodder species (table 10).

Table 15: Constraint analysis of animal production in the Warja watershed

Constraints list	Percentage(%)	Rank
Animal breeding constraint		
Animal feed shortage	46.0	1
Lack of improved genotype	38.0	2
Disease	30.2	3
Animal feed constraint		
Un availability of feed	39.7	1
Climatic problem/drought	31.7	2
Lack of access to improved forage/fodder seed/seedlings	12.7	3
Poor access to extension services	3.2	4
Livestock fattening constraint		
Lack of improved breed	36.5	1
Unavailability of feed	23.8	2
Lack of access to credit services	14.3	3
Poor access to extension services	7.9	4
High interest rate	6.3	5
Lack of improved agricultural technologies (mechanization)	6.3	6
Un availability of inputs on time	1.6	7
Shortage of labor force	1.6	8
Dairy production constraints		
Lack of improved breed	54.0	1
Un availability of feed	23.8	2
Lack of improved dairy technologies	11.1	3
Lack of access to credit services	3.2	4
Shortage of labor force	1.6	5
High interest rate	1.6	6
Livestock marketing constraints		
Market fluctuation	39.7	1
Lack of market information	34.9	2

Theresults (Table 11) of baseline survey were indicated that in Warja watershed, beekeeping was practiced by few farmers (8 farmers out of 63 household respondents with too minimum number of farmers holding moveable frame) (table 11) and, consequently no attention was given in order to improve their income livelihood from the sale of honey and nutrition and employment opportunities. Although lack of beekeeping equipment's and farmer's awareness in solving constraints of beekeeping exist in the area, the few farmers holding honeybee colony have been getting significant honey production. As constraints poor access to extension services includes; Poor honey processing facilities, inadequate skills on improved beekeeping, inadequate skills of seasonal bee management, etc.(Table 11). So, improving these is about improving the production of honeybee in the watershed.Access to credit services (Table 11) is also important for farmers to establish modern production sites individually or as a group and also without such kind of facility farmers have no capacity to incur costs of the beehives.

Table 16: Beekeeping characteristics in the Warja watershed

No.	Categories by beekeeping practices	Frequency	Percent (%)
1	Respondents having practices of beekeeping	8	12.7
	Traditional	6	75
	Movable frame	2	25
2	Respondents with no practices of beekeeping	55	87.3

Table 17: Apiculture constraints analysis of Warja Watershed

Constraints list	Percentage (%)	Rank
Poor access to extension services	20.6	1
Lack of improved bee technologies	19.0	2
Un availability of feed	11.1	3
Lack of access to credit services	3.2	4
Climatic problem/drought	3.2	5
Lack of access to improved forage seed and / seedlings)	1.6	6
Pest problem	1.6	7

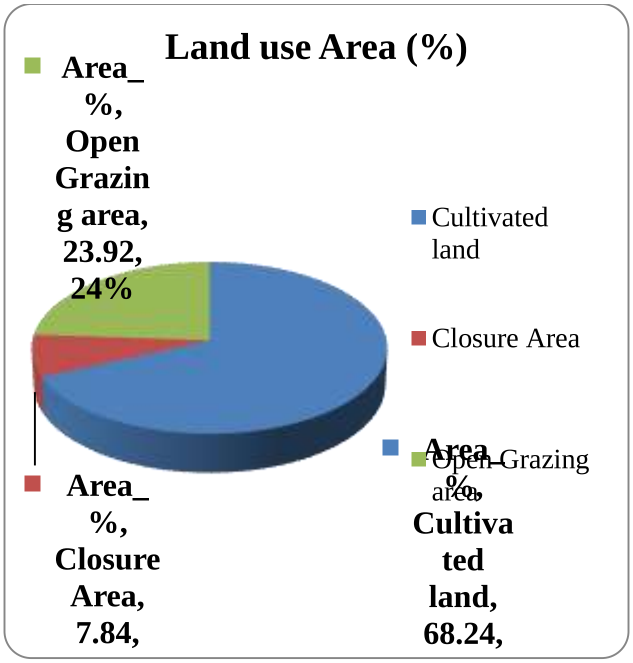
Bio-physical Resources Characteristics of Warja Watershed

Land uses of Warja Watershed

Cultivated land covers the highest portion of area (Table 13 and Fig. 3) in the watershed while followed by open grazing area, mostly of hill slope.

Table 18: Land use types of Warja Watershed 2009 E.C

No	Land use	Area_ha	Area_ %
1	Cultivated land	473.87	68.24
2	Closure Area	54.44	7.84
4	Open Grazing area	166.11	23.92
	Total	694.42	100



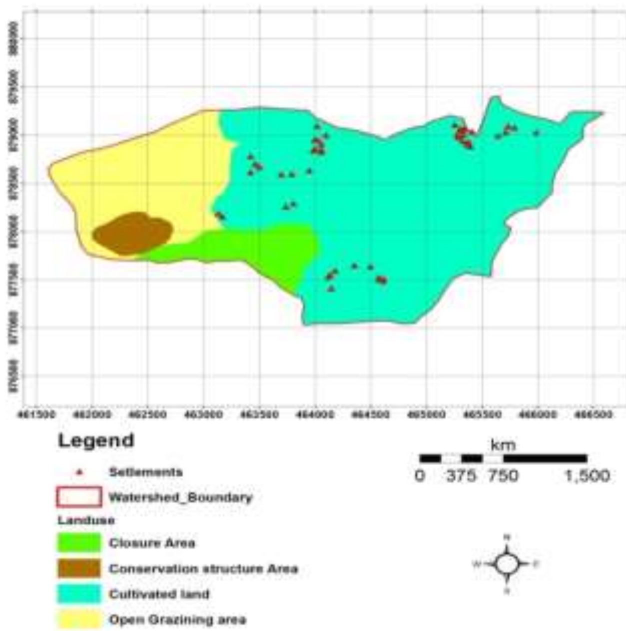


Figure 8: Land use/ cover of Warja WatershedFigure 9: Land use/ cover Map of Warja Watershed

Topographic characteristics of Warja watershed

Location Map of Warja Watershed

Warja watershed is located between 7º56’0’’ to 7º57.5’0’’ N latitude and 38º39’0’’ to 38º42’0’’ E longitude (Fig. 5).

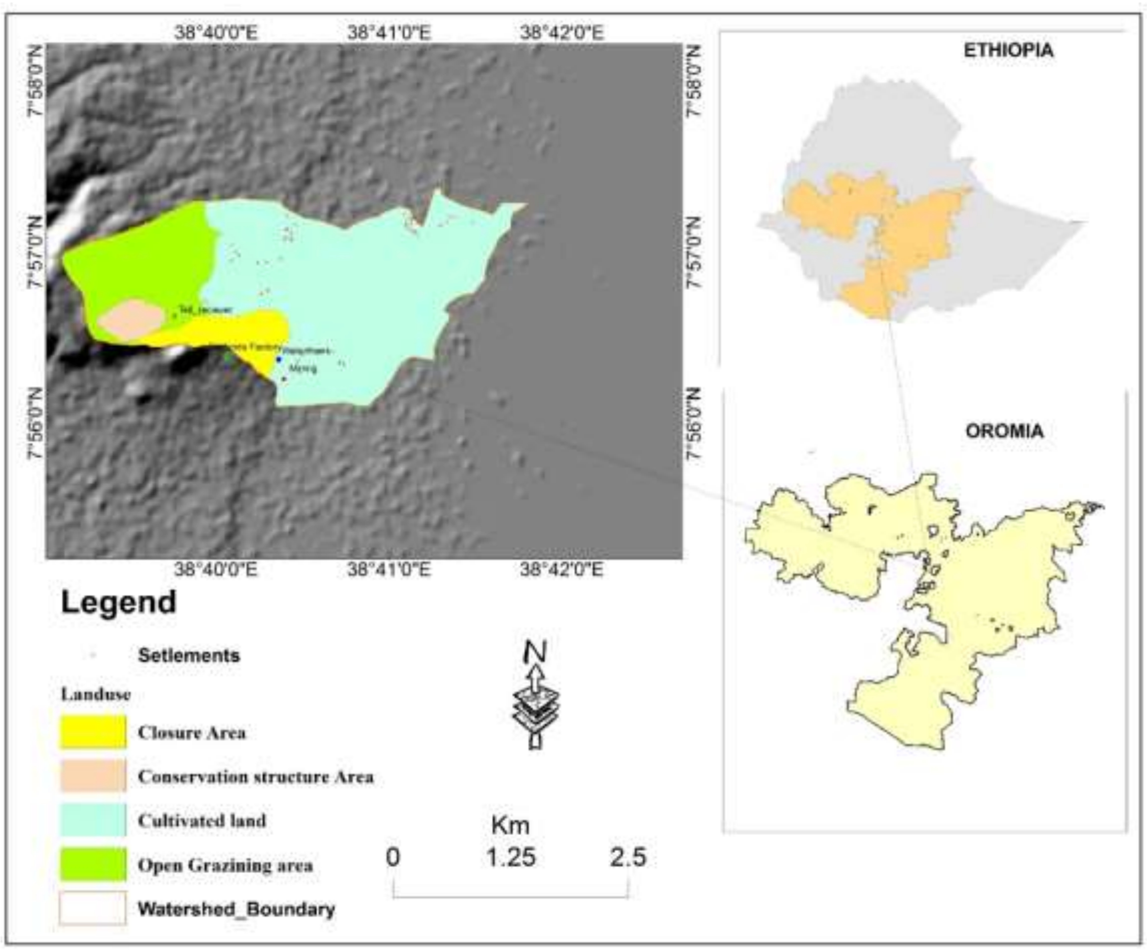


Figure 10: Map of Warja Watershed

Slope

Topography affects landscape by facilitating physically land cover changing problems like flooding, degradation, etc. based on steepens of slope and slope length. Slope gradient of Warja watershed ranges from 0 to more than 30 and the slope gradient of 2-5 and 5-10 cover the greatest in area coverage representing 204 ha and 145 ha respectively (table 14). This indicate that more of the watershed landscape might be exposed to extreme flooding at time of high rain fall occurrences which implies that the need of soil and water conservation structures for sound natural resources conservation in the area. This is agreed with the findings of Betteridge*et al.* (1999) stating that the slope configuration provides few depositional sites within the hill slope. However, where excessive slope lengths occur, off slope transport of sediment (erosion) can be anticipated.

Table 19: Slope gradient of Warja watershed

No	Slope (%)	Area_ha	Area_ (%)	Rank
1	0 – 1	99	14	3
2	1 – 2	72	10	6
3	2 – 5	204	29	1
4	5 – 10	145	21	2
5	10 – 15	86	12	4
6	15 -30	75	11	5
7	>=30	12	2	7

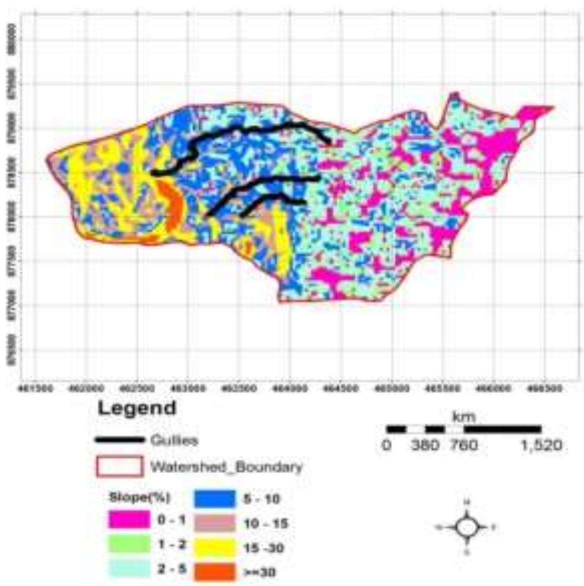


Figure 11: Slope Map of Warja Watershed

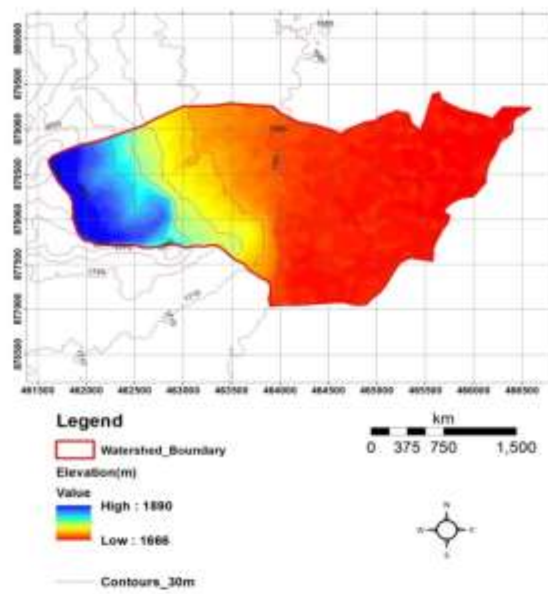


Figure 12: Elevation Map of Warja Watershed

Climate of the Watershed

In the periods of five years the mean minimum temperature of the area obtained maximum value in May and June almost 15°c while lowest value 9°c in December (table 15). When say Minimum temperature is actually about hot nights and Daily temperature observations show significantly much large increasing trends in the frequency of hot nights according to UNDP country portal (Abbadi GR, 2016). The result is almost similar with the observation did in Amhara and Tigray parts of Ethiopia in the periods of 1980-2010.

These are clearly an indication of warming nights over the years and shows those seasons are getting hotter in recent years (Gebrehiwot and Veen, 2013).

Table 20: Minimum Temperature (2012-2016)

Variable	Mean	Variance	Min	Max	Median	Range
January	10.5±2.4	5.972	8	14.4	9.8	6.4
February	10.96±1.6	2.603	9.1	13.2	10.6	4.1
March	12.5±1.5	2.32	11.4	15.1	12.2	3.7
April	14.3±1.8	3.177	12.6	16.9	13.5	4.3
May	15.3±0.7	0.538	14.3	16	15	1.7
June	15.26±1.02	1.048	14.2	16.8	15.2	2.6
July	14.84±0.82	0.668	13.6	15.7	15.1	2.1
August	14.4±0.81	0.655	13.4	15.3	14.8	1.9
September	13.36±1.17	1.373	11.8	14.6	13.3	2.8
October	11.22±1.34	1.807	9.7	12.7	11	3
November	10.36±1.35	1.823	9.1	12.4	9.9	3.3
December	9.08±2.48	6.137	6.2	12.8	9.3	6.6

In the periods of five years the maximum temperature of the area obtained mean minimum value in July and August having a value of 25.5°c while the rest of the months obtained maximum value between 28°c to 32°c. When see as a single months maximum value 35°c scored in March while 23.6°c in July (Table 16).

Table 21: Maximum Temperature (2012-2016)

Variable	Mean	Variance	Min	Max	Median	Range
January	29.54 ± 0.68	0.46	28.9	30.6	29.5	1.7
February	31.44 ± 1.13	1.27	29.7	32.7	31.8	3
March	32.44 ± 1.48	2.20	30.9	34.9	32	4
April	31.24 ± 1.06	1.12	29.7	32.6	31.2	2.9
May	30.12 ± 1.10	1.22	29	31.7	29.6	2.7
June	28.44 ± 0.73	0.53	27.3	29.3	28.5	2
July	25.48 ± 1.79	3.22	23.6	27.9	26	4.3
August	25.5 ± 1.33	1.76	24.1	26.9	25.1	2.8
September	26.92 ± 1.11	1.23	25.8	28.2	26.8	2.4
October	29.12 ± 2.36	5.59	27.2	33.1	28	5.9
November	29.46 ± 1.45	2.10	28.4	32	28.9	3.6
December	29.26 ± 1.19	1.41	28.1	31	28.9	2.9

Table 22: Relative Humidity (2012–2016)

Variable	Mean	Variance	Min	Max	Median	Range
January	52 ± 2.55	6.5	49	55	52	6
February	49.6 ± 6.58	43.3	44	60	49	16
March	49 ± 8.31	69	38	58	49	20
April	56.6 ± 8.71	75.8	42	64	59	22
May	62.2 ± 7.33	53.7	53	70	65	17
June	62.6 ± 3.91	15.3	59	68	62	9
July	72 ± 5.15	26.5	64	77	74	13
August	71.8 ± 7.33	53.7	63	81	73	18
September	69.4 ± 4.72	22.3	64	75	71	11
October	58.2 ± 4.97	24.7	52	65	57	13
November	53 ± 4.24	18	49	59	53	10
December	51.82.59	6.7	49	55	51	6

The result (Table 18) shown the area obtained 65mm average rain fall in five years (2012-2016) and 121mm average rainfall in five years (2012-2016) during cropping seasons (from May-September).These is almost closer to the average result obtained 63 mm rain in ten (10) years (1996-2005) and 100 mm average result in cropping seasons (May-September) by Mesku *et al* (2008).

Table 23: Rain Fall of Warja Watershed (2012-2016)

Variable	Mean	Variance	Min	Max	Median	Range
January	7.28 ± 15.73	247.29	0	35.4	0	35.4
February	14 ± 27.14	736.52	0	62.3	1.1	62.3
March	32.82 ± 26.45	699.62	2.9	75.5	28.7	72.6
April	60.5 ± 61.39	3768.19	0	154.1	43.4	154.1
May	101.14 ± 51.11	2612.45	37.9	160.7	81.7	122.8
June	95.82 ± 55.30	3058.63	22.4	159.7	111.1	137.3
July	214.84 ± 72.82	5302.13	147.5	320.4	206.1	172.9
August	111.24 ± 46.34	2146.99	51.2	161.4	100.8	110.2
September	80.54 ± 70.64	4989.81	1.6	195.6	66.5	194
October	57.96 ± 97.31	9468.38	0	228	9.7	228
November	0.58 ± 1.30	1.68	0	2.9	0	2.9
December	0 ± 0	0	0	0	0	0

Table 24: Evaporation status of Warja Watershed (2012-2016)

Variable	Mean	Variance	Min	Max	Median	Range
January	7.58 ± 0.89	0.80	6.5	8.45	7.68	1.95
February	8.17 ± 1.13	1.28	6.77	9.5	8.21	2.73
March	8.43 ± 1.38	1.90	7.47	10.47	7.89	3
April	7.66 ± 1.70	2.90	6.19	9.69	7.39	3.5
May	6.33 ± 0.83	0.68	5.34	7.36	6.31	2.02
June	6.96 ± 0.73	0.53	5.9	7.52	7.21	1.62
July	5.11 ± 0.70	0.49	4.18	5.79	5.23	1.61
August	4.92 ± 0.62	0.38	4.26	5.56	4.92	1.3
September	4.92 ± 0.42	0.17	4.6	5.53	4.78	0.93
October	5.88 ± 0.84	0.71	5.28	7.12	5.55	1.84
November	6.46 ± 0.30	0.09	6.06	6.73	6.52	0.67
December	6.97 ± 0.57	0.32	6.39	7.7	6.90	1.31

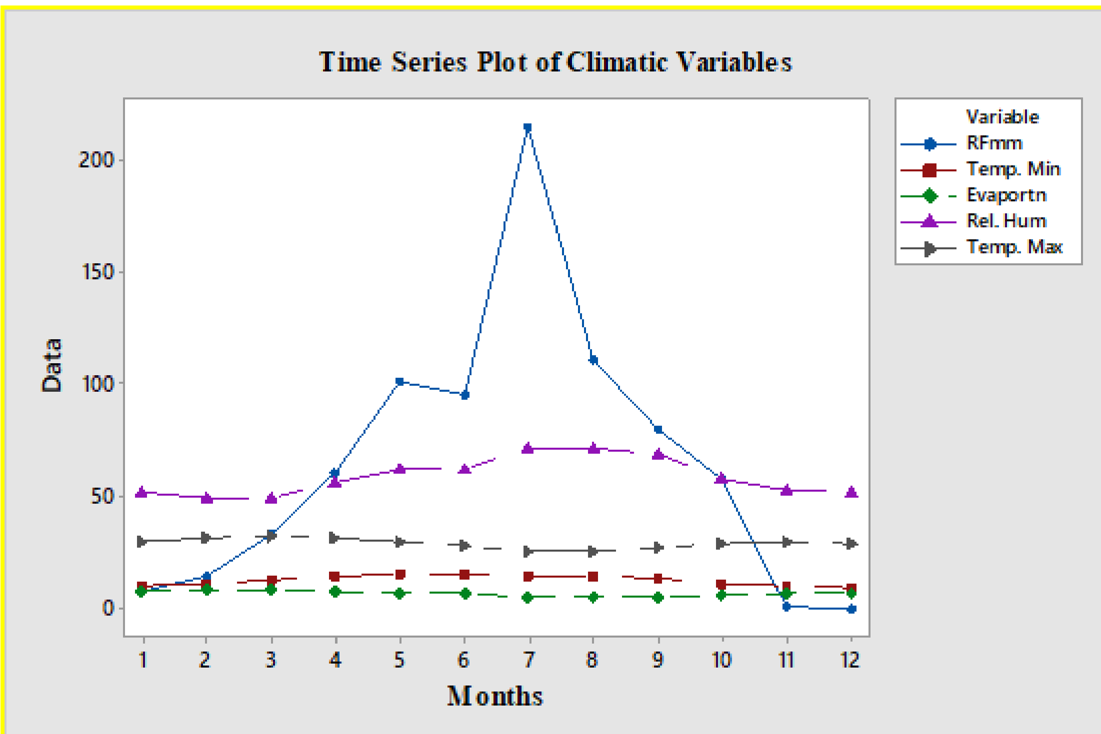


Figure 13: Time series of climate variables

Soil properties of the Watershed

The proportion of Watershed soil texture is 72.6% sand, 21.6% silt, 6% under category of sandy loam (Table 20). This is similar with what Kasahun and Tesfaye (2014) stated most of the areas soil texture is under the category of sandy loam.

Table 25: The soil textural classification of Warja Watershed

Textures	Mean	Std Dev.
% Sand	72.6	8.8
% Silt	21.6	6.8
% Clay	5.9	3.8

The recorded mean soil bulk density of the watershed was 0.18 ± 0.02 (mean±std). This means the soil is a bulk soil that is important for tree root development. The critical value of bulk density for restricting root growth varies with soil type (Hunt and Gilkes, 1992) but in general bulk densities greater than 1.6 g/cm3 tend to restrict root growth (McKenzie et al., 2004).

The range of the soil PH in the watershed falls between the optimum ranges 6-7. EC was also in its normal range (less than 1 dS/m). The result agrees with suitability indicated by Horneck et al. (2011) reported that EC less than one is suitable for plant growth.Allan et al. (2010) described guidelines for interpreting phosphorus (P) for neutral and acid soils puts the fertility level of the soil as Low (<20), Medium (20-40), High (40-100), Excessive (>100); for potassium (K) puts the fertility level of the soil as Very low (<75), Low (75-150), Medium (150-250), High (250-800) and very high (>800) and Nitrogen (ppm) levels in soil test result as low(<10), medium(10-20), high(20-30), Excessive(>30). Accordingly, the watershed soil has low Av. p and high Av. K.

Overall average CEC of the watershed was 16 meq/100 g (milli-equivalents per 100 grams of soil) and it was almost the same with the upper maximum CEC 15 meq/100 g reported by Spargo (2013) for fine textured soils. This could be true since the textural soil type of the watershed was sandy loam (Table 20). This all could help any intervening body as a base line for important improvements.

Table 26: Soil chemical properties of Warja Watershed per land uses

Land Uses	EC	PH	Av. P	CEC	Av. K	OC	% Sand	% Silt	% Clay
Cultivated Land	0.15 ± 0.07	7.4 ± 0.6	3.86 ± 1.8	18.5 ± 4.8	663.55 ± 126.8	1.15 ± 0.2	68.9 ± 10.3	24.1 ± 7.7	7 ± 4.5
Grazing Land	0.22 ± 0.06	7.6 ± 1.07	2.9 ± 1.43	12.7 ± 6.08	650.8 ± 133.9	1.6 ± 0.6	76.9 ± 3.7	18.9 ± 4.2	4.2 ± 1.8
Protected Land	0.16 ± 0.08	6.67 ± 0.06	3.4± 1.4	17.95 ± 1.196	653.3 ± 105	2.6 ± 0.28	77.9 ± 00	16.9 ± 4.2	5.2 ± 1.2

Table 27: Major soil fertility improvement constraints

No.	Constraints list	Percentage %	Rank
1	Fertility of Cultivable land declined	30.2	1
2	Lack of improved agricultural technologies(mechanization)	19.0	2
3	Lack of access to inputs(fertilizer)	9.5	3
4	Climatic problem/drought	6.3	4

Erosion status of the watershed

Many rills that has prominent role in the development of gullies were observed in the watershed. Accordingly, three big gullies (Fig. 9) were formed because of water erosion in the watershed. According to the rangeland health and pasture condition (2003) scoring models, Reduction of vegetative cover causes increased surface runoff and often leads to accelerated erosion. Rills and gullies develop, followed by larger flow concentrations. Runoff is closely linked to chemical and nutrient cycling, erosion, and contaminant transport. It can also be a sensitive indicator of ecosystem change. Plant community types and the character of vegetative cover are one of the factors that determine the rate and areal distribution of runoff from a watershed. For every watershed and site within the watershed, there exists a critical point of deterioration resulting from surface erosion.

Different physical and bio-physical soil and water conservation measures were recorded in the watershed. Accordingly, Gabion dam in Gully, soil and stone bunds, Micro catchments like half-moon and V-shape with trees especially *Acacia saligna* were available in the watershed. The statuses of most structures were declined while few of them were under good performance for *Acacia saligna* tree obtained growth benefit because of stored water by the structure.

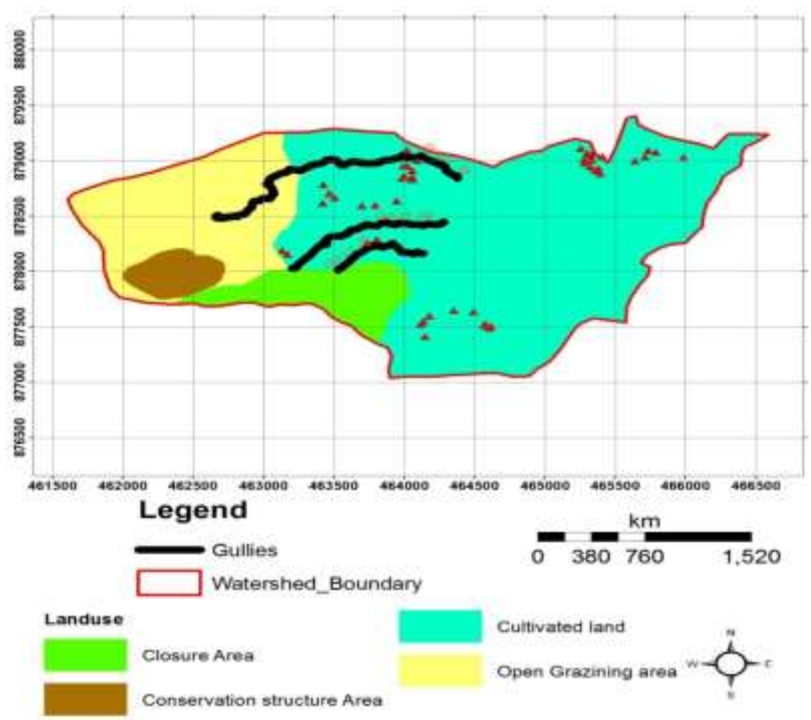


Figure 14: Digitized gullies in the Warja Watershed

Watershed Vegetation Diversity and Composition

Knowing the distribution and the slopes on which trees exist in the watershed help for preparing interventions plan for massive tree planting. Hence, *Acacia tortilis* and *Albizia lobbeck* (Table 23) were trees highly distributed in the watershed.

Table 28: Distribution (%) and slope of existence of woody tree/ shrub species in the watershed

No.	Species scientific name	Local name of spp.	Percent	Slope of existence	Growth status
1	*AcaiaSaligna*		6.90	10-30	tree & bush
2	*Acacia tortilis*	*Dhaddacha*	27.59	0-10	Tree
3	*Albizalobbek*	*Qarxafaa*	17.24	0-30	Tree
4	*Croton macrostachyus*	*Makkannisa*	3.45	2-5	Tree
5	*Acacia negrii*	*Dodota*	10.34	5-30	tree& bush
6	*Acacia albida*	*Garbii*	6.90	0-2	Tree
7	*Brideliamicrantha*	*Riga-arbaa*	3.45	5-10	bush
8	*Caparistomentosa*	*Harangama*	3.45	10-15	bush
9	*Maytenusarbutifolia*	*Kombolcha*	3.45	15-30	bush
10	*Olea africana*	*Ejersa*	3.45	15-30	bush
12	*Acacia seyal*	*Waaccuu*	3.45	5-10	Tree

Table 29: Mean richness of woodytree/ shrub species in the Watershed

No.	Trees scientific names	Trees local name	Mean	std.	Min	Max
1	*Acacia tortilis*	Dhaddacha	2.1	1.2	1.0	4.0
2	*Acacia Saligina*		6.0	1.4	5.0	7.0
3	*Albizalobbek*	Qarxafaa	3.3	2.6	1.0	9.0
4	*Croton macrostachyus*	Bakkanniisa	1.0	*	1.0	1.0
5	*Acacia negrii*	Doddota	5.3	2.3	4.0	8.0
6	*Acacia albida*	Garbii	4.0	0.0	4.0	4.0
7	*Brideliamicrantha*	Riga-arbaa	1.0	*	1.0	1.0
8	*Caparistomentosa*	Harangama	1.0	*	1.0	1.0
9	*Maytenusarbutifolia*	Kombolcha	1.0	*	1.0	1.0
10	*Olea Africana*	*Ejersa*	4.0	*	4.0	4.0
11	*Acacia seyal*	Waaccuu	1.0	*	1.0	1.0

Diversity is higher as the value is closer to 1. Shannon Index consider the evenness and shown low diversity. Overall, few species were abundant than others and low species diversity recorded in the watershed (Table 25).

Table 30: Mean richness and diversity of woody tree/shrub species in the watershed

Variable	Mean	Min	Max
Over all Richness	3 ± 2.24	1	9
Shannon Index	0.22 ± 0.14	0	0.4

Farmers tree use preference

Based on tree use preference by farmers (Fig. 10) *Acacia tortilis, Albizia lobbeck* and *Balanites aegyptiaca* were among the most three species obtained the highest use value index. This helps any intervening bodies where to focus to increase the community benefit from these trees.

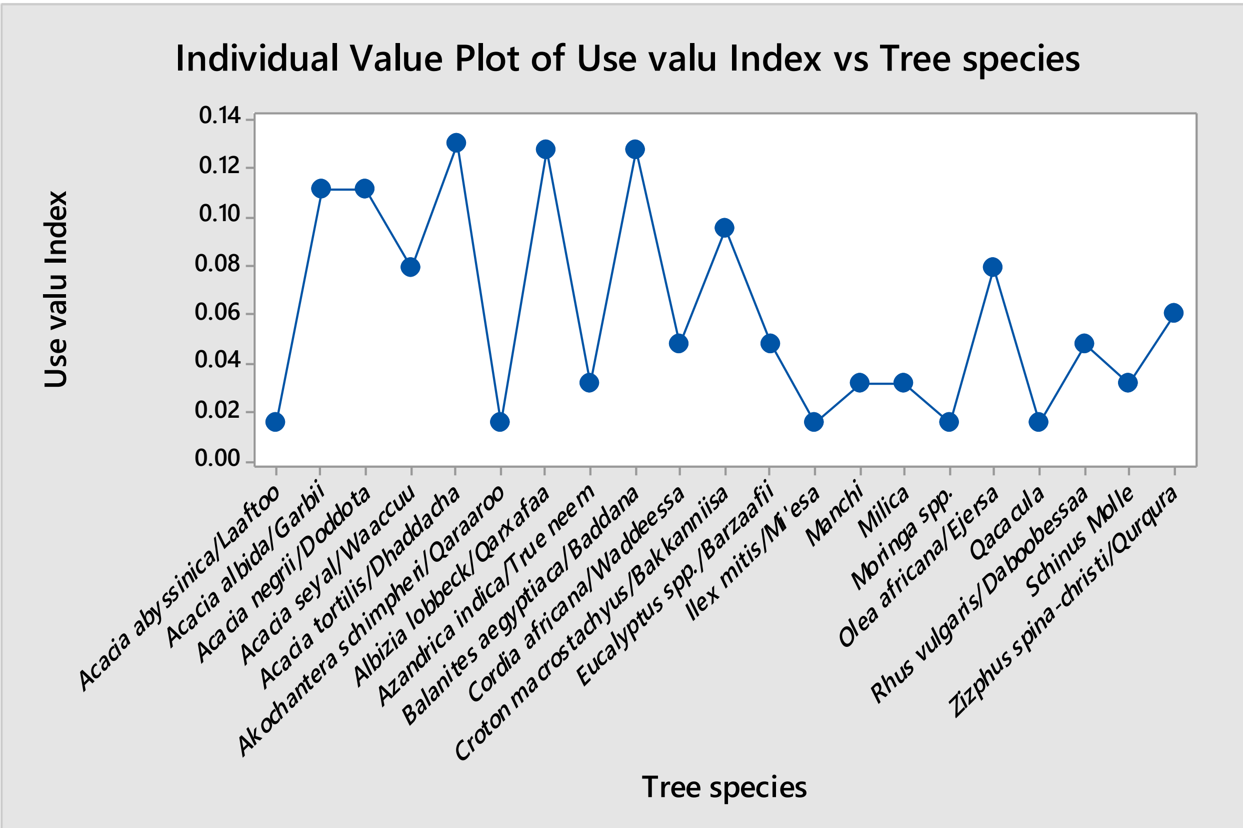


Figure 15: Use value Index of Tree species mentioned by respondents

Table 31: Different uses (%) obtain from trees in the Watershed

No.	List of uses	Species category
1	Shade	*Acacia albida* (3.2%), *Acacia tortilis* (54%), *Acacia negrii* (3.2%), *Balanites aegyptiaca* (14.3%), *Albizia lobbeck (*7.9%), *Olea africana* (1.6%), *Azadirachtaindica (4.8%), Croton macrostachyus* (3.2%), *Cordia africana* (9.6), *Schinusmolle*(3.2%)
2	Fodder	*Acacia tortilis* (20.6%), *Acacia albida* (1.6%), *Acacia negrii* (15.9%), *Acacia seyal* (1.6%), *Balanites aegyptiaca* (28.6%), *Albizia lobbeck* (28.3%), *Zizphus spina-christi*(4.8%)
3	Medicine	*Olea africana* (1.6%), *Croton macrostachyus* (1.6%), *Azadirachtaindica*(1.6%)
4	Firewood/Fuelwood	*Acacia tortilis* (28.6), *Acacia albida* (1.6%), *Acacia negrii* (15.9%), *Acacia abyssinica* (1.6%), *Balanites aegyptiaca* (19%), *Acacia lobbeck* (11.1%), *Eucalyptus spp.* (4.8%), *Rhus vulgaris* (1.6%),*Schinusmolle*(3.2%)
5	Fence	*Acacia tortilis* (50.8%), *Acacia albida* (1.6%), *Acacia negrii* (11.1%), *Acacia seyal* (3.2%), *Balanites aegyptiaca* (12.7%), *Albizia lobbeck* (15.9%), *Eucalyptus spp. (*1.6%), *Zizphus spina-christi*(4.8%)
6	Charcoal	*Acacia tortilis* (7.9%), *Acacia negrii* (4.8%), *Acacia seyal* (1.6%), *Balanites aegyptiaca* (12.7%), *Albizia lobbeck* (1.6%)
7	Construction (mostly house)	*Acacia tortilis* (7.9%), *Acacia negrii (*4.8%), *Acacia seyal* (1.6%), *Balanites aegyptiaca* (12.7%), *Albizia lobbek*(1.6%), *Olea africana* (1.6%), *Croton macrostachyus* (4.8%), *Eucalyptus spp*.(12.7%), *Cordia africana* (11.1%), *Zizphus spina-christi*(3.2%), *Rhus vulgaris* (1.6%), *Acokanthera schimpheri*(1.6%), *Qacacula*(4.8%), *Milica*(1.6%), *Manci*(1.6%)
8	Fertility improvement	*Acacia tortilis (9.5%)*, *Balanites aegyptiaca* (4.8%), *Albizia lobbeck* (1.6%)
9	Farm Implement	*Acacia tortilis (7.9%)*, *Acacia negrii* (1.6%), *Acacia seyal* (6.3%), *Balanites aegyptiaca* (9.5%), *Albizia lobbeck* (7.9%), *Olea africana* (3.2%), *Croton macrostachyus* (4.8%), *Cordia africana* (1.6%), *Rhus vulgaris* (1.6%), *Ilex mitis* (1.6%)
10	House utensils	*Croton macrostachyus* (3.2%)
11	Smoking (good smell for house and equipment's)	*Olea africana* (11.1%)

Other natural resources constraints

Table 32: Major Agroforestry constraints in the Warja watershed

No.	N- agroforestry constant	Percentage (%)	Rank
1	Lack of access to inputs(improved seed/seedlings)	57.1	1
2	Un availability of inputs (seed and /or seedling) on time	6.3	2
3	Poor access to extension services	4.8	3
4	Climatic problem/drought	4.8	4

Table 33: Major fruit production constraints in the Warja watershed

No.	Constraints list	Percentage (%)	Rank
1	Climatic problem/drought	49.2	1
2	Lack of access to inputs(improved seed/seedlings, fertilizer)	12.7	2
3	Poor access to extension services	4.8	3
4	Un availability of inputs on time	3.2	4

Table 34: Waterharvesting constraints in the Warja watershed

No.	irrigation water harvesting contracts	Percentage (%)	Rank
1	Lack of improved water harvesting technologies	38.1	1
2	Climatic problem/shortage of rain/	22.2	2
3	Poor access to extension services on water harvesting	12.7	3
4	Lack of access to credit services	1.6	4

CONCLUSION AND RECOMMENDATIONS

Conclusion

Warja watershed encompasses remarkable natural capital with potential to support households residing in the area. However due to miss use of the resources on the site and less attention given for the area's resources management; surrounding societies are not utilizing the existing resources potential of the area. The cause and impact of land degradation in Warja watershed had been explored using different methods explained in the study. Natural resources degradation such as Land, and or/ soil fertility, reduction and recent changes in the areas' weather condition in line of climate change (rain fall in amount and duration, unusual length of dry season) prevailing in current years are few of the many factors that are contributing to the crop productivity reductions in the area. It was observed that in addition to the nature of the topography of the land anthropogenic factors were a great contribution for the resources depletion that affecting the societies in the area and their livelihoods. Factors that affect these natural resources depletion by hampering the production and productivities of the local community in the areas were the scarcity of land for farming family, soil infertility, and fluctuation of weather condition. These situations are happening at the expense of species diversity and bringing a reduction in food provision for poor rural households in addition to others resources depletion in the area. It can be concluded that planned watershed managements as interventions for Warja watershed improvements are impressive for the success of any development works carried out for the surrounding communities.

Recommendations

Based on the findings of this study, the following recommendations are suggested:

Attention should be given to make Warja watershed more productive for local people by improving their awareness on integrating crops, livestock and natural resource management technologies for effective soil and water conservation measures should be enhanced.

Participatory implementation of degraded land rehabilitation in the watershed particularly construction of integrated physical and biological soil and water conservation measures should have to be encouraged.

Provisions of Warja watershed should be included in the programs of conservation agency and others concerned bodies to enhance the livelihoods of rural poor and conservation of natural resources on a sustainable basis.

Provisions of improved breeds of livestock's and the modern beehives by organizing young and land less through integrated improved beekeeping practices with multi propose trees as means of income generating should be implemented.

Further study is needed to identify adoptable conservation technologies like adaptable multipurpose tree /species plant varieties of ecological and locals' needs.

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